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ORIGINAL ARTICLE

Retrospective analysis of maxillary sinus septa – A cone beam computed tomography study

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KEYWORDS

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Abstract *Background:* Sinus lift procedures have become a routine and reliable way to gain bone volume in the posterior maxilla for implant placement. The presence of an antral septum in the maxillary sinus increases the risk of complications and subsequent implant failure. This study was designed to estimate the prevalence of maxillary sinus septa and its correlation with age, sex, dentition status and the risk of perforating the Schneiderian membrane using cone beam computed tomography (CBCT).

Methods: This retrospective, cross-sectional study consisted of a total of 178 CBCT images (100 male, 78 female), 63.0% were dentate, 36.0% partially dentate and 1.1% edentate subjects with a mean age of 35 ± 45 years was analyzed to determine the prevalence, height, location, and orientation of maxillary sinus septa. The septa were classified according to the modified Al-Faraje's classification into VII septal patterns, and the risk of perforation of the Schneiderian membrane was estimated. The chi-square test was used to compare categorical variables, and Student's *t*-test and the Kruskal-Wallis test were used to compare continuous variables.

Results: Septa were present in 25.6% of the sinus segments (37.64% of the subjects). The mean septum height was 5.22 mm ± 2.06 in males and 6.27 mm ± 3.55 in females. The majority of septa were located in the middle 76.92%, while 4.40% were anterior, and 18.68% were posterior; 76.92% were in a buccopalatal direction, whereas 23.08% were in an anteroposterior direction. Class III was the most prevalent type. Overall, 60.4% had a moderate risk of membrane perforation, 30.8% had a low risk, and only 8.8% had a high risk.

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Conclusion: Three-dimensional CBCT image analyses can be used as a diagnostic tool to provide accurate information that can help avoid unnecessary intra- and postoperative complications during sinus augmentation procedures by identifying the anatomic structures inherent to the maxillary sinus.

1. Introduction

In the posterior maxilla, once a tooth is lost, the alveolar bone begins resorbing. As a result, the maxillary sinus floor extends in a process known as pneumatization (Tadinada et al., 2015). Due to its high success rate, implant-supported restoration has become the option of choice for restoring missing teeth. Extensive pneumatization of the maxillary sinus and alveolar bone loss may obstruct the use of dental implants (Neugebauer et al., 2010). However, to overcome this issue and increase the survival rate of implants in the edentulous maxillary posterior region, sinus augmentation was introduced (Tadinada et al., 2016). The augmentation procedures require osteotomy on the lateral wall of the sinus to separate the Schneiderian membrane from the sinus floor. Therefore, a complete understanding of the anatomical variations in the maxillary sinus is important during sinus augmentation procedures.

In 1910, Underwood first described septa in the maxillary sinus (Underwood, 1910). These septa are cortical plates of bone that could be present in any region of the sinus and divide the sinus into multiple compartments. The prevalence of maxillary sinus septa ranges between 32.2 and 58% (Javier et al., 2017). The highest reported prevalence reached 69% (Sigaroudi et al., 2017; Van Zyl and Van Heerden, 2009).

The septa separates the sinus into 2 or more compartments and are present in any region of the sinus. Their role is to strengthen the bony structure of the sinus. The sinus septa is an important structure for successful sinus elevation surgery because the septum occasionally becomes a cause of perforation of the sinus membrane during sinus augmentation surgery (Park et al., 2011). A possible modification involves cutting and removing the septa to facilitate bone grafting or modifying the design of the buccal window without fracturing the septa by making two access windows or W-shaped windows, depending on the septa location (Malec et al., 2015).

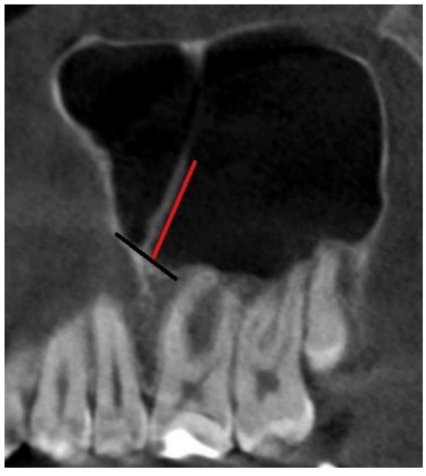


Fig. 1 Demonstrate the measurement of the height of the septa. The black line is the tangent to the floor of the sinus and the red line denotes the height.

All sinus augmentation procedures are technique sensitive and can lead to complications if completed without a thorough preoperative evaluation. The most common complication is perforation of the Schneiderian membrane (Wen et al., 2013). Perforation risk ranges from 10% to 55% (Kim et al., 2016). Extreme caution must be taken during the surgical procedure, as the sinus membrane may rupture, leading to the development of postoperative sinusitis due to bacterial graft contamination or graft migration into the sinus cavity. (Schwarz et al., 2015; Souza et al., 2019). In sinuses with septa interference, the incidence of membrane perforation was 44.7% (Irinakis et al., 2017).

Hence, accurate knowledge and identification of the presence and location of maxillary sinus septa in presurgical radiographs is crucial to properly select the surgical technique and avoid complications. Different radiographic modalities have been used to investigate the anatomical site; however, CBCT remains the gold standard, as it provides high resolution while keeping the radiation dose to a minimum and overcomes the limitations of superimposition and magnification of traditional 2D techniques (Tadinada et al., 2015).

There is a paucity of literature on estimating the risk of perforation of the Schneiderian membrane predicted from CBCT. Hence, in this study, we aimed to estimate the prevalence, height, dental status, location and orientation of the septa of the maxillary sinus and predict the risk of perforation of the Schneiderian membrane according to the modified Al-Faraje (2011) classification by Sigaroudi et al. (2017) and correlate that risk with patients' age, dental status, height, location and orientation of septa using CBCT images.

2. Materials and Methods

This retrospective, cross-sectional study design underwent formal review and received approval from the institutional review board of our institution. The CBCT images were obtained from the archives of the Department of Dentomaxillofacial Radiology at Qassim University in Saudi Arabia. Sample size was determined from Krejcie and Morgan's sample size table (Krejcie and Morgan, 1970).

A total of 178 CBCT images of 356 sinuses were evaluated. Demographic data, including age and sex, were retrieved from the information registered in CBCT software before performing the procedure. The sample consisted of 100 males and 78 females with an M:F ratio of 1.3:1. The dental status of the sample was investigated according to the number of posterior teeth present: dentate (complete set of maxillary posterior teeth) or partially dentate (at least one premolar and one molar

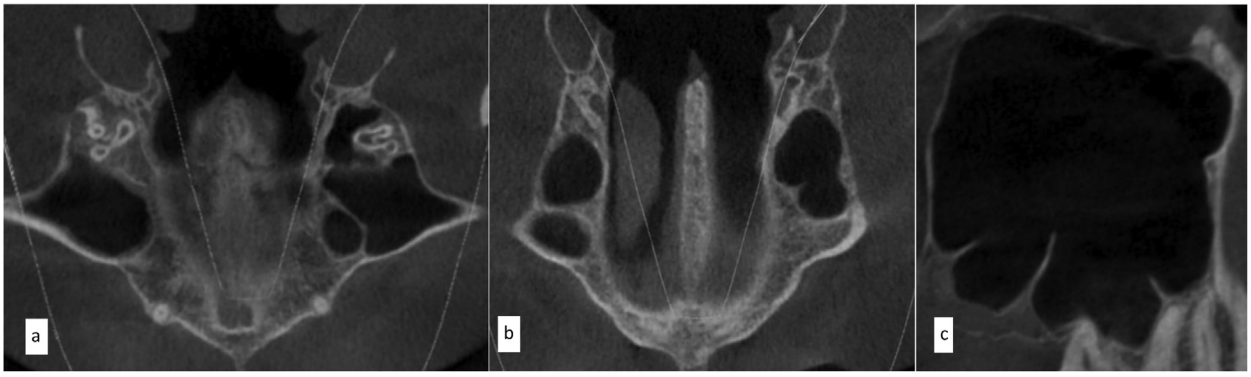


Fig. 2 Axial view of CBCT showing septa in antero-posterior direction (a); septa in bucco-palatal direction (b); sagittal view showing location of septa in anterior, middle and posterior(c).

present) or edentate (absence of all posterior teeth). The sample included 112 (63.0%) dentate, 64 (36.0%) partially dentate and 2 (1.1%) edentate subjects.

2.1. Inclusion and exclusion criteria:

Inclusion criteria:

Patients above 18 years of age.
Healthy periodontium
No previous surgeries performed on the maxillary sinus
No artifacts present in the maxillary sinus region
Exclusion criteria:
Any partial or incomplete images
Patients with any pathology, such as inflammatory disease, including benign and malignant neoplasms, bone dysplasia, etc., affecting the sinus or maxillary posterior region.

2.2. CBCT imaging and analysis

All scans were taken on the same machine (Sirona Dental Systems GmbH, Bensheim, Germany). The scan parameters were 85 KvP, 25 mAs, and 14 s exposure, a field of view of 15 × 15 cm, and a 0.03 mm^3 voxel size. All scans were taken in high definition mode with metal artifact reduction software. The data were reconstructed in slices of 1 mm intervals. Analysis was completed using Sidexis 4 software.

All examinations and measurements were performed by two observers. There was a calibration session prior to initiation of image evaluation and a training session to understand the various functions of the software. In the event of disagreement between the observers, cases were discussed until consensus was reached. All measurements were performed twice by the same investigator, and the average measurement was recorded.

2.3. Height of septa

To evaluate septum height, a tangent was drawn to the floor of the maxillary sinus at the base of the septa, and height was measured by a perpendicular line drawn from the top of the septa to the tangent by the measurement tool of the software Fig. 1.

2.4. Location and orientation of septa

The locations of the septa were recorded based on the protocol put forth by Kim et al. (2006): anterior (mesial to second premolar), middle (distal to second premolar to second molar), or posterior (distal to second molar). The orientations of the septa were recorded as either buccopalatal (from the buccal or palatal side of the sinus) or anteroposterior (from the anterior or posterior wall of the sinus) Fig. 2.

2.5. Classification and perforation risk

The types of septa and risk of Schneiderian membrane perforation were classified according to a modification of Al-Faraje (2011) introduced by Sigaroudi et al. (2017). Table 1 elaborates more on each septa class and its corresponding risk score.

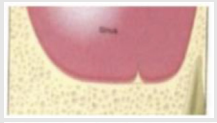
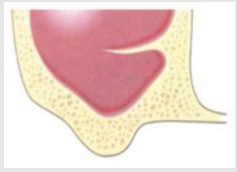
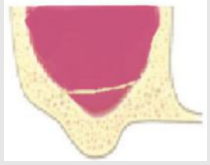
2.6. Statistical analysis

Data were collected and entered using Microsoft Excel and then analyzed using IBM® SPSS® Statistics for Windows, version 24 (IBM Corp, Armonk, NY, USA). Mean and standard deviation (SD) were used for continuous variables and numbers and percentages for categorical variables. The chi-square test was used to compare categorical variables (sex, classification, location, orientation and risk scores). Continuous variables were evaluated using Student's *t*-test to correlate age with sex, and the Kruskal-Wallis test correlated the relation of age with classification and risk scores. P values < 0.05 were considered statistically significant.

3. Results

A total of 178 CBCT images from 356 sinuses were evaluated. The Cohen's kappa scores for both interobserver and intraobserver agreement values were 0.89 and 0.91 respectively. Septa were present in 91 (25.6%) of the sinus segments in 67 (37.64%) of the subjects. Unilateral septa were present in 43 (64.18%) of patients with septa, whereas bilateral septa were present in 24 (35.82%) Other septa configurations are shown in Table 2.

Table 1 Classification method modified from Al-Faraje (2011) to categorize septal patterns © Sigaroudi et al. (2017).

Class	Description	Images	Risk degree (score)
I	Single basal perpendicular septum		Low risk (0)
II	Multiple (2 or more) basal perpendicular septa		Low risk (0)
III	Single long partial perpendicular septum that is not limited to the base of the sinus		Moderate risk if not considered (1)
IV	Multiple (2 or more) long partial perpendicular septa that are not limited to the base of the sinus		High risk and relative contraindication for sinus surgery (2)
V	Partial horizontal septum		Low risk (0)
VI	Complete perpendicular septum that divides the sinus into separate anatomic cavities		Low risk (0)
VII-div I	Complete horizontal septum placed inferiorly		Moderate risk if not considered (1)
VII-div II	Complete horizontal septum placed superiorly		Low risk (0)

According to sex, septa were present in 48 (52.75%) males and 43 (47.25%) females. The mean age of the study sample was 35.71 years ± 12.45 (95% CI: 33.40–39.58). The prevalence of septa did not differ according to sex or age ($p = 0.42$ and $p = 0.45$, respectively). However, the results were statistically significant ($p = 0.03$) according to dental status.

The mean septum length was 5.22 mm ± 2.06 in males and 6.27 mm ± 3.55 in females, without any statistically significant association ($p = 0.08$). There were 4 (4.40%) septa in the anterior region, 70 (76.92%) in the middle and only 17 (18.68%) in the posterior region. No statistical significant association have been found between gender and septum location ($p = 0.06$) Our study sample consisted of 70 (76.92%) in the buccopalatal direction and 21 (23.08%) in the anteroposterior direction.

The prevalence and distribution of different patterns of maxillary sinus septa based on age, sex, dental status, location and orientation of septa according to a modification of Al-Faraje (2011) introduced by Sigaroudi et al. (2017) is shown in Table 3 Class III was the most frequent (58.3% and 60.5%)

Table 2 Different septa configurations.

Configuration of septa	No. Pt	% of all Patients
One septum in one sinus	38	56.72%
One septum in each sinus	19	28.36%
Two septa in one sinus	5	7.46%
Two septa in each sinus	0	0
One septum/two septa	2	2.99%
One septum/three septa	3	4.48%

in males and females, respectively. The most frequent location was the middle region of the sinus. However, no statistically significant difference was associated with any of the variables investigated.

The prevalence for the level of perforation risk score was as follows: low (30.8%), moderate (60.4%), and high (8.8%). The level of perforation risk was not significantly related to the mean patient age ($p = 0.224$), sex ($p = 0.083$), dentition status (0.811) or location ($p = 0.092$). As seen in Table 4, orientation of the septum was the only variable significantly related to perforation risk score ($p < 0.001$*).

4. Discussion

In this study, the prevalence of sinus septa was 25.6% in the sinus segments. There is wide variation in the prevalence of maxillary sinus septa from different populations. For example, the lowest prevalence was 20.45% in study from Taiwan, 49% in a study from Poland and 59.7% % in a study from United State segments (Shen et al., 2012; Malec et al., 2015; Tadinada et al., 2016). In a recent *meta*-analysis by Pommer et al. (2012), which reviewed published articles from 1995 to 2011, the authors found a prevalence of 28%. The variance in reported septa prevalence is due to different populations examined, different examination modalities (direct examination from cadaver, CT, panorama and CBCT), and the minimum septa height.

Regarding the presence of septa and its relation to age and sex, no statistically significant relationship was found. This is in agreement with previously published work (Talo Yildirim et al., 2017; Hungerbühler et al., 2019). In contrast, Fokas et al. (2017) observed that patients aged < 30 years had a significantly higher number of septa; however, there was still no significant association with sex. Only Shen et al. (2012) reported that sex was significantly associated with septa presence.

Regarding the correlation between dental status and the presence of septa, a positive association was found in our study. This supports previous reports (Krennmair et al., 1999; Velásquez-Plata et al., 2002; Lee et al., 2010). Other studies (Wagner et al., 2017; Demirkol and Demirkol, 2019)) did not find any association between dental status and the development of septations.

The mean height of the septa was not associated with either sex or age. This is in agreement with Talo Yildirim et al. (2017) and Orhan et al. (2012). However, Demirkol and Demirkol (2019) observed a significant relationship between height and sex, which was higher in males. Additionally, Taleghani et al. (2017) found a positive association.

The majority of septa in this study were located in the middle of the sinus (76.92%). This is in accordance with the majority of the published articles, where the middle area is the most frequent site (Orhan et al., 2012,Bornstein et al., 2016; Hungerbühler et al., 2019). Rancitelli et al. (2015) reported equal prevalence in all locations. Krennmair et al. (1999), however, reported a conflicting finding, with the anterior region having the highest prevalence at 75%.

Nearly three-quarters of the sample took a buccopalatal direction. All of the Koymen et al. (2009) samples also took a buccopalatal direction, and in the Pommer et al. (2012) *meta*-analysis, 87.6% took a buccopalatal direction. The percentage of buccopalatal direction reported in published studies was: Tadinada et al., (2016) 70.8%; Irinakis et al., (2017) 71.1%; and Shen et al., (2012) 93.8%.

According to the modification of Al-Faraje (2011) introduced by Sigaroudi et al., (2017), Class III was the most frequent sinus pattern encountered. This pattern possesses a moderate risk for sinus perforation, requiring modification of the sinus lift surgery to avoid postoperative complications. Class IV, which had the highest perforation risk, was present only in 8 of the sinuses examined. Class IV septum requires a modification in the surgical procedure by opening a separate window in the sinus lift procedure to avoid further complications. There was no significant association between the pattern

Table 3 Different septum classes in relation to sex, age, location, and orientation.

Class	Prevalence, n (%)	Age (years)	Male	Female	Dentate	Partially dentate	edentate	Anterior	Middle	Posterior
I	8 (8.8)	36 ± 14.38	5 (10.4)	3 (7.0)	5 (10.2)	3 (7.1)	0	0	6 (8.6)	2 (11.8)
II	1 (1.1)	20	1 (2.1)	0	1 (2.0)	0	0	0	1 (1.4)	0
III	54 (59.3)	38.09 ± 12.01	28 (58.3)	26 (60.5)	29 (59.2)	25 (59.5)	0	0	45 (64.3)	9 (52.9)
IV	8(8.8)	31.38 ± 10.88	7 (14.6)	1 (2.3)	5 (10.2)	3 (7.1)	0	1 (25.0)	6 (8.6)	1 (5.9)
V	19(20.9)	34.53 ± 12.65	7 (14.6)	12 (27.9)	9 (18.4)	10 (23.8)	0	3 (57.0)	11(15.7%)	5 (29.4)
VI	1(1.1)	35	0	1 (2.3)	0	1 (2.4)	0	0	1 (1.4)	0
Total	91 (100)	36.34 ± 12.24	48 (100)	43 (100)	49 (100)	42 (100)	0	4(100)	70 (100)	17 (100)
P-Value		H = 6.195 p 0.288	χ^2 = 8.14 p 0.15		χ^2 = 2.83 p 0.73			χ^2 = 12.37 p 0.26		

H = Kruskal-Wallis, χ^2 = Chi-squared test.

Table 4 Level of perforation risk in relation to sex, age, location, and orientation.

Risk Score	Prevalence	Age (years)	Male	Female	Dentate	Partially dentate	edentate	Anterior	Middle	Posterior	BP	AP
Low	28 (30.8)	34.96 ± 12.68	12 (25.0)	16 (37.2)	14 (28.6)	14 (33.3)	0	3 (75.0)	18 (25.7)	7 (41.2)	11 (15.7)	17 (81.0)
Moderate	55 (60.4)	37.76 ± 12.14	29 (60.4)	26 (60.5)	30 (61.2)	25 (59.5)	0	0	46 (65.7)	9 (52.9)	53 (75.7)	2 (9.5)
High	8 (8.8)	31.38 ± 10.88	7 (14.6)	1 (2.3)	5 (10.2)	3 (7.1)	0	1 (25.0)	6 (8.6)	1 (5.9)	6 (8.6)	2 (9.5)
Total	91 (100)	36.34 ± 12.24	48 (100)	43 (100)	49 (100)	42 (100)	0	4 (100)	70 (100)	17 (100)	70 (100)	21 (100)
P-Value		H = 2.995 p 0.224	χ^2 = 4.975 0.083		χ^2 = 0.419 0.811			χ^2 = 7.984 p 0.092			χ^2 = 34.07 p < 0.001*	

H = Kruskal-Wallis, χ^2 = Chi-squared test, *p < 0.05 statistically significant.

of septa and age, sex, dental status or location. We found a higher prevalence of moderate perforation risk (60.4%) in the middle area (molar), whereas Sigaroudi et al. (2017) reported a higher prevalence risk of low perforation risk (68%) in the molar area.

Schwarz et al. (2015) reported that the risk of membrane perforation in the presence of septa had an odds ratio of 4.8. Thus, it is highly important to have good knowledge of the location of the septa pattern and its related membrane perforation risk to avoid intra- and postoperative complications.

The present study had some limitations because of its retrospective design, as no records are present for the length of the period where teeth were lost in the partially dentate group. Further research is required to investigate the influence of tooth loss on bony septation development.

5. Conclusions

In conclusion, the prevalence of maxillary sinus septa was 25.6%, and the locations and shapes were diverse. We found a higher prevalence of moderate perforation risk, especially in the middle of the sinus. Overall, this study found that there was no relationship between age, sex and the presence of sinus septa, and dental status was the only positive association. The orientation of the septa was significantly associated with Schneiderian membrane perforation risk. Hence, appropriate presurgical treatment planning of maxillary sinus septa with 3D CBCT scan images should be performed to assist the clinician in evaluating the risk of intra- and postoperative complications caused by anatomic determinants.

6. Data availability

The data set is available upon reasonable request.

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Declaration of Competing Interest

The authors declare no conflicts of interest regarding this study.

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