Annals of Oral & Maxillofacial Surgery
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Research study

Implantology

Prevalence, location and orientation of maxillary sinus septa.

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Abstract

Introduction

The most common complication of sinus floor elevation procedures is the perforation of the Schneiderian membrane. This often occurs during the membrane elevation, and it is associated with the presence of antral septa. The prevalence of the sinus septa differs between populations. So far, no information concerning the Middle East population has been published. The aim of this retrospective study was to evaluate the prevalence, location and orientation of the sinus septa in the Department of Dentomaxillofacial Radiology of a Lebanese hospital.

Materials and methods

The CBCT scans of 348 consecutive patients were analysed to identify the presence of septa within the sinus cavities. Axial, coronal and sagittal slices were used to explore the location and orientation of the sinus septa. Axial and coronal slices were divided into 3 thirds to evaluate and compare the anatomical position of the septa. Sagittal slices were used to evaluate the height and the angulations of the septa.

Results

37.07% of the patients presented at least one septa. No difference was detected between dentate and edentulous patients. Coronal slices showed that the majority of the septa (76.04 %) were localized in the lower third of the sinus cavity. Axial slices of the sinus indicated no difference in the antero-posterior location of the septa. The analysis of the sagittal slices showed a mean septal height ranging from 1.6 mm to 24.52 mm. The angle between the septa and the medial palatal suture ranged from 31° to 120°; whereas, the angle with the sinus floor ranged from 61° to 150°.

Conclusion

In the present study, the prevalence of septa is in the top third values published so far in the literature. This high prevalence indicates that medical imaging of the sinus is mandatory prior to sinus floor augmentation procedures, and may impact the sinus membrane elevation procedures.

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Introduction

Due to the presence of the maxillary sinus above the surgical site, and the lack of osseous volume into which implants may project, dental implants placement in the posterior maxilla is complicated. Thus in these cases, sinus lift procedures are needed before the placement of dental implants[2,3,4]. The most common complication of sinus floor elevation procedures is the perforation of the Schneiderian membrane[4]. This often occurs during the membrane elevation in the presence of antral septa[5].

Maxillary sinus septa are barriers of cortical bone that divide the maxillary sinus floor into multiple compartments, known as recesses. They were first analysed by Arthur S. Underwood, an anatomist at King's College London, who reported information concerning their prevalence and characteristics and were afterwards referred as Underwood's septa[1].

The latter, can have a congenital origin or may be acquired structures: primary septa arise during development of the maxilla, secondary septa arise from irregular pneumatization of the sinus floor after tooth loss[5,6].

Although for decades sinus septa have been considered clinically insignificant variations, they have become increasingly important after the introduction of sinus floor augmentation surgery since their presence may complicate both creation and inversion of the access window in the lateral sinus wall, as well as elevation of the sinus membrane from the bony sinus floor[7]. The prevalence of the sinus septa differs between populations. So far, no information has been published from the Middle East population.

The aim of this retrospective study was to evaluate the prevalence, location, size and orientation of the sinus septa, using 3-D cone beam computed tomography for posterior maxilla.

Materials and methods

This work conforms to the values laid down in the Declaration of Helsinki (1964). The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed. All subjects gave full informed consent to participate in this study.

Imaging Modes

CBCT scans were performed with an ICAT® (Imaging Sciences International, Hatfield, PA) in the Department of Dentomaxillofacial Radiology and Imaging, of a Lebanese hospital.

The field-of-view (FOV) or the beam diameter at the surface of the image receptor (beam height) was adjustable. The protocols were set to visualize the entire jaws or at least the upper maxilla, giving between 135 and 540 slices of 0.25/0.4-mm of thickness. Images were obtained at 120 kVp and 5 mAs.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

FOR CITATION PURPOSES: *Hadchiti W, Nasseh I, Hayek E, Mora F, Bouchard P. Prevalence, location and orientation of maxillary sinus septa. Annals of Oral & Maxillofacial Surgery 2014 May 04;2(1):9.*

Annals of Oral & Maxillofacial Surgery
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Research study

Study population and indications

The CBCT scans were performed to the patients attending the Department of Dentomaxillofacial Radiology and Imaging at the School of Dentistry of the Lebanese University between January 2008 and December 2012. The study included 348 patients, presenting the following characteristics:

- 159 male (45.69%) and 189 female patients (54.31%).
- The mean age of patients was 44 years (SD), range 5-82 years
- The youngest patient was 5 years old and the oldest patient was 82 years old at the time of the investigation. (Table 1) 62.36 % of the scans were prescribed for implant site assessment, 16.67% were done for orthodontic treatment and 20.97% for other reasons (neoplasia, trauma, sinusitis…etc.). Note that patients exhibiting a pathologic appearance in the maxillary sinus (53 patients), and those with "incomplete sinus" due to a small field of view, were excluded from this study.

In the presence of at least two teeth in the posterior maxillary region, the patient was considered dentate, and in the absence of all teeth in the posterior maxillary region, the patient was considered edentulous.

According to the physical examination, 290 cases (83.33 %) were dentate (D) and the remaining 58 cases (16.67 %) were edentulous (CE).

Data Acquisition and Statistical Analysis:

The obtained images were viewed with the proprietary ICAT software (ICAT Vision) using the panoramic view module and the multiplanar reconstruction module. All images were assessed at an examination workstation under standardized conditions. Computer equipment at the examination station consisted of two monitors and a personal computer. The computer was a 3.4-GHz Pentium IV HT unit (Intel) with 1 GB of RAM, 256 MB of memory, a 400-MHz clock speed, and a 128-bit memory interface graphic accelerator card (Radeon 9600 series, ATI Technologies Inc). Both monitors were 19-inch diagonal units with a resolution of 1280 x 1024 pixels, a contrast of 700:1.

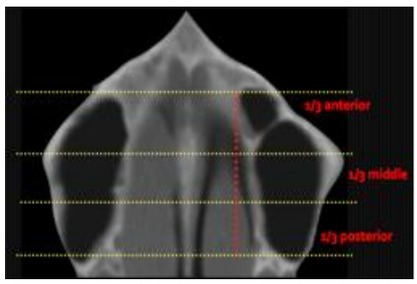

Figure 1: Axial slice used to localize the antero-posterior position of the septum.

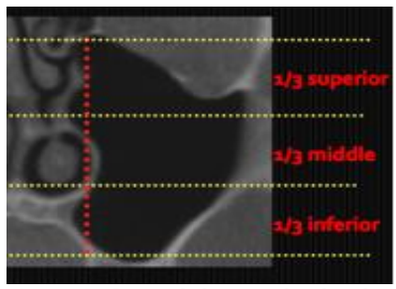

Figure 2: Coronal slice used to localize the infero-superior position of the septum.

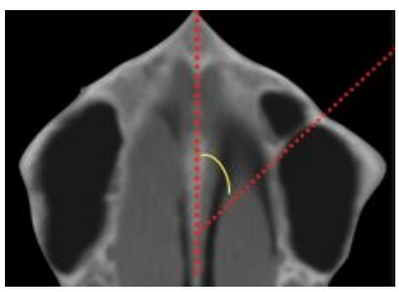

Figure 3: Axial slice used to calculate the angle between the septum and median palatine suture.

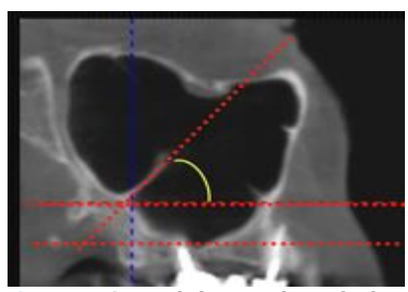

Figure 4: Sagittal slice used to calculate the angle between the septum and the sinus floor.

All hardware components were technically approved for radiologic diagnostics. The room containing the examination workstation was equipped with window shades and dimmable light for standardized low-lit ambience illumination.

Image measurements were performed by three independent examiners (W.H., I.N. and E.H.) who were experienced in dental and oral radiology (one periodontist and two oral radiologists). They were allowed to adjust the brightness and contrast of the images and to use the zoom function provided by the visualization software.

Before image measurement, the examiners were trained for ImageJ measurements. Intra-examiner reproducibility was set following a calibration phase showing a repeatability frequency > 93 % on one slice of interest in 20 CT scans. For interexaminer calibration, one slice of interest was selected from 40 randomly selected CT scans. The angle between the septa and the medial palatal suture was measured by each examiner. When the difference between two values was 5 degree, measurements were repeated to achieve an intraclass correlation coefficient of 0.90.

Axial, coronal and sagittal slices were used to explore the location and orientation of the sinus septa (Figure 1, Figure 2, Figure 4). Axial and coronal slices were divided into three thirds to evaluate and compare the anatomical position of the septa (Figure 1, Figure 2), and sagittal slices were used to evaluate the height and the angulations of the septa (Figure 4).

Table 1: study population.

Age	Male	Female
0-20	17	24
21-40	53	73
41-60	63	79
61-85	26	13
TOTAL	159	189
Total	348	

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
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All the measurements were acquired in millimetres using the proprietary software measuring tool.

Each maxillary sinus bearing a septum was divided into three thirds: anterior (mesial to distal aspect of second premolar), middle (from the distal aspect of second premolar to distal aspect of second molar), and posterior (distal aspect of second molar).

For edentulous patients, i) a line was drawn on the axial cuts going from the most anterior point to the most posterior point of the sinus, ii) the axial cuts were divided into three portions (anterior, middle and posterior third) (Figure 1), iii) the angle between the direction of the septum and the median palatine suture was averagely measured using axial images (Figure 3).

For the supero-inferior location of the septa, i) a line was drawn on the coronal cuts going from the most superior point to the most inferior point of the sinus, ii) the coronal cuts were divided into three portions (superior, middle and inferior third) (Figure 2). The angle between the direction of the septum and the sinus floor was averagely measured using sagittal slices (Figure 4).

Obtained patient data, scan data, and assigned scores were recorded in a Microsoft Excel 2010 database (Microsoft). Statistical analysis was performed with the software SPSS Statistics 17.0 for Windows (SPSS).

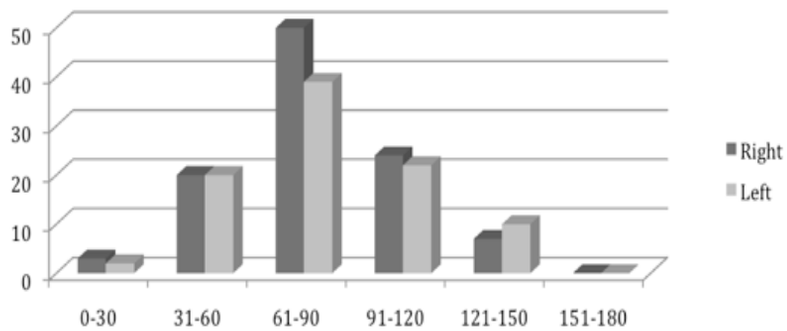

Figure 5: Percentages of the septa (y axis) according to the angle with the medial palatal suture(x axis). Angle values are categorized every 30°.

Results

An interesting observation from these first results was that out of the 348 investigated patients 219 (62.93%) showed no septum and 129 (37.07%) showed at least one septum in one sinus. No significant difference was detected between totally and partially edentulous patients.

The partition of the septa is summed up in Table 2:

- In 78 patient cases, one single septum was detected in one sinus.
- In 121 patient cases, a single septum was found in each sinus.
- Other combinations: two septa in one sinus (19 patients), one septum in one sinus and two in the other (12 patients).
- In only 2 patient cases, at least three septa were found in one sinus.

No statistically significant difference was found between the right and the left side.

In terms of position,
- In the anteroposterior direction: Axial slices of the sinus indicated no difference in the antero-posterior location of the septa. 55 septa (28.65%) were posteriorly located, in proximity of the molar region, and 75 (39.06%) were near the first and second premolar. In the anterior area, 67 septa (34.90%) were detected.
- In the inferosuperior direction: Coronal slices showed that the majority of the septa (76.04 %) were localized in the lower third of the sinus cavity.

Figure 5 shows that the angle between the septa and the medial palatal suture ranged from 31° to 120°. Thus the angle was inferior to 90° in 68 % of the cases. Figure 6 shows that the angle between the septa and the sinus floor ranged between 61° and 150°, the angle was inferior to 90° in 55.83 % of the cases.

To conclude, the analysis of the sagittal slices showed a mean septal height ranging from 1.6 mm to 24.52 mm.

The prevalence of septa presented no relation with patient's sex, age or edentulous type (Table 3).

Table 2: distribution of septa.

Location of septum	patients	Nb of septum	Nb of Right septum	Nb of Left septum
1 Septum in right sinus	39	39	39	0
1 Septum in left sinus	39	39	0	39
2 Septum in right sinus	4	8	8	0
2 Septum in left sinus	2	4	0	4
1 in right sinus + 1 in left sinus	31	62	31	31
1 in right sinus + 2 in left sinus	5	15	5	10
2 in right sinus + 1 in left sinus	7	21	14	7
2 in right sinus + 2 in left sinus	0	0	0	0
3 in right sinus + 2 in left sinus	1	5	3	2
3 in right sinus + 1 in left sinus	1	4	3	1
Total	129	197	103	94

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
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Table 3: The multivariate analysis showed the factors correlated to the prevalence of septa in the sinus.

	Estimate	Std. Error	Pr (>|z|)	OR	IC. inf	IC. sup
(Intercept)	-0.744	0.307	0.015	0.475	0.26	0.868
Age	0.002	0.007	0.836	1.002	0.987	1.016
Sex M	0.078	0.227	0.732	1.081	0.693	1.686
Edentulous yes	0.141	0.319	0.659	1.151	0.616	2.152

Discussion

Nowadays sinus floor elevation is a standard procedure in implant dentistry indicated when the available amount of bone for the placement of implants in an atrophic maxilla is insufficient. In certain oral surgical procedures, the internal structure of the maxillary sinus is a critical determinant for complications[10,12]. With normal sinus anatomy, preparation and horizontal rotation of a trap door in the maxillary sinus wall is common, provided that the Schneiderian membrane is sufficiently lifted[10,11,13].

The most frequent complication is the tearing of the sinus membrane, which in turn is correlated to the presence of septa in the maxillary sinus[8].

As a result of tooth loss and remnant interseptal bone, Septa seemed to develop in two ways, either primary (developmental) or secondary[9].

All detected septa were orientated in the medio-lateral course. However, septa often did not lie in a straight course but showed different variations. A great emphasis should be put on the morphology of the septa (localization and complete route) as septal structure can precipitate mucosal rupture.

Previous studies using radiologic examination methods reported septa in 13% to 35.9% of sinuses[4,5,6,7,23,24] and 16% to 38% of patients[6,7]. Shibli et al.[14] investigated 1024 panoramic radiographs and found a total of 307 septa, with a prevalence of 14.9% calculated for both sinuses. Ulm et al.[3] found septa in 82 sinuses, with a prevalence of 18.3%. Krenmmair et al. reported[4] septa in 200 sinuses,

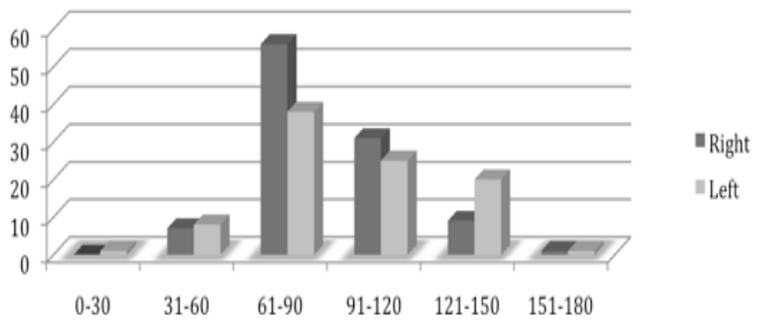

Figure 6: Percentages of the septa (y axis) according to the angle with the inferior border of the sinus (x axis). Angle values are categorized every 30°.

demonstrating a 16% prevalence, and Velasquez-Plata et al. reported 75 septa in 312 sinuses, demonstrating a prevalence of 24%.

These low numbers can be explained in part by the method used to detect and describe the septa. Frequently measuring less than a millimetre in width, septa are very subtle structures that can only be detected with an imaging method that has sufficient resolution in all directions of space.

Therefore, the lower prevalence of septa detected in panoramic imaging compared to the method used in the present study could be attributed to the different imaging modalities. The total prevalence of radiologically detected septa described in this study appears to be the highest reported in the literature so far, with 37.07 % of patients featuring at least one septum. This result is close but a little bit higher than the prevalence of the abovementioned studies.

The majority of the cases had one septum in each sinus (49.77 %). The rest, presented two or even three septas (2 cases only with 3 septa in the same sinus). In 78 patient cases, one single septum was detected in one sinus and a single septum in each sinus was found in 121 patient cases. Prevalence of one septa in the present study was higher than that reported in previous studies[6,7,15,16,17,18].

However, this difference may be attributed to the difference between the radiographic examinations: panoramic and computerized tomography. Panoramic imaging as a two-dimensional imaging technology possesses limitations for assessing an implant site when used alone[15,16]. Pathologies present in the maxillary sinus are frequently overprojected and distorted. Therefore, three-dimensional imaging modalities are found to be superior for evaluating changes in the maxillary sinus[26,27].

CT images provide a three-dimensional representation of the anatomy and are suitable to detect morphologic changes in the maxillary sinus. However, spatial resolution of CT imaging is frequently non isotropic, ie, the resolution is not equivalent for all three directions in space. The resolution within one slice can be less than 1 mm, while the spacing between slices is frequently in the range of a millimetre or more. If the spatial orientation of a structure to be imaged is known, this can be

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
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compensated by orientating the structure while it is being imaged. However, the orientation of septa in the maxillary sinus is not known in advance; therefore, compensation is not an option, and the sensitivity of CT imaging to subtle septa could be reduced. This conclusion is supported by the fact that more septa were found clinically than when CT imaging was used[4].

The modality chosen for this study provides a three dimensional volumetric dataset with an isotropic resolution of 300/400 μm.

Mischkowski and al.[28] concluded that the geometric accuracy is sufficient for clinical usage and comparable to the resolution of a CT image. However, the required radiation dose for a CBCT scan is generally lower than that of a CT examination of the same region[29].

Therefore, this imaging method appears appropriate for diagnostic preparation prior to a maxillary sinus lift. The therapeutic consequence could either be a change in implant position(s) or size to avoid lateral approach access opting for a crestal approach for sinus lift.

If the sinus lift cannot be avoided, at least the access strategy for placing the bone or bone substitute material underneath the sinus membrane can be adjusted[8,30].

Thus, if these parameters (prevalence, location, size and orientation) are present, the unfavourable anatomic situation can represent a contra-indication of the implant project. Indeed, the prevalence of septa in the right sinus (52.25%) was higher than in the left sinus (47.75%). Hence no statistically significant difference was found between the right and left side.

The antero-posterior location of the septum was assessed on the basis of dental formula in previous studies[5,6,7].

Underwood et al.[1] described septa as arising between areas of two adjacent teeth. They usually are present in three specific regions of the sinus floor, dividing the floor into three regions:
- Anterior: Krennmair et al.[4]
- Middle: Plata et al.[5], González-Santana et al.[31] and Velásquez[6].
- Posterior: Ulm et al.[3]

Selcuk et al.[23] found that the distribution of septa in the anterior region is higher than in the posterior region (20.3% and 2.5%, respectively).

In our study, there were no statistically significant differences in the antero-posterior location, 55 septa (28.65%) were posteriorly located in the molar region, 75 (39.06%) were near the first and second premolar (middle area) and 67 (32.29%) septa were detected in the anterior area.

Differences in our results are due to the fact that CBCT is more specific in detecting the location of septa using the three orthogonal slice views: axial, coronal, and sagittal, compared to the panoramic view. In the infero-superior plane, most of the septa were localized on the inferior third (76.04 %). This is important since the trap door of sinus lift technique is located in the inferior third of the maxillary sinus.

Regarding the type of edentulous, some studies reported a higher prevalence of septa in totally edentulous/atrophic areas than in partially edentulous/non-atrophic ones, with statistically significant differences. In contrast, the present study shows no statistically significant difference between totally and partially edentulous patients.

Septa high more than 2 mm (which are an important factor regarding the sinus floor elevation technique) were registered. Septa of at least 2.5 mm of height were evaluated in previous studies[1,4,6]. In this study, septa of less than 2mm of height were included for evaluation.

We reported the mean septal height to be from 1.6 to 24.52 mm on CBCT examination. The mean height was not close to that of previous studies as in Naitoh et al.[33]

A septum was defined as a pointed bone structure, and an exostosis was defined as a rounded bone structure. Besides, all septum inferior to 5 mm of height were considered as exostosis.

Naitoh et al.[33] calculated the angle of the septum between the anterior maxillary sinus and transverse palatine suture regions. They found that most of the septa in anterior maxillary sinus region were antero-laterally directed from the interior wall, and most of the septa in the transverse palatine suture region were laterally directed from the interior wall. Thus, they concluded that the direction of septa might be influenced by the growth of maxillae and palatine bones. In addition, we evaluated the angle between the septum and the median palatine suture using axial images (Figure 3) and the angle between the septum and the inferior border of the sinus using sagittal slices (Figure 4).

We realized that the angle with the medial palatal suture ranged mainly from 31 to 120 degrees and that in 68 % of the cases, the angle was inferior to 90 degrees. On the other hand, the angle with the inferior border of the sinus and the septa ranged mainly from 61 to 150 degrees and in 55.83 % of the cases, the angle was inferior to 90 degrees.

Conclusion

In the present study, the prevalence of septa is in the top third values published so far in the literature. This high prevalence indicates that medical imaging of the sinus is mandatory prior to sinus floor augmentation procedures, and may impact the sinus membrane elevation procedures.

Limitations of the experimental methods

Further investigations should be conducted to experimentally verify the prevalence of septa as stated in this study on anatomical specimens.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
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Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

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Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
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