Maxillary Sinus Septa: A 3-Dimensional Computerized Tomographic Scan Analysis

Diego Velásquez-Plata, DDS, MSD1/Lawrence R. Hovey, DMD, MS2/Chris C. Peach, RDH3/Marden E. Alder DDS, MS4

Purpose: The purpose of this study was to determine the prevalence, size, location, and morphology of maxillary sinus septa in dentate, partially dentate, and edentulous maxillae. Materials and Methods: Data from 312 sinuses were analyzed from reformatted computerized tomograms utilizing SI/Plant software. The sample consisted of 156 patients (106 women and 50 men, with ages ranging between 24 and 86 years and a mean age of 55.4 years) who were being treatment-planned to receive implant-supported restorations. Results: A total of 75 septa were found in 312 maxillary sinuses (24%), which corresponded to 32.7% of the patients (51 of 156). Completely edentulous patients presented with 33.3% of the total septa, while 66.7% of the septa were identified in partially edentulous patients. Analysis of the anatomic location of the septa within the sinus revealed that 18 (24.0%) septa were located in the anterior region, 31 (41.0%) were in the middle, and 26 (35.0%) were in the posterior region. Measurements of height of the septa varied among different areas. The lateral area ranged from 0 to 15.7 mm (with a mean of 3.54 ± 3.35 mm), the middle area ranged from 0 to 17.3 mm (with a mean of 5.89 ± 3.14 mm), and the medial area ranged from 0 to 20.6 mm (with a mean of 7.59 ± 3.76 mm). A total of 20 septa (26.7%) were located in the immediate apical region of teeth. The remaining 55 septa (73.3%) were related to edentulous areas. Discussion: Septa may arise in any of the 3 regions of the maxillary sinus irrespective of the degree of dentulism or edentulism present. Conclusion: To avoid unnecessary complications during sinus augmentation procedures, adequate and timely identification of the anatomic structures inherent to the maxillary sinus are required. (INT J ORAL MAXILLOFAC IMPLANTS 2002;17:854–860)

Key words: antral septa, computed tomography, dental implants, dental radiography, maxillary sinus
demonstrated that of 164 failures analyzed, 79 (48%) could be attributed to perioperative complications, 38 (48%) of which were associated with sinus membrane perforations.8

The presence of anatomic variations within the maxillary sinus, such as septa, have been reported to increase the risk of sinus membrane perforation during sinus elevation procedures.2,3,10,16–18 This anatomic variation was first described by Underwood in 1910.18 The shape of septa has been described as resembling an inverted gothic arch arising from the inferior and lateral walls of the sinus and coming to a sharp edge along its most apical border.17,19 They tend to partially—or, in some cases, completely—divide the floor of the sinus into 2 or more compartments radiating out from the medial wall toward the lateral wall of the sinus (Figs 1 and 2).18,20

The etiology of the maxillary septum has been hypothesized by several authors.17,18,21,22 Underwood18 described septa as arising between areas of 2 adjacent teeth and usually presenting in 3 specific regions of the sinus floor, thus dividing the floor into 3 basins: anterior, between the second premolar and first molar roots; middle, between the first and second molar roots; and posterior, distal to the third molar roots. Each basin corresponds to 3 defined periods of tooth development and eruption separated by intervals of time. This same author mentioned that septa were most commonly observed in the posterior region, supposedly because of the later occurrence of eruption. He also noted that the size of septa could be accentuated by further pneumatization of the alveolar process. Neivert21 proposed that septa were derived from the fingerlike projections produced by the embryologic out-pouching of the ethmoid infundibulum in which contiguous walls did not resorb. Krennmair and coworkers17 further classified septa into primary septa (which arise from development of the maxilla) and secondary septa (which arise from irregular pneumatization of the sinus floor following tooth loss).

Other authors have also reported on the prevalence of septa.17,18,23 Underwood18 found 30 septa in
of 45 skulls (90 maxillary sinuses), demonstrating a 33% prevalence. Krennmair and coworkers\textsuperscript{17} reported a prevalence ranging from 14% to 31.7%, depending on patient age and tooth loss. The height of septa has also been measured. Underwood\textsuperscript{18} reported an average height of 0.25 to 0.5 inches (6.4 to 12.7 mm). Two cases of complete septa demonstrating union with the antral roof were also described. Krennmair and coworkers\textsuperscript{17} observed a mean height of 7.7 mm for septa identified in edentulous maxillae and 12.2 mm for septa in dentate maxillae.

The common location for septa described by Underwood\textsuperscript{18} was the posterior, as stated earlier; however, Krennmair and coworkers\textsuperscript{17} observed a majority of septa in the anterior/premolar region of edentulous maxillae (75%) and dentate maxillae (57.1%). The remaining septa were located in the middle/first molar region, with only 1 septum identified in the posterior region of all specimens examined. These same authors also presented important information regarding the ability to detect the presence of septa with panoramic radiography. They demonstrated the limitations of the orthopantomograph by showing an inability to correctly identify the absence or presence of septa in 21.3% of the cases examined. Thus, computerized tomography (CT) and subsequent reconstruction of axial sections allow a more accurate visualization of anatomic variations within the maxillary sinus.\textsuperscript{24,25}

The purpose of this study was to examine a cross-sectional sample of 312 sinuses in 156 patients using preoperative axial CT scans serially processed and analyzed using a software program to determine the prevalence, size, location, and morphology of septa in dentate, partially dentate, and edentulous maxillae.

**MATERIALS AND METHODS**

Data from 312 sinuses were analyzed from reformatted CT images utilizing SIM/Plant software (Columbia Scientific, Columbia, MD). The protocol utilized 1.25-mm-thick reconstruction algorithms. The sample consisted of 156 patients (106 women and 50 men, with an age range of 24 to 86 years and a mean age of 55.4 years) who were being treatment-planned to receive implant-supported restorations. Forty-one patients (26.3%) were completely edentulous and the remaining population was partially edentulous (73.7%). Partial edentulism was classified according to Kennedy,\textsuperscript{26} and the location and extent of the edentulous space(s) were identified.

The CT images were examined for the presence of antral septa using axial planes of section. The “panoramic” reconstructions of SIM/Plant were used to assess the height of the septa. Axial plane images were utilized to locate the segment to be measured in the lateral, middle, and medial aspects of the septa (Fig 3). Vertical measurements were accomplished with the SIM/Plant measuring tool, as shown in Fig 4. Each antral cavity exhibiting a septum was divided into 3 portions: anterior (mesial to distal aspect of second premolar), middle (from distal aspect of second premolar to distal aspect of second molar), and posterior (distal aspect of second molar region). The height of each septa identified...
was measured at 3 regions selected along its course across the sinus floor: the lateral, the middle, and the medial aspects. Septa measuring more than 2.5 mm in height at 1 of 3 positions measured were included in the analysis. Not all septa demonstrated a measurable component at each aspect; a value of zero was recorded for such regions.

Statistical analysis was performed using a paired Student t test to determine whether there was a significant difference in the size and location of septa identified in completely and partially edentulous areas.

RESULTS

A total of 75 septa were found in 312 maxillary sinuses (24%), which corresponds to 51 (32.7%) of 156 patients. Septa were found unilaterally in 33 patients (64.7%) and bilaterally in 18 patients (35.3%). Completely edentulous patients presented 33.3% of the total septa, while 66.7% of the septa were identified in partially edentulous patients. Thirty-six antral septa (48%) were identified on the right side, while 39 septa (52%) were found on the left side. Four patients (2.66%) presented with multiple septa in 5 sinuses (1.6%). Sixty-four sinuses harbored 1 septum, 4 sinuses presented with 2 septa, and 1 sinus had 3 septa.

Analysis of the anatomic location of the septa within the sinus revealed that 18 (24.0%) septa were located in the anterior region, 31 (41.0%) were in the middle region, and 26 (35.0%) were in the posterior region. The location of septa observed in this study population demonstrated a greater prevalence (41.0%) in the middle region (first and second molar), followed by the posterior region (35.0%), and the anterior region (24.0%). This distribution varied when partially and completely edentulous sinuses were compared (Table 1). A closer examination of the partially edentulous population revealed a 40% prevalence of septa located superior to a maxillary tooth (primary septa) and 60% of septa located superior to an edentulous ridge (primary septa, secondary septa, or a combination of both) (Table 1).

Measurements of the height of each individual septum varied among different regions. The lateral region ranged from 0 to 15.7 mm (with a mean of 3.54 ± 3.35 mm), the middle region ranged from 0 to 17.3 mm (with a mean of 5.89 ± 3.14 mm), and the medial region ranged from 0 to 20.6 mm (with a mean of 7.59 ± 3.76 mm) (Table 2). When mean values for septa identified in partially edentulous versus completely edentulous areas were compared, septa found in partially edentulous areas demonstrated statistically significantly higher values at all points of measurement. When septa found in partially edentulous areas were broken down into those

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**Table 1** Summary of Septa Location Data

<table>
<thead>
<tr>
<th>Septa identified</th>
<th>No. of septa</th>
<th>Location prevalence*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior region</td>
<td>Middle region</td>
</tr>
<tr>
<td>CE 25</td>
<td>7 (28%)</td>
<td>9 (36%)</td>
</tr>
<tr>
<td>PE 50</td>
<td>11 (22%)</td>
<td>22 (44%)</td>
</tr>
<tr>
<td>PE, primary septa</td>
<td>6 (30%)</td>
<td>9 (45%)</td>
</tr>
<tr>
<td>PE, other septa</td>
<td>5 (17%)</td>
<td>14 (47%)</td>
</tr>
<tr>
<td>Total 75</td>
<td>18 (24%)</td>
<td>31 (41%)</td>
</tr>
</tbody>
</table>

*All differences were statistically significant (P < .0001; paired Student t test).  
CE = completely edentulous patients; PE = partially edentulous patients; primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge.

**Table 2** Summary of Septa Height Measurements

<table>
<thead>
<tr>
<th>Septa identified</th>
<th>No. of septa</th>
<th>Height (mm ± SD)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lateral</td>
<td>Midpoint</td>
</tr>
<tr>
<td>CE 25</td>
<td>2.79 ± 1.68</td>
<td>4.87 ± 1.99</td>
</tr>
<tr>
<td>PE 50</td>
<td>3.91 ± 3.90</td>
<td>6.39 ± 3.48</td>
</tr>
<tr>
<td>PE, primary septa</td>
<td>3.33 ± 2.16</td>
<td>6.11 ± 2.16</td>
</tr>
<tr>
<td>PE, other septa</td>
<td>4.30 ± 4.71</td>
<td>6.58 ± 4.16</td>
</tr>
<tr>
<td>Total 75</td>
<td>3.54 ± 3.35</td>
<td>5.89 ± 3.14</td>
</tr>
</tbody>
</table>

*All differences were statistically significant (P < .0001; paired Student t test).  
CE = completely edentulous patients; PE = partially edentulous patients; primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge.
Krennmair and associates\(^2\) counted 32 antral septa in 82 maxillary sinuses (18.3% prevalence). Underwood\(^1\) found a 33% prevalence of septa (30 antral septa in 90 maxillary sinuses). In his classic skull study, the remaining 30/50 (60%) were located apical to a maxillary root and classified as primary, while the PE population, 20/50 (40%) were located apical to remaining teeth (primary septa) to an edentulous ridge. In his classic skull study, Ulm and coworkers\(^2\) reported 15 septa in 82 maxillary sinuses (18.3% prevalence). Krennmair and associates\(^24\) counted 32 antral septa in 200 maxillary sinuses (ie, 16% of sinuses) utilizing CT imaging. Krennmair and associates\(^17\) later reported 19 antral septa in 184 maxillary sinuses (10%) evaluated using CT examinations. It is important to know that the majority of the sinuses in this study harbored only 1 septum, while only 5 sinuses (1.6%) presented multiple septa.

As described previously, all septa demonstrated a medial-lateral orientation. No sagittally oriented septa were observed. The morphology of septa did, however, demonstrate significant variability. This is evident in the results obtained from measuring each septum at 3 aspects along its medial-lateral dimension. A total of 65.3% demonstrated a morphology similar to the classic inverted gothic arch form, with a significant (> 2.5 mm) lateral and medial insertion; however, the average height of the medial insertion was generally greater than the height of the lateral insertion (Table 2). This observation may be the result of the inherent limitations of the radiographic technique employed in this study when detecting fine details of anatomic structures. Other septa demonstrated insignificant height at 1 of the 3 points measured: lateral height (32%), middle height (5.3%), or medial height (2.7%). This demonstrates the wide range of septum morphology identified within a given population. Previous studies have reported on the height of septa but have failed to describe the specific point of measurement. As demonstrated in the 75 septa identified in the 312 examined sinuses, the height and morphology of septa can vary dramatically, depending on the site chosen for measurement.

The location of septa observed in the total study population demonstrated a greater prevalence in the middle region (first and second molar) (41.0%), followed by the posterior region (35.0%), and the anterior region (24.0%). When partially edentulous and completely edentulous patients were compared, this distribution remained relatively similar (Table 1). This is in contrast to a recent study by Krennmair and coworkers,\(^17\) which reported a greater prevalence of septa in the anterior region (70% to 75%) in partially edentulous, edentulous, and atrophic edentulous maxillae. These authors also examined a group of partially or completely dentate maxillae and observed a decreased prevalence in the anterior segment (57%). Of the 51 septa identified, only 9 (18%) were found in the molar region, and 1 (2%) was found in the second molar region. This information was used to make conclusions regarding the etiology of septa—namely, that the increased prevalence of septa in the anterior region of the edentulous maxilla was a result of earlier tooth loss and pneumatization of the posterior maxillary ridge, which resulted in an increased prevalence of septa at the junction between the premolar and molar segments. Stover\(^22\) criticized these conclusions, stating that a greater prevalence of septa in the posterior segments resulting from remnant interradicular bone between adjacent maxillary molars, ie, secondary septa, would be more likely. Underwood\(^18\) actually noted in his study that the majority of septa identified were located in the posterior segment. He hypothesized that septa (primary) formed as a result of different timing of tooth eruption. Thus, since primary posterior septa are the last to develop, they would remain for a longer period of time because of their decreased exposure to resorptive mechanisms proper to the antral cavity. Differences between the results obtained from different studies may reflect variability between methods of measurement, tools utilized to gather data, and variation among populations studied.

Septa appear to develop in either of 2 ways, either primary (developmental) or secondary as a result of tooth loss and remnant interseptal bone. Tooth loss and pneumatization adjacent to either a primary or secondary septum may also exaggerate the height or size of a septum. It is impossible to label a septum located apical to an edentulous ridge as primary or secondary without a radiographic history of the sinus in question. Thus, it can be stated...
that septa located apical to dentate regions are primary (developmental), and septa located apical to an edentulous region can be either primary or secondary. Further examination of the 20 primary septa identified within this study demonstrates a distribution similar to that observed in the edentulous population examined (Table 2).

No conclusions can be drawn from this cross-sectional study regarding the etiology of septa in the sinus; however, it is important for the clinician to realize that because of the design of this image reformatting procedures allow. It is important making allowances for the potential maximum error related to operator misinterpretation, which would help prevent anatomic complications during surgery. The measurements collected in the present study appear to be as accurate as the image reformattting procedures allow. It is important to realize that because of the design of this study, there was no clinical verification of these measurements.

SUMMARY

To avoid unnecessary complications during sinus augmentation procedures, adequate and timely identification of the anatomic structures inherent to the maxillary sinus must be accomplished. Through examination of a cross-sectional sample of 312 sinuses using preoperative axial CT scans, the prevalence, size, location, and morphology of septa in dentate, partially dentate, and edentulous maxillae were determined.

REFERENCES