

## Prevalence of bony septa, antral pathology, and dimensions of the maxillary sinus from a sinus augmentation perspective: A retrospective cone-beam computed tomography study

Aditya Tadinada<sup>1,\*</sup>, Elnaz Jalali<sup>1</sup>, Wesam Al-Salman<sup>2</sup>, Shantanu Jambhekar<sup>3</sup>, Bina Katechia<sup>4</sup>, Khalid Almas<sup>5</sup>

<sup>1</sup>Department of Oral and Maxillofacial Radiology, University of Connecticut, School of Dental Medicine, Farmington, CT, USA

<sup>2</sup>Section of Periodontology, University of Connecticut, School of Dental Medicine, Farmington, CT, USA

<sup>3</sup>Department of Prosthodontics, University of Connecticut, School of Dental Medicine, Farmington, CT, USA

<sup>4</sup>Department of Pediatric Dentistry, University of Connecticut, School of Dental Medicine, Farmington, CT, USA

<sup>5</sup>Division of Periodontology, University of Dammam, College of Dentistry, Dammam, Saudi Arabia

### ABSTRACT

**Purpose:** Sinus elevation procedures have become a routine and reliable way to gain bone volume in the edentulous maxilla for dental implant placement. Presence of bony septations and pathology in the maxillary sinus often cause complications leading to graft or implant failure or both. The aim of this study was to retrospectively evaluate the prevalence of pathology, direction of the septa, and sinus width measured at 2 mm, 5 mm, and 10 mm from the sinus floor in maxillary sinuses using cone-beam computed tomography (CBCT).

**Materials and Methods:** Seventy-two sinuses from 36 random preoperative CBCT scans referred for implant therapy were retrospectively evaluated for the number, prevalence, and direction of bony septations and presence of pathology. Width of the sinus was also measured at 2 mm, 5 mm, and 10 mm from the sinus floor to account for the amount of bone available for implant placement.

**Results:** Maxillary sinus septa were found in 59.7%. Presence of a single septum was noted in 20 sinuses (27.7%), followed by two septa in 17 sinuses. The most common direction of the septum was the transverse direction. Retention pseudocyst and mucosal thickening were the most commonly seen abnormality/pathology.

**Conclusion:** Based on the high prevalence of septa and sinus pathology in this sample, a preoperative CBCT scan might be helpful in minimizing complications during sinus augmentation procedures for dental implant therapy.  
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**KEY WORDS:** Cone-Beam Computed Tomography; Dental Implants; Maxillary Sinus

### Introduction

Implant-supported restorations are increasingly becoming the option of choice for restoring missing teeth due to their high rate of documented success.<sup>1</sup> However, implant placement can be challenging, especially in the posterior maxilla, due to poor bone quality and the dual-pattern resorption of maxillary alveolar bone.<sup>2</sup> According to Wolff's law, tooth loss leads to disuse atrophy and trabecular bone

adaptation resulting in marked alveolar bone resorption.<sup>3</sup> In addition to alveolar bone resorption, bone volume is further compromised due to the continuous pneumatization of the maxillary sinus.<sup>4</sup>

The edentulous posterior maxilla with extensive bone resorption and sinus pneumatization requires prior augmentation of bone volume to facilitate dental implant placement and to increase the chances of long term success. This has been reported to be achievable with sinus elevation procedures to create bone for implants using the crestal osteotome approach or lateral window approach with or without the use of biomaterials.<sup>5-10</sup> The newly gained bone provides sufficient primary stability, and it has been shown that osseointegration can predictably be

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\*Correspondence to : Prof. Aditya Tadinada

Department of Oral and Maxillofacial Radiology, University of Connecticut Health Center, 263 Farmington Ave., Farmington, CT 06030, USA  
Tel) 1-869-679-2719, Fax) 1-860-679-4760, E-mail) tadinada@uchc.edu

achieved with a high implant survival rate ranging between 61.7% and 100%, with the average survival rate of all interventions being 92.6%.<sup>11</sup> The clinical success and or survival ( $\leq 3$  years) of implants placed with an osteotome sinus floor elevation technique have been reported to be similar to that of implants conventionally placed in the partially edentulous maxilla, making it a very reliable option to gain bone volume.<sup>12</sup>

However, sinus augmentation procedures are not only technique sensitive but are also prone to complications if a thorough preoperative evaluation is not performed.<sup>13-17</sup> In developing any treatment plan for rehabilitation of the edentulous posterior maxilla with implant-supported prostheses, sound knowledge of the anatomy and common variations, patency, and health of the maxillary sinus must be carefully considered. Diagnostic imaging with traditional two-dimensional (2D) radiographic methods using panoramic radiographs and intraoral radiographs plays a crucial role but does not yield three-dimensional (3D) information of the area of interest. The introduction of CBCT has changed the imaging paradigm in preoperative treatment planning for implants. Several studies have shown that CBCT can play a vital role in providing reliable information like available bone height, presence of pathology, and number and location of bony septations when present, and can also aid in preoperative implant planning.<sup>4-8,18-23</sup> Encountering unexpected complications during sinus elevation surgery can often jeopardize the final outcome of the bone graft and implant placement itself, also at times leading to serious sino-nasal complications. Sinus membrane perforation has been reported to be the most common (7-44% occurrence) of the intraoperative complications. Other post-operative complications like nasal bleeding, sinus infection, and barrier membrane or graft exposure are less common.<sup>22-26</sup>

Factors that can increase the risk of the chance of Schneiderian membrane perforation include anatomical variations, presence of septa, previous sinus infection or surgery, and surgeon's experience.<sup>18,21,22</sup> Anatomical factors consist of residual alveolar height, bone density, maxillary sinus septa, and morphology of the sinus floor.<sup>2,3,10,16-18</sup> Maxillary sinus septa have been reported to occur in 13%-35% of maxillary sinuses.<sup>20</sup> The presence of septa has been implicated as a potential cause for perforation during sinus elevation surgery.<sup>21-27</sup> Thus the information on the prevalence, location, and direction of the septa as well as the presence of pathology at the base of the sinus would help patients and their doctors better appreciate the risks associated with surgery in that region. Careful

preoperative assessment of the presence of anatomical variations, pathology, and 3D evaluation, especially at the base of the maxillary sinus with CBCT can help in better planning the procedure and aid the clinician in mitigating the chances of surgical complications.

The aim of this study was to retrospectively determine the prevalence of pathology, prevalence, and direction of bony septae in the maxillary sinus and to correlate these measures with age and gender by using CBCT. The dimensions of the maxillary sinus were evaluated at 2 mm, 5 mm, and 10 mm from the sinus floor. The clinical significance of this study and its measurements should help the clinician in understanding the width of the sinus at the most commonly augmented heights, which will suggest the amount of bone graft material and membrane needed for the procedure. Understanding the prevalence of septations will help in anticipating this potential complication and establishing a treatment plan that accounts for the presence of the septa and the increased time necessary to manage this complication if it were in the area of interest for augmentation.

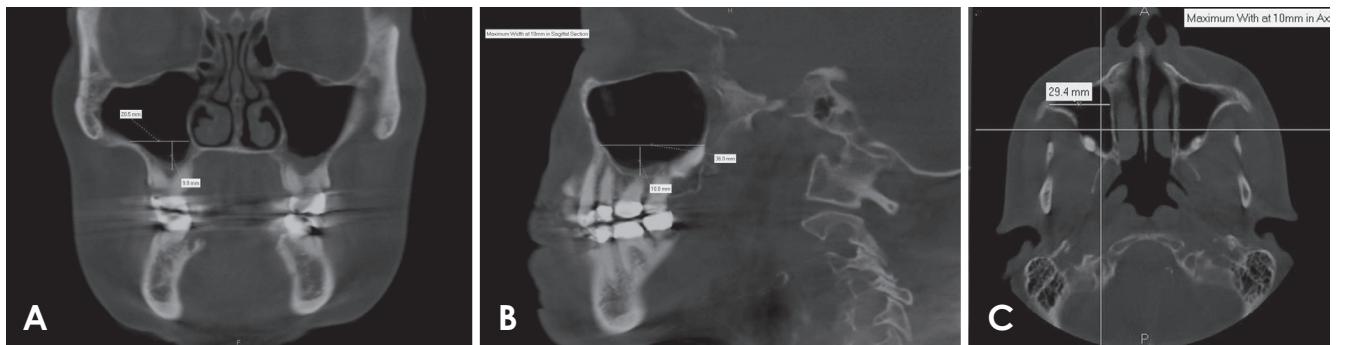
## Materials and Methods

This retrospective study evaluated a randomly selected sample of 36 CBCT volumes acquired at the University of Connecticut Health Center's Oral and Maxillofacial Radiology Clinic between January 2008 and June 2013. Patients who were referred for dental implant therapy were imaged with a CBCT scan that did not show any patient motion or metallic artifacts that rendered the scans non-diagnostic were included. CBCT scans that did not have the entire sino-nasal complex in the field of view, CBCT scans that had patient movement. CBCT scans that had metallic artifacts from dental restorations that would make it challenging to evaluate the maxillary sinus for the presence of pathology when present and make height/width measurements were excluded from the study. The study was approved by the Institutional Review Board (IRB) and the local ethics committee (IRB number: 13-174-1).

The exams were performed using a CBCT unit (CB Mercuray, Hitachi Medical Systems, Kyoto, Japan). The acquisition specifications were a 6-inch field-of-view (FOV) scan covering the maxillary region including the maxillary sinuses, with a voxel size of 0.2 mm and a scan time of 10 seconds. Operating parameters were set at 120 kVp and 15 mA. The images were visualized using a 22 inch HP Compaq LA2205wg screen (HP Corporation, Palo



**Fig. 1.** Septa are seen on an axial (A) and coronal (B) section images.



**Fig. 2.** A. Maximum disto-medial dimension is measured at 10 mm cranial to the floor of the sinus in coronal section. B. Maximum antero-posterior dimensions at 10 mm cranial to the floor of the sinus is measured on the sagittal section. C. Maximum width at 10 mm cranial to the floor of the sinus is measured in axial section.

Alto, CA, USA) with a resolution of  $1680 \times 1050$ ; 1.8 MP. A CB Works version 3.0 (Cybermed, Seoul, Korea), a DICOM viewing software program, was used to analyze the images. The images were reconstructed with a slice thickness of 0.5 mm and a slice interval of 1.5 mm.

The CBCT images were evaluated by a radiology resident and a periodontology resident under the guidance of a board certified oral and maxillofacial radiologist. There was a calibration session prior to initiation of image evaluation to understand the purpose of the study and a training session was conducted to understand the various functions of the reconstruction software. The prevalence, number, and direction of the septum were measured on the coronal, sagittal, and axial planes (Fig. 1). The presence of any pathological/abnormal landmarks was also investigated. In addition, the presence or absence of the posterior teeth (first and second premolars, and molars) was evaluated. The maximum antero-posterior dimension at the levels of 2 mm, 5 mm, and 10 mm and the height cranial to the floor of the sinus were measured on

the coronal, sagittal, and axial images (Fig. 2). The maximum disto-medial dimension at the 2-mm, 5-mm, and 10-mm levels were measured. Based on the direction of the septa with reference to the floor of the sinus, the septa were marked in the transverse sagittal and horizontal directions. Although all septa did not exactly follow these specific directions, they were judged and marked based on the closest direction to their orientation. Descriptive statistical analysis was used, including mean, range, and standard deviation.

## Results

This cross-sectional study consisted of 36 patients (72 bilateral maxillary sinuses) with a mean age of 53.2 years (range of 31 to 85 years). The male to female ratio was 19 to 17 with males accounting for 52.8% and females 47.2%. The posterior teeth in this study were defined as premolars and molars, with the exception of the third molars. The mean percentage of the presence of erupted pre-

molars and molars at the time of evaluation was 57.0% ( $\pm$  0.5) distributed on both sides as follows: 56.0% ( $\pm$  0.4) on the right and 58.0% ( $\pm$  0.4) on the left side.

Maxillary sinus septa were found in 59.7% of the 72 sinuses; that is, 20 sinuses (27.7%) showed a single septum, followed by 2 septa in 17 sinuses (23.6%), and 3 septa in 5 sinuses (6.9%), and in one particular sinus in the sample, 4 septations were recognized (1.3%) (Table 1). In total, 73 septa were found from 72 maxillary sinuses.

The most common direction of the septum in the sinus was found to be the transverse direction, which existed in 51 septa (70.8%), followed by the sagittal direction in 17 septa (23.6%), and the least common was the horizontally oriented septa, which are found in 5 septa (6.9%).

Abnormalities were found in 23 sinuses (31.9%), 9 of which were in the right sinus (25.0% of the patients) and 14 in the left sinus (39.0% of the patients). The most common abnormality was mucus retention pseudocyst, which

**Table 1.** The number of maxillary sinuses according to the number of septa

Number of septa	Number of sinuses	% Prevalence
1 septum	20	27.7
2 septa	17	23.6
3 septa	5	6.9
4 septa	1	1.3
	43	59.7%

**Table 2.** The prevalence of abnormalities in the maxillary sinuses

Abnormalities	Number of cases	% Prevalence
Mucous retention cyst	17	73.9
Periosteal thickening	3	13.0
Metastatic lesion	1	4.3
Keratocystic odontogenic tumor	1	4.3
Antrochoanal polyp	1	4.3

**Table 3.** The dimensions of the sinuses (n = 72) at the level of 2 mm, 5 mm, and 10 mm cranial to sinus floor (mean  $\pm$  standard deviation, range; unit: millimeters)

Distance cranial to the sinus floor		Antero-posterior	Disto-medial (Medio-lateral)
Right sinus	At 2 mm	16.3 $\pm$ 6.1 (9.3-29.4)	10.8 $\pm$ 4.5 (6-30.8)
	At 5 mm	23.7 $\pm$ 5.7 (10.0-34.8)	14.8 $\pm$ 3.9 (9.3-31.6)
	At 10 mm	31.3 $\pm$ 3.3 (22.0-37.7)	19.9 $\pm$ 4.5 (11.9-36.3)
Left sinus	At 2 mm	14.3 $\pm$ 5.0 (5.1-26.3)	9.6 $\pm$ 3.2 (5.4-23.9)
	At 5 mm	24.5 $\pm$ 6.5 (12.7-39.0)	14.3 $\pm$ 4.3 (2.2-29.8)
	At 10 mm	32.4 $\pm$ 4.7 (18.7-47.5)	19.1 $\pm$ 3.6 (12.7-30.8)
Total	At 2 mm	15.3 $\pm$ 5.6 (5.1-29.4)	10.2 $\pm$ 3.9 (5.4-30.8)
	At 5 mm	24.1 $\pm$ 6.1 (10.0-39.0)	14.5 $\pm$ 4.1 (2.2-31.6)
	At 10 mm	31.8 $\pm$ 4.1 (18.7-47.5)	19.5 $\pm$ 4.12 (11.9-36.3)

**Table 4.** The maximum dimensions of the sinuses (n = 72) (mean ± standard deviation, range; unit: mm)

	Antero-posterior	Disto-medial (Medio-lateral)	Cranio-caudal
Right sinus	36.3 ± 4.8 (23.1-45.0)	38.4 ± 3.1 (30.1-44.3)	26.9 ± 3.6 (18.9-34.2)
Left sinus	36.2 ± 4.6 (25.7-45.0)	38.1 ± 3.9 (28.3-48.5)	27.7 ± 5.1 (18.1-44.2)
Total	36.3 ± 4.7 (23.1-45.0)	38.2 ± 3.5 (28.3-48.5)	27.3 ± 4.4 (18.1-44.2)

## Discussion

Various studies have reported on the prevalence, direction, and location of septa with a range of percentages. The clinical prevalence of septa reported in various studies accounts for up to 57.6% of maxillary sinuses based on clinical and radiological examination.<sup>20</sup> Gosau et al.<sup>28</sup> stated that most septa are present in the posterior region. Ulm et al.<sup>29</sup> claimed conversely that most are in the anterior, while Velasquez-Plata et al.<sup>30</sup> and Gonzalez-Santana et al.<sup>31</sup> described them to be prevalent in the middle region. Since no consensus has emerged on the location and prevalence, we tailored this study to address this question with a reasonably large sample size.

The total prevalence of radiographically detected septa described in this study appears to be the highest reported in the literature so far. The maxillary sinus septa were found in 59.7% (50.0% of right sinuses; 69.4% of left sinuses) (Table 1). A single septum was most frequently recognized in 20 sinuses (27.7%), followed by two septa in 17 sinuses (23.6%), and three septa in 5 sinuses (6.9%), and in a single sinus there was 4 septa (1.3%).

The most common direction of the septum in the sinus was found to be the transverse direction, and this orientation occurred in 51 septa (70.0%), followed by the sagittal direction in 17 septa (23.3%), and least common was the horizontally oriented septa, which are found in 5 septa (6.9%). The lower rate of prevalence reported in previous studies might be a result of diagnosis of the sinus septa using 2D panoramic radiographs. Sinus septa showing a sagittal orientation might not have been diagnosable at all using panoramic radiographs and thus led to the false assumption of narrow internal sinus anatomy and subsequent non-augmentation of the medial portion of the sinus cavity.<sup>20,30,32</sup>

The high correlation of the values between the reported clinical prevalence and radiological prevalence of septa obtained in this study highlighted the ability of high spa-

tial resolution CBCT in evaluating anatomy or septa.<sup>20</sup> Furthermore, 31.9% of the sinuses showed the presence of abnormalities, with mucus retention cyst (17 cases in 74.0% of the abnormalities) being the most common abnormality to be found, followed by periosteal thickening (3 cases in 13.0% of the abnormalities). Other less commonly recognized abnormalities were metastatic lesion, keratocystic odontogenic tumor, and antrochoanal polyp.

The dimensions of the maxillary sinus in antero-posterior, disto-medial, and crano-caudal planes were evaluated at the levels 2 mm, 5 mm, and 10 mm cranial to the sinus floor. This was predominantly the area of interest during sinus elevation in most clinical situations, and elevation was obtained ranging from a minimum of 2 mm to a maximum of 10 mm, with 5 mm routinely. Thus, the presence or absence of septa and pathology in this region would be of particular interest to the clinician. This might dictate a different approach in case of sinus floor augmentation ranging from modification in the surgical access strategy (or window design) to a change in implant positions or total avoidance of bone augmentation procedures. During the lateral window approach, the direct visualization of the sinus membrane within the sinus would be limited or compromised due to the nature of the surgical site and challenges of the surgery. The pre-operative three-dimensional radiographic analyses would help the clinician estimate the amount of elevation needed in the medio-lateral dimension, thus minimizing or even preventing augmentation of the medial portion of the sinus and its effect on implant placement. There was no significant difference between the prevalence of septa between the right and left sides, or by the age and sex of the patient.

Different radiographic techniques for evaluation of the maxillary sinus septa include standard oral radiography, panoramic radiography, and CBCT scans. Panoramic radiography may lead to a misdiagnosis of sinus septa about 12-44% of the time because it is difficult to identify the overlapping anatomic structures due to superimposition.<sup>20,32</sup> In contrast, CBCT allows high-resolution images of delicate bony structures. CBCT does not have the inherent problem of superimposition and magnification, and it helps in visualizing the craniofacial structures with more precision than the 2D conventional methods. Therefore, CBCT may be considered the 3D method of choice for visualization of the antral septa. Perpendicular to the orientation of the maxillary septa, an axial image can be considered the optimal sectional plane for revelation of bony variation.<sup>15,18</sup> For accurate diagnosis and treatment planning, CBCT scans may be a very useful diagnostic

tool to avoid or at least minimize complications.

Further studies may be necessary in the future to evaluate the correlation between the orientation of the septa and rate of complications in the outcome of a sinus augmentation surgical procedure for implant placement. Based on the results of this study, it can be concluded that the prevalence of bony septa and presence of sinus pathology in the maxillary sinus is very high in the population we studied, and preoperative imaging of the maxillary sinus using CBCT can be a very useful aid in planning sinus augmentation procedures for dental implant therapy.

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