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Three-Dimensional Evaluation of Maxillary Sinus Septa for Implant Placement

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Background: The aim of our study was to investigate, in 3 dimensions, the maxillary sinus septa as an alternative site for dental implant placement to avoid sinus lift procedures.

Material/Methods: We selected 100 dentate and 100 edentate patients with the presence of a maxillary sinus septum by reviewing a larger cone beam computer tomography (CBCT) database from the Department of Oral and Maxillofacial Surgery at Cliniques Universitaires Saint Luc in Bruxelles, Belgium. Three-dimensional reconstructions of 200 maxillary sinus septa were performed using Maxilim software. Ten measurements (length, lateral height, and thickness of the middle and medial region of the septum) were performed by 1 observer, 2 times, with an interval of 1 week between measurements. The angle between the septum and the maxillary plane was also measured. Finally, localization and orientation were assessed for each septum.

Results: There was no statistically significant difference between the 2 intraobserver measurements ($p > 0.05$). Student's t-test was used to compare means. Middle height was the only measurement for which there was a difference between edentate and dentate patients ($p = 0.0095$, edentate mean < dentate mean). The location of the septa observed in our study groups demonstrated greater prevalence in the posterior region than in the anterior and middle regions. For the spatial orientation of the septum, we found that most septa (81.2% in dentate patients, 53% in edentate patients) were oblique.

Conclusions: Three-dimensional evaluation of maxillary sinus septa using 3D CBCT imaging showed that the sinus septum could offer an alternative site for implant placement in the maxillary sinus.

MeSH Keywords: **Cone-Beam Computed Tomography • Dental Implants • Sinus Floor Augmentation**

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Background

Pre-implantological sinus floor augmentation serves to restore bony mass in the maxilla of partially or totally edentulous patients. There are various surgical techniques available for this procedure [1].

Although the complication rate is low, there are intraoperative risks, such as sinus membrane perforation and bleeding, and postoperative risks of wound infection and sinusitis, graft or barrier membrane exposure, graft infection (warranting its removal), cyst formation, and flap dehiscence [2–15].

The panoramic X-ray can provide a sufficient view of the residual crest height under the sinus floor. For anatomical features such as the anterior or posterior wall and the septa of the sinus, the palatal curvature, and the pterygoid process, it is important to consider that panoramic image quality is highly dependent on the radiologist's skill and is a 2-dimensional image of a 3-dimensional volume with the superimposition of anatomical structures. Fortin demonstrated that the use of a panoramic radiological exam for oral implant planning in severely resorbed maxillae overestimates the need for a sinus augmentation procedure compared with the use of both 3-dimensional planning software and strategic implant placement when there is little remaining bone volume. Furthermore, this technology allows the surgeon to take advantage of the septa and palatal curvature, an option that is not routinely described in conventional procedures [16].

To overcome the drawbacks of sinus lifting, some authors have suggested using alternative anatomic features to place the implant, such as the pterygoid process or tangential to the palatal curvature in the area of the first or second molar [17–20]. For the non-grafted maxilla, Krekmanov placed the implants into the pterygoid plate, palatally tilted, close to and parallel with the posterior sinus wall or close to and parallel with the anterior sinus wall. The most posterior implant was tilted distally, approximately 30 to 35 degrees [21].

However, some authors mentioned severe complications after inserting implants into the pterygoid process. Reychler and Olszewski reported a unique intracerebral penetration of a pterygoid implant inserted into the pterygoid region. An episode of acute left maxillary sinusitis, chronic fatigue, and severe headaches occurred shortly after insertion of the fixed denture. Cerebral magnetic resonance imaging (MRI) demonstrated the penetration of a pterygoid implant into the middle cranial fossa [22].

To avoid the sinus atrium and improve posterior prosthetic support in the resorbed posterior maxilla, the implant can be tilted to a 45° incline [23].

Fortin was the first to demonstrate that maxillary sinus septa could be a location of interest to place implants, avoiding the sinus lift technique in a severely resorbed maxilla, in a clinical case series study [17]. In completely edentulous patients, inserting implants into the sinus septa does not exclude the need for sinus grafting, but in partially edentulous patients, this minimally invasive technique is an alternative to subantral augmentation [24].

Maxillary sinus septa were first described by Underwood in 1910 as the walls of cortical bone within the maxillary sinus [25]. The shape has been described as an inverted gothic arch, arising from the inferior or lateral walls of the sinus, which may divide the sinus into 2 or more cavities.

Various studies were conducted on height, location, prevalence, and morphology of the maxillary sinus septa, in adult patients, using diverse medical imaging techniques such as cone beam computed tomography (CBCT) [26–34]. The measurements were performed in 2 dimensions (2D) in axial, sagittal, or panoramic images. The angle between the septum and the median palatine suture was also evaluated by several authors [27,29].

Unlike traditional 2D radiography, CBCT avoids structural superimposition and image enlargement and distortion, thus allowing precise 3-dimensional (3D) visualization and measurement of dental and maxillofacial structures, at a lower radiation dose than a multislice computed tomography (CT) [35,36]. To the best of our knowledge, there are still no 3D experimental studies in the literature that evaluated the thickness of the maxillary septa and the inclination of the maxillary septum plane toward the horizontal maxillary plane.

The aim of this investigation was therefore to evaluate, in 3D, the maxillary sinus septa as a potential site for implant placement.

Our second purpose was to compare the anatomy of the maxillary sinus septa in dentate and edentate patients to determine if immediate implant placement in maxillary sinus septa is more favorable than delayed implant placement.

Material and Methods

We performed an experimental and retrospective study. We selected 200 patients with maxillary sinus septa from a 3000 patient database from the Department of Oral and Maxillofacial Surgery at Cliniques Universitaires Saint Luc in Bruxelles, Belgium.

The patients were divided into 2 groups: 100 dentate patients (group 1) and 100 edentate patients (group 2). In the first

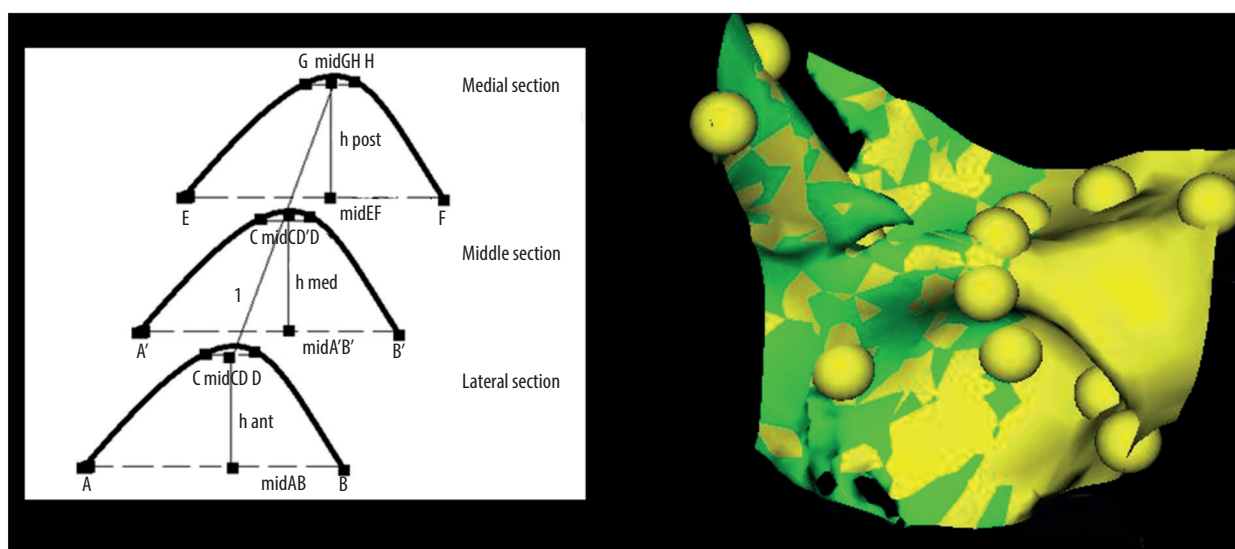


Figure 1. The sections at the level of the maxillary sinus septum.

group, patients with the septum located in a dentated region were chosen. In the second group, patients with the septum located in an edentated region were included.

We did not have access to information related to sex and we were only able to obtain information related to age for the dentate group. The age range of the population was from 18 to 86 years, with a mean age of 46.53 ± 18.67 years.

The study was retrospective, and the indication for CBCT was not considered as part of this study. Minors and pregnant women were excluded from the study. CBCT images with inadequate information or that showed signs of a previous maxillary sinus surgery were excluded.

The study received approval from the Comité d'éthique hospitalo-facultaire of the Université catholique de Louvain in Brussels, Belgium (2014/13MAR/104).

The Cone Beam CT (iCAT) protocol specified 120 kVp, 18 mas, 0.3 mm voxel size, 21 cm height, and a 16-cm diameter field of view.

The images were examined for the presence of antral septa first on the axial slices and then on the reconstructed sagittal and coronal slices.

We created maxillary sinus septa 3D reconstructions using Maxilim software (Medicim, Mechelen, Belgium). Three 3D reconstructions were prepared for each septum: 1) at the level of septum insertion on the lateral wall, 2) at the middle of the septum (green section in the middle), and 3) at the level of septum insertion on the medial wall (Figure 1). 3D reconstructions were performed for each maxillary sinus and for

each maxillary sinus septa when there were 2 septa present in the same maxillary sinus.

Twenty-one anatomic landmarks (Table 1) were identified by 1 observer twice, with a 1-week interval between identifications, on 3D reconstructions of the maxillary sinus septa to measure the septum angle, height, thickness, and length of the maxillary sinus septa (Table 2). The observer was not a trained radiologist, but he was a clinically experienced oral surgeon using CBCT as part of his clinical routine.

For each maxillary sinus septum, we also assessed localization (anterior, middle, or posterior third), orientation (sagittal, transverse, or oblique [buccopalatal]) and if it was complete or partial (incomplete septa on the sinus floor and on the medial or lateral sinus wall). We considered a septa complete when the bony crest was inserted both on the lateral wall and on the medial wall of the maxillary sinus.

The orientation was defined according to the angle between the septum plane and the median palatine suture and separated into 3 categories: 1) transverse if at 90° with the median palatal suture, 2) oblique if less or more than 90° , and 3) sagittal if parallel to the medial palatal suture.

The data were recorded and analyzed using SPSS software (IBM). Statistical analysis was performed using SPSS version 20 for Windows 7 (IBM).

Results

The Intraclass correlation coefficient (ICC) showed that there was no statistically significant difference between the 2 intraobserver measurements ($p > 0.05$).

Table 1. Landmark definitions.

Type of landmark	Definition
Manually identified landmark	A – section at the level of septum insertion on the lateral wall, anterior and inferior point; B – section at the level of septum insertion on the lateral wall, posterior and inferior point; C – section at the level of septum insertion on the lateral wall, anterior and superior point; D – section at the level of septum insertion on the lateral wall, posterior and superior point; A' – section at the middle of the septum, anterior and inferior point; B' – section at the middle of the septum, posterior and inferior point; C' – section at the middle of the septum, anterior and superior point; D' – section at the middle of the septum, posterior and superior point; E – section at the level of septum insertion on the medial wall, anterior and inferior point; F – section at the level of septum insertion on the medial wall, posterior and inferior point; G – section at the level of septum insertion on the medial wall, anterior and superior point; H – section at the level of septum insertion on the medial wall, posterior and superior point; • Maxillary median landmark – anterior and median landmark at the anterior edge of the maxillary alveolar crest between central incisors for dentate patients or at the anterior edge of the maxillary alveolar crest between alveolar sockets of extracted central incisors for edentate patients; • Pterygoid inferior right: junction between right lateral pterygoid plate and right maxillary tuberosity (approach from right lateral view of the skull) • Pterygoid inferior left: junction between left lateral pterygoid plate and left maxillary tuberosity (approach from left lateral view of the skull)
Automatically identified landmark	Mid AB – midway point between points A and B; Mid CD – midway point between points C and D; Mid A'B' – midway point between points A' and B'; Mid C'D' – midway point between points C' and D'; Mid EF – midway point between points E and F; Mid GH – midway point between points G and H

Table 2. Measurements.

Septum angle	The angle between the maxillary plane and the maxillary sinus septum plane (midAB, midA'B', midEF, midCD, midC'D', midGH landmarks) was measured. The maxillary plane, was defined by 3 points: maxillary median landmark, pterygoid inferior right, pterygoid inferior left (Figure 2)
Thicknesses	AB thickness (lateral) – Distance between points A and B; CD thickness (lateral) – Distance between points C and D; A'B' thickness (middle) – Distance between points A' and B'; C'D' thickness (middle) – Distance between points C' and D'; EF thickness (medial) – Distance between points E and F; GH thickness (medial) – Distance between points G and H
Height	Lateral height – distance between mid AB and mid CD; Middle height – distance between mid A'B' and Mid C'D'; Medial height – distance between mid EF and mid GH
Length	Distance between mid CD and mid GH

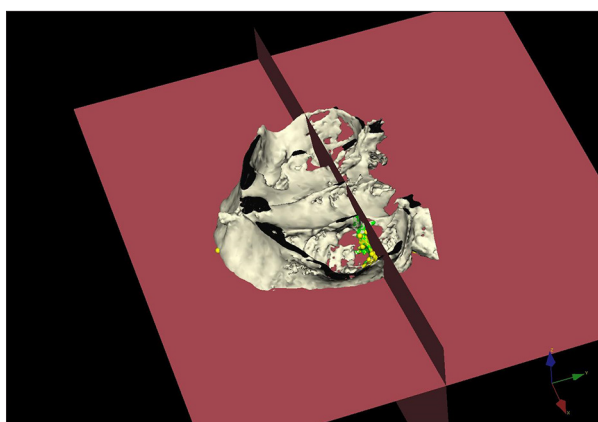


Figure 2. The angle formed by the septum plane and the maxillary plane.

Ninety-eight percent of the dentate patients and 96% of the edentate patients presented with complete septa. Two percent of the dentate patients and 4% of the edentate patients presented with incomplete septa.

The analysis of the anatomic location of the septa within the maxillary sinus was performed only in dentate patients and revealed that 55.4% were located in the posterior region, followed by the middle region (33.7%) and the anterior region (10.9%).

For dentate patients, the spatial orientation of the septum was transverse in 18.8% of patients and oblique in 81.2% of patients. For edentate patients, 53% of the septa were oblique and 47% were transverse. We did not identify sagittal septa in either of the 2 groups.

The range and mean values for septum angle, length, height, and thickness are shown in Table 3.

Student's t-test was used to compare means between the 2 groups. Middle height was the only distance that was different between edentate and dentate patients ($p=0.0095$, edentate mean < dentate mean).

Discussion

There were no statistically significant differences among the 2 groups, except for the middle height. This is in agreement with Orhan [29]. Qian [33] observed a significantly ($p<0.05$) greater occurrence rate of 57.4% in the edentulous group compared with the rate of 39.7% observed in the dentulous group.

The results of our study concerning the morphology of the septa are different from those of other studies [34]. Bruno et al. confirmed that 40% of patients have bony septa that can partially separate the maxillary sinus [37]. In our study, 98% of the dentate patients and 96% of the edentate patients presented with complete septa. These differences may be because Bruno et al. excluded bony septa less than 4 mm in height or width.

As for the location of the septa, a greater number were found in the posterior regions (55.4%), but several studies observed them in the anterior [26,28,31,38] and in the middle regions [29,30,32]. Differences in localization may be because we did not exclude secondary septa such as bony crests on the maxillary sinus floor, also known as secondary septa, which can be considered a result of tooth loss and atrophy [39].

Table 3. The mean values and standard deviation for dentate and edentate patients and the intraclass correlation coefficient.

	Dentate			Edentate			p	ICC
	Range	Mean	SD	Range	Mean	SD		
Angle septum	35.7°– 140.9°	86.03	17.9672	53.8°–176.1°	89.38	18.2447	0.07	0.851
Length	3–16.5	9.53	2.5198	4.7–17.5	9.42	2.4385	0.69	0.879
Lateral height	0.5–10.3	3.68	1.7760	0.7–12.7	3.92	1.6991	0.16	0.698
Medial height	0.5–10.6	4.7	2.5474	0.2–7.7	5.02	2.6597	0.22	0.766
Middle height	0.6–12.2	2.8	1.7105	0.9–17.5	2.40	1.2982	0.01	0.932
Thickness lateral AB	0.9–10.9	5.05	1.8091	0.6–9.6	4.76	1.5681	0.09	0.61
Thickness lateral CD	0.6–7.8	2.45	1.3961	0.5–5.4	2.32	0.8224	0.26	0.641
Thickness middle A'B'	0.7–11.5	4.30	1.8416	0.5–8.2	4.13	1.5599	0.31	0.74
Thickness middle C'D'	0.5–7.2	1.24	0.7746	0.3–3.8	1.12	0.5311	0.07	0.659
Thickness medial EF	0.4–11.7	4.22	1.6428	1–8.7	4.28	1.4250	0.39	0.484
Thickness medial GH	0.5–7.9	2.06	1.1641	0.6–8	2.19	1.1972	0.3	0.654

To the best of our knowledge, there are no 3D studies that evaluated the inclination of the septum plane on the horizontal maxillary plane. The results of this study indicate that the angle formed by the septum plane and the horizontal maxillary plane is favorable for implant insertion (86.03° for dentate patients and 89.38° for edentate patients). According to Malo, the implant can be placed from a vertical position in the canine/first premolar region to a tilted implant in the second premolar/first molar region, following the anterior sinus wall up to 45 degrees of inclination [40].

The reproducibility of the 3 landmarks that defined the maxillary horizontal plane was not evaluated.

Previous studies reported different heights for the septa, ranging from 1 to 42 mm [1,29,32,39,41,42]. The mean septum heights in our study groups were lower than those found in other studies [28,29,34,35]. In comparison with other studies [28,29,39], our measurements were performed on 3D reconstructions. 3D measurements are more reliable than 2-dimensional measurements.

CBCT is an alternative to conventional multislice CT, with a low radiation dose (4 to 10 times lower, depending on the volume scanned) [43].

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For both study groups, the oblique orientation was the most frequent. This is similar to other studies [28]. As seen in the literature, horizontal septa are rare. Gulsen presented 2 horizontal sinus septa in a case report [44].

We are the first to use the technique of 3D imaging to assess the thickness of the septa, along its lateral-medial dimension. Our results indicate that the lateral and medial aspects of the septa are the most likely to increase available alveolar bone height for implant placement.

Further studies should focus on improving the accuracy of the 3D evaluation method and on the potential for using sinus septa to clinically evaluate virtual implant placement into the maxillary sinus septa.

Conclusions

Reliable measurements may be performed using CBCT 3D reconstructions.

Extensive evaluation of sinus septa using 3D imaging showed that the sinus septum can increase the available bony height for implant placement.

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