# PREVALENCE, LOCATION, AND MORPHOLOGY OF MAXILLARY SINUS SEPTA IN A UNITED STATES PATIENT POPULATION

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**ABSTRACT**

**Objectives:** The presence of sinus septa may cause complications in maxillary sinus elevation surgery such as perforations. CBCT is important for planning the size, shape, and position of the sinus septa, and help separation of the sinus membrane from the bony septum. The purpose of this study is to determine the prevalence, location and morphology of maxillary sinus septa in patients of Temple University Kornberg School of Dentistry.

**Materials and Methods**: Eight hundred and twenty one scans taken in Temple University Kornberg School of Dentistry between 2009 to July 31, 2013 were evaluated by use of the iCAT software. Age, gender, ethnicity, and dentition status were also evaluated to determine potential relationship of the presence of sinus septa.

**Results**: This study included 680 patients subdivided by gender into 360 female and 320 male, and subdivided by ethnicity into 408 Caucasian, 61 Asian, 51 Hispanic, and 160 African Americans. Septa were present in 303 of 680 patients (44.56%) and 485 of 1360 sinuses (35.7%) evaluated. 26.76% of patients with one or multiple sinus septa were present on both sides of the sinus, and 17.79% of patients with one or multiple septa were present on either right or left side only. Septa height has a mean of 5.26 mm (range of 1.2 to 22.30 mm). Septa were located in premolar, molar, and retromolar regions in 43.4%, 42.03% and 14.6 % respectively. The most common location of the septa is the second premolar region. Orientation of septa was vertical in 67.8 %, transverse 31.68 %, and

horizontal 0.005% of cases. Complete septa were found in only 0.01 % of patients evaluated.

**Conclusions:** Incidence of septa was found in 44.56% of the scans. The age, gender, and ethnicity factors are not statistically significant. However, according to the Wald test, the prevalence of septa in Caucasian and Hispanic groups are statistically significant ($p< 0.05$) from African Americans. Prior to sinus augmentation surgery, CBCT scans should be carefully evaluated for the septa location and height to prevent surgical complication such as perforations.

# ACKNOWLEDGEMENTS

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**CHAPTER 1**
**INTRODUCTION**

Maxillary posterior teeth have demonstrated a high incidence of tooth loss due to caries, periodontal diseases, furcation involvements, patient compliance regarding home care, dental appointments and difficult reaching the posterior teeth due to anatomical restriction, such as masticatory muscles, short vestibule, limited jaw opening, and gaging reflexes. Loss of posterior maxillary teeth poses a unique challenge compared to any other area of the mouth. The pneumatization of the maxillary sinus can compromise the alveolar bone height available for placement of dental implants.



**Figure 1: Illustration of sinus pneumatization from adult tooth loss**

The maxillary sinus begins to develop between the second and third month of pregnancy. It is about 0.1 to 0.2 cm$^3$ in size and remains small until eruption of permanent teeth (Testori 2009). Sinus pneumatization, which is the increase of volume of air contained in it, is completed by adolescence. The volume increases further in an inferior direction after tooth loss. (Seong, 2011) showed that of more than 500 posterior maxillary implants that were placed over a 4 year period, 54% required sinus augmentation procedures to facilitate placement of a dental implant.

Maxillary sinus septa were first analyzed regarding their prevalence and characteristics by Arthur S. Underwood, and thus also referred to as Underwood's septa (Pommer, 2012). Underwood (1910) defined septa as a sickle-shaped reaching up the

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inner to outer wall. Septa is an irregular development (irregular as to period as well as shape, size and position). Septa are frequently divided the sinus into 3 basins, a small anterior one over the premolar region, a large median one descending between roots of the first and second molars and a small posterior one corresponding to the third molar region and extending backwards and upwards slightly beyond the third molar roots. The sections of floor of sinus often marked off by ridges, rising sometimes to distinct septa, correspond to 3 defined periods of tooth activity, which are separated from each other by intervals of tooth eruptions.

Sinus septa have gained practical relevance for periodontists, oral and maxillofacial surgeons as well as otolaryngologists (Rysz & Bakon, 2009). Identification of maxillary sinus septa has gained increasing importance for sinus augmentation surgery because their presence may increase the risk of Schneiderian membrane perforation during sinus elevation surgery. The perforation of the Schneiderian membrane may be associated with the development of maxillary sinusitis. (Betts, 1994), (Krennmair, 1999), (van den Bergh, 2000), (Quiney, 1990), and (Zimbler, 1998).

**Figure 2: Illustration of the perforation of the Schniederian membrane (Clinician: Dr. Yueh Hsiao)**

Therefore, one must consider the possible complications related to sinus augmentation procedures. The purpose of this study is to determine the prevalence, location and morphology of maxillary sinus septa in a group of patients of Temple University Kornberg School of Dentistry, who were referred for head and neck CBCT for diagnosis and treatment planning. The study also aims to determine if age, gender, ethnicity, and dentition status have relation on the prevalence of maxillary sinus septa.

# CHAPTER 2
# MATERIALS AND METHODS

The study was based on a retrospective evaluation of CBCT scans taken from 2009 to July 31, 2013. The study received Temple University Office for Human Subjects Protections Institutional Review Board approval. Eight hundred and twenty-one (821) scans were screened initially. CT images with inadequate information (e.g. absent of maxillary sinus, the field of images did not extend including orbital floor and ostium, unclear images, multiple data of same subject) were excluded. A total of 680 scans of which subject factors of gender, age, ethnicity, and dentition status were finally included in the study. The CT scans were performed using i-CAT machine (Imaging Science International, Inc. Hatfield, PA, USA) with flat panel image detector. Images were taken at 120 kvp, 5 mA, and a voxel size of 0.3 mm, with an exposure time of 8.9 seconds. Fourteen (14) bits gray scales and 8.9 second scan times. The number of slices in one CBCT volume is 327.

Obtained CBCT images were viewed using i-CAT vision viewing software giving a panoramic reconstruction view module and the MPR screen module, i.e. axial, sagittal and coronal slides. All images were assessed under standardized conditions at the same examination workplace (Window XP with Microsoft Offices Software). All scans were analyzed twice (by Y. H. trained under Misch Institute by C.M. & R.R.) and questionable findings were discussed with a boarded oral and maxillofacial radiologist (J.Y.) and 10% of the data were calibrated with a boarded periodontist (J.B.S.).

The mean age of patients at the time of scan was 48.53 years (range 8-90 years). There were 360 females and 320 males. There were 408 Caucasians, 160 African Americans, 61 Asians, and 51 Hispanics. The subjects were also categorized based on

age into 9 groups. <13 years, 13-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years and 80-90 years. Group 0 to 5 were combined to group age < 60 and group 6 to 8 were combined to group age ≥ 60 for the convenient of statistical analysis. There were 413 aged < 60 years and 267 aged ≥ 60 years.

| Age | <13 | 13-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 | 80-90 |
|-------|-----|-------|-------|-------|-------|-------|-------|-------|-------|
| Group | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| n = | 25 | 102 | 49 | 31 | 61 | 145 | 181 | 70 | 16 |

**Table 1: Summary of age distribution.**

The maxillary sinuses septa findings were categorized to no sinus septa presence, presence of one septa, and presence of multiple (>1) septa in either right or left maxillary sinus. Orientation of sinus septa is categorized into transverse (mesial to lateral wall), vertical (inferior to superior wall), and horizontal (anterior to posterior wall). Location of the septa is also determined by the location of the existing tooth except in the partial or complete edentulism patient, the location is determined into anterior, middle and posterior portion of the maxillary sinus.

Dentition status of each side of the sinus were categorized into complete dentition regardless presence of third molar (CD), complete edentulism (CE), partial edentulism (PE), partial edentulism with implants (PI), complete edentulism with implants (PI), and mixed dentition (MD).

Data were recorded using Microsoft Excel spreadsheet (table 2) and R project (http://www.r-project.org) was used for statistical analysis of the results. Multinomial logistic regression was then applied to right septa and left septa data separately to determine if age, gender, or ethnicity has any relationship on Septa incidence. Association patterns of covariate were checked by chi-square test. The validity of the

logistic regression model was evaluated by lack of fit test and likelihood test. 95% confidence intervals of septa incidence rates were calculated with normal approximation under binomial distribution assumption.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Patient ID | Age | Age Catagory | Gender | Ethnic | ght Septa (Y/ | eft Septa (Y/N | R Location | L Location | R Direction | L Direction | R Distance | L Distance | entition Righ | Dentition Left |
| 2 | T170790 | 69 | 6 | M | C | N | Y | | (T) | | IC (V) | | 6 mm | CD | CD |
| 3 | 222222 | 40 | 4 | M | C | Y | N | (M1) | | IC (V) | | 2.70 mm | | PE | PE |
| 4 | E040577 | 43 | 4 | M | AA | N | Y | | (PM2) | | IC (V) | | 3 mm | PE | PE |
| 5 | 147201 | 16 | 1 | M | Asian | Y | N | (T) | | IC (V) | | 3.96 mm | | CD | CD |
| 6 | 0131622 | 64 | 6 | M | C | N | Y | | (M2) | | IC (T) | | 8.44 mm | PE | PE |
| 7 | 143424 | 21 | 2 | F | AA | N | Y | | (M1) | | IC (V) | | 5.20 mm | CD | CD |
| 8 | 0144577 | 13 | 1 | M | Asian | Y | N | (PM1-PM2) | | IC (V) | | 2.68 mm | | CD | CD |
| 9 | 0051930 | 74 | 7 | M | H | N | M | | (PM2), (PM1) | | IC (V), IC (T) | | 6.12 mm, 3.95 n | PE | PE |
| 10 | 140441 | 16 | 1 | M | AA | N | M | | (PM2), (PM2) | | IC (V) | | 3.30, 8.10 mm | CD | CD |
| 11 | 11330610 | 47 | 4 | M | AA | M | N | (M1) & (M2) | | IC (T) | | 3.05 mm | | PE | PI |
| 12 | 124009 | 74 | 7 | F | C | M | N | (PM2) & (T) | | IC (V) | | 8 mm- 14.99 mm | | PE | PE |
| 13 | 0155795 | 52 | 5 | F | AA | M | N | (PM2), (M2) | | IC (T), IC (V) | | 7.47 mm | | CD | CD |
| 14 | 0155223 | 67 | 6 | M | C | M | N | (PM2) & (M1) | | IC (T), IC (V) | | 5.60 mm, 5.47 mm | | PE | PE |
| 15 | 138138 | 18 | 1 | M | AA | N | M | | (M1) & (M2) | | IC (V) | | 3.75 mm/0.56 n | CD | CD |
| 16 | 0161477 | 90 | 8 | F | C | N | M | | Middle & Posterior | | IC (V) & IC (T) | | 8.4 mm | PE | PE |
| 17 | 0135982 | 26 | 2 | M | H | N | M | | (M3) & (T) | | C(T) & IC (V) | | | CD | CD |
| 18 | 135275 | 63 | 6 | F | AA | N | M | | (PM2) & (M2) | | IC (T) & IC (V) | | 10.5, 22.3 mm | PE | PE |
| 19 | 0149476 | 13 | 1 | M | C | M | N | M1-PM2) & (M2) | | IC (T), IC (V) | | 17.49 mm | | CD | CD |
| 20 | 0155749 | 58 | 5 | M | H | N | M | | (PM2) & (PM1) | | IC (T), IC (V) | | 3.22 mm, 5.44 n | PE | PE |
| 21 | 132288 | 54 | 5 | M | C | Y | Y | (T) | (M2) | IC (V) | IC (V) | 5.60 mm | 4.87 mm | CE | CE |
| 22 | 120560 | 72 | 7 | F | AA | Y | Y | (T) | (PM2) | IC (V) | IC (T) | 9.79 mm | 9.38 mm | PE | PE |
| 23 | R100001 | 63 | 6 | F | C | Y | Y | (M1) | (PM2) | IC (V) | IC (V) | 2.1 mm | 6.04 mm | PE | PE |

**Table 2: Examples of data Collection**

**Figure 3: Direction and orientation of sinus septa**

# CHAPTER 3
# RESULTS

Of the 680 CBCT scans, which were reviewed, Three hundred and three (303) subjects have either one or multiple sinus septa presence in one or both maxillary sinuses. This translated to a prevalence of maxillary sinus septa of 44.56% in the population studied, with the remaining 55.44% not significant for any finding of maxillary sinus septa. Out of the 303 subjects, 182 subjects (60.1%) with sinus septa in both sinuses, and 121 subjects (39.9%) with sinus septa in either right or left side of maxillary sinus. Therefore, out of 1360 sinuses, 485 sinuses (35.67%) presented with either one or multiple septa.

| Total Data | Exclude | Study | Sinus Septa | Bilateral | Unilateral | Total Sinuses |
|---|---|---|---|---|---|---|
| 821 | 141 | 680 | 303 | 182 (60.1%) | 121 (39.9%) | 485 |

**Table 3: Number of patients and sinuses exhibiting septa bilaterally and unilaterally respectively.**



**Figure 4: Percent of sinuses exhibiting septa on either side, bilaterally, or no septa**

Septa height has a mean of 5.26 mm (range of 1.2 to 22.30 mm). 187 septa are

presented in vertical orientation, 400 septa in transverse orientation, and 3 septa in

horizontal orientation. This translated to 67.8% in vertical orientation, 31.68% in

transverse, and 0.005% in horizontal. There are 6 complete septa (0.01%) and 590

incomplete septa (99.99%).

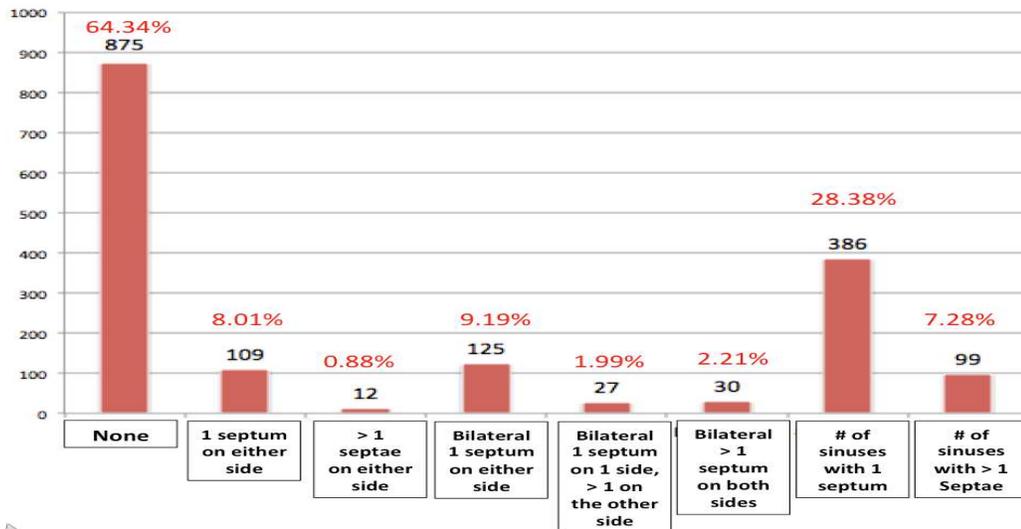| % | Septa | Transverse | Vertical | Horizontal |
|---|---|---|---|---|
| Complete Septum | 6 | 6 | 0 | 0 |
| Incomplete septum | 584 | 181 | 400 | 3 |
| Total | 590 | 187 (31.69%) | 400 (67.80%) | 3 (0.005%) |

**Table 4: Summary of Orientation of sinus septa**

| | Transverse | Vertical | Horizontal |
|---|---|---|---|
| Complete dentition | 78 | 134 | 0 |
| Partial edentulism | 87 | 175 | 2 |
| Complete edentulism | 11 | 62 | 1 |
| Complete edentulism/Implant | 1 | 3 | 0 |
| Partial Edentulism/Implant | 8 | 21 | 0 |
| Mixed dentition | 2 | 5 | 0 |
| Total | 187 | 400 | 3 |

**Table 5: Summary of orientation of sinus septa based on dentition status**

Location of the septa were categorized into teeth location, first premolar, between

first and second premolar, second premolar, between second premolar and first molar,

first molar, between first and second molar, second molar, third molar and tuberosity

area. There are few septa, unable to determine exact tooth location due to edentulism.

The most common location is the second premolar region. Location is also categorized

into anterior (first and second premolar), middle (first and second molar), and posterior

(third molar and retromolar pad) region. Septa were located in anterior, middle, and posterior regions in 43.4%, 42.03% and 14.6 % respectively.

| Dentition Status | PM1 | PM1-PM2 | PM2 | PM2-M1 | M1 | M1-M2 | M2 | M3/Tuberosity | Unable to determine exact tooth location |
|---|---|---|---|---|---|---|---|---|---|
| Complete dentition | 30 | 9 | 75 | 3 | 32 | 0 | 33 | 30 | 0 + 1 + 1 = 2 |
| Partial edentulism | 31 | 3 | 68 | 5 | 54 | 2 | 52 | 26 | 1 + 12 + 12 = 25 |
| Complete edentulism | 0 | 0 | 6 | 0 | 3 | 0 | 5 | 2 | 8 + 33 + 12 = 53 |
| Complete edentulism/Implant | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 + 3 + 0 = 3 |
| Partial Edentulism/Implant | 3 | 0 | 9 | 0 | 9 | 0 | 9 | 1 | 0 |
| Mixed Dentition | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 0 |
| Total | 65 | 12 | 162 | 8 | 98 | 2 | 99 | 61 | 83 |

**Table 6: Summary of the location of sinus septa**

|  | Anterior (PM1-PM2) | Middle (M1-M2) | Posterior (M3-tuberosity) | Total |
|---|---|---|---|---|
| Complete dentition | 117 | 66 | 31 | 214 |
| Partial edentulism | 108 | 120 | 38 | 266 |
| Complete edentulism | 14 | 41 | 14 | 69 |
| Complete edentulism/Implant | 1 | 3 | 0 | 4 |
| Partial Edentulism/Implant | 12 | 18 | 1 | 31 |
| Mixed dentition | 4 | 0 | 2 | 6 |
| Total | 256 | 248 | 86 | 590 |

**Table 7: Summary of the location of sinus septa based on dentition status**

When categorizing in terms of gender of 360 female and 320 male studied, 153 females and 150 males presented with evidence of sinus septa. This translated to 22.50% of females and 22.06% of male with evidence of sinus septa. In both gender, most

common prevalence is bilateral single septum present in both sinuses, following by 1

septum on one side.

| | Septum Present | No Septum | 1 septum on one side | > 1 Sinus Present on one side | Bilateral 1 septa on both sides | Bilaterally 1 septum on either side, > 1 on the other side | Bilateral > 1 septa on both sides |
|---|---|---|---|---|---|---|---|
| Female | 153 (22.50%) | 207 (30.44%) | 56 | 4 | 68 | 14 | 11 |
| Male | 150 (22.06%) | 170 (25%) | 53 | 8 | 57 | 13 | 19 |
| Total | 303 | 377 | 109 | 12 | 125 | 27 | 30 |

**Table 8: Prevalence of sinus septa based on gender.**
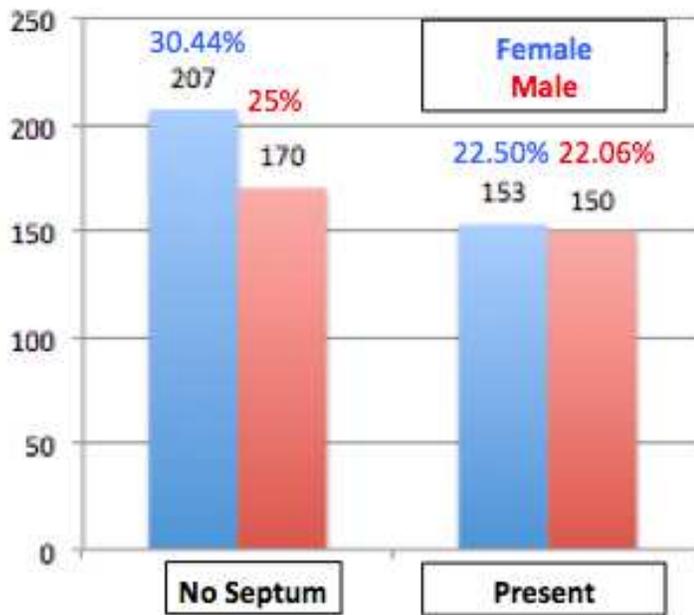


**Figure 5: Prevalence of sinus septa based on gender.**

When categorizing the results in terms of ethnicity, the prevalence of sinus septa

was 27.79%, 4.12%, 3.97%, and 8.68% respectively for the groups Caucasians, African

Americans, Asians and Hispanics. There was no statistically significant difference.

| | Septum Present | No Septum | 1 septum on one side | > 1 septa Present on one side | Bilateral 1 septa on both sides | Bilaterally 1 septum on either side, > 1 on the other side | Bilateral > 1 septa on both sides |
|---|---|---|---|---|---|---|---|
| Caucasian | 189 (27.79%) | 219 (32.21%) | 63 | 4 | 82 | 22 | 18 |
| Asian | 28 (4.12%) | 33 (4.85%) | 10 | 0 | 13 | 0 | 5 |
| Hispanic | 27 (3.97%) | 24 (3.52%) | 11 | 3 | 9 | 2 | 2 |
| African Americans | 59 (8.68%) | 101 (14.85%) | 25 | 5 | 21 | 3 | 5 |
| Total | 303 | 377 | 109 | 12 | 125 | 27 | 30 |

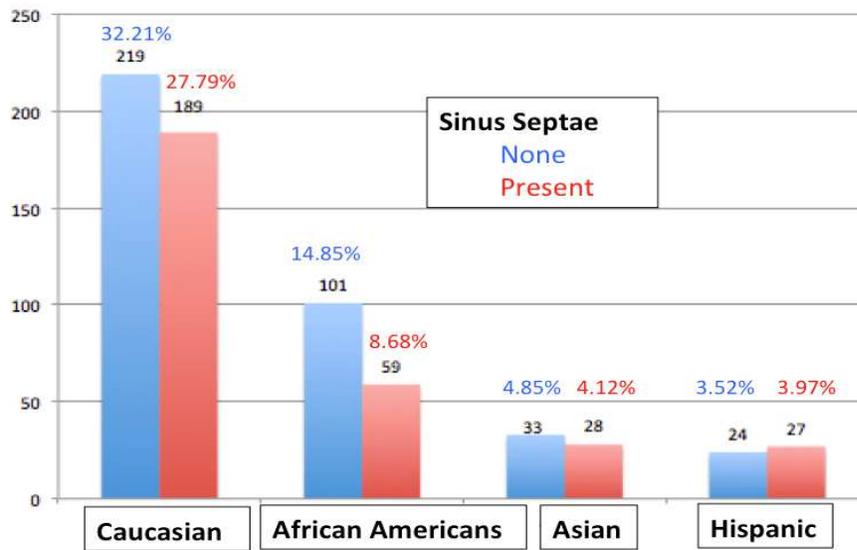**Table 9: Prevalence of sinus septa based on ethnicity.**



**Figure 6: Prevalence of sinus septa based on ethnicity.**

When categorizing the results in terms of age, 186 subjects < 60 years and 117 subjects ≥ 60 years presented with sinus septa, which translated to 17.21% and 27.35%. There is no statistical significant difference.

33.38%
227
27.35%
186

Sinus Septae
None
Present

22.06%
150
17.21%
117

< 60 yr old    ≥ 60 yr old

**Figure 7: Prevalence of sinus septa based on age.**

| | Patient | Complete Dentition (CD) | Partial edentulism (PE) | Complete edentulism (CE) | Complete edentulism/implant (CI) | Partial edentulism/implant (PI) | Mixed Dentition (MD) |
|---|---|---|---|---|---|---|---|
| 1 septum on one side | 109 (22.47%) | 45 (9.28%) | 56 (11.55%) | 2 (0.41%) | 0 | 5 (1.03%) | 1 (0.21%) |
| > 1 septum on one side | 12 (2.47%) | 5 (1.03%) | 7 (1.44%) | 0 | 0 | 0 | 0 |
| Bilaterally 1 septum on either side | 125 (25.77%) | 81 (16.70) | 125 (25.77%) | 23 (4.74%) | 4 (0.82%) | 16 (3.30%) | 1 (0.21%) |
| Bilateral Mixed | 27 (5.57%) | 11 (2.27%) | 14 (2.89%) | 1 (0.21%) | 0 | 1 (0.21%) | 0 |
| Bilateral > 1 septum on both side | 30 (6.19%) | 20 (4.12%) | 19 (3.92%) | 16 (3.30%) | 0 | 3 (0.62%) | 2 (0.41%) |
| # of Sinus with 1 septum | 386 (79.59%) | 137 (28.25%) | 195 (40.21%) | 26 (5.36%) | 4 (0.82%) | 22 (4.54%) | 2 (0.41%) |
| # of Sinus with > 1 septum | 99 (20.41%) | 36 (7.42%) | 40 (8.25%) | 17 (3.51%) | 0 | 4 (0.82%) | 2 (0.41%) |
| Total Sinuses | 485 | 173 (35.67%) | 235 (48.45%) | 43 (8.87%) | 4 (0.82%) | 26 (5.36%) | 4 (0.82%) |

**Table 10: Prevalence of sinus septa based on dentition status.**

**Patterns of association**

The septa occurrence is handled as a "Yes", "No" dichotomous variable on individual patient: the M and Y in the raw data are polled together as a Yes; if a patient has a septum or septa, either one side or two sides, the patients is labeled as a yes. Dentition status is not evaluated due to the complexity of classification.  The age of the patients is categorized into two groups: < 60 years and ≥60 years.

A chi-square test was conducted on each independent variable to detect the association between the selected variable and septa occurrence. Ethnicity and gender seem to have a moderate association with septa prevalence.

**Septa Prevalence Vs Each Covariate**

|  | Age | Gender | Ethnic |
|---|---|---|---|
| Septa | 0.8161 | 0.2853 | 0.12 |

**Association between covariates**

|  | Age vs Gender | Gender vs Ethnic | Age vs Ethnic |
|---|---|---|---|
| No septa | 0.1468 | 0.4205 | **\*4.52e-5** |
| Septa | 0.5678 | 0.9164 | **\*0.003398** |

**Table 11: Septa Prevalence vs Each Covariate and Association between covariates with chi square test**

The p-value of chi square test indicates that there are associations between age and ethnicity.

In the later regression analysis, model was constructed including each factor (age, gender, ethnicity) individually.

1. **Simple Logistic Regression**

*Age Model*

$$log \frac{\pi_1}{1 - \pi_1} = \beta_{ia} + \beta_1 Age$$

$\pi_1$ : the incidence rate of septa; $\frac{\pi_1}{1-\pi_1}$ is the odds of having septa vs being normal;

$\beta_{ia}$ : the intercept term of the age model, the logit estimate at baseline level in age model, where the baseline is age<60.

$\beta_1$ : the expected change of logit estimate comparing people older than 60 to people younger than 60; It can also be interpreted as the log of odds ratio for patients older than 60 vs younger than 60.

*Gender Model*

$$\log \frac{\pi_1}{1 - \pi_1} = \beta_{im} + \beta_2 Male$$

$\beta_{im}$ : the intercept term of the gender model, the logit estimate at baseline level in gender model, where the baseline is female.

$\beta_2$ : the expected change of logit estimate comparing males to females.

*Ethnicity Model*

$$\log \frac{\pi_1}{1 - \pi_1} = \beta_{ie} + \beta_3 Asian + \beta_4 C + \beta_5 H$$

$\beta_{ie}$ : the intercept term of the ethnicity model, the logit estimate at baseline level in ethnicity model, where the baseline is African American.

$\beta_3$ : the expected change of logit estimate comparing Asian to African American

$\beta_4$ : the expected change of logit estimate comparing Caucasian to African American

$\beta_5$ : the expected change of logit estimate comparing Hispanic to African American

*Predict of Fitted values*

Let $g_i(x) = \log \frac{\pi_1}{1-\pi_1} = \beta_{ix} + \beta_x x$

$$\pi_1 = \frac{exp(g_i(x))}{1 + \sum exp(g_i(x))}$$

*Example: Ethnicity Model*

$$log \frac{\pi_1}{1 - \pi_1} = \beta_{ie} + \beta_3 Asian + \beta_4 C + \beta_5 H$$

The regression analysis result is as below:

Regression with Ethnicity

|  | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | -0.538 | 0.164 | -3.281 | 0.001 |
| EthnicAsian | 0.373 | 0.305 | 1.225 | 0.221 |
| EthnicC | 0.390 | 0.192 | 2.037 | *0.042 |
| EthnicH | 0.655 | 0.325 | 2.017 | *0.044 |

Degrees of Freedom: 15 Total (i.e., Null); 12 Residual;
Null Deviance: 15.5
Residual Deviance: 9.615;     AIC: 75.3

**Table 12: Regression analysis with ethnicity.**

First analyze the fit of the model using lack of fit test:

The residual deviance of the model is 9.6154, and the degree of freedom (df) are 12 Using the chi-square distribution, the p-value of the lack of fit test is 0.65.

At 5% significance level, the age model fits reasonably well to the pathology data.

Next, evaluate the significance of the model coefficients:

Using the likelihood test, residual deviance in ethnic model is compared to a model that includes the intercepts only. The difference of the residual deviance follows a chi-square distribution and corresponding p-value is therefore calculated.

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The likelihood test result is shown in the likelihood test table. The p-value is 0.1176, indicating that the ethnic factor as a group is not significant at 5% level.

Interpretation of the coefficients:

For example, consider the intercept, notated as $\beta_{ie}$, at baseline level (African American)

$$log \frac{\pi_1}{1-\pi_1} = \beta_{ie} = -0.538$$

$\beta_{ie}$ is the log odds of African American patients having septa relative to being normal;

$\beta_3, \beta_4, \beta_5$ in the ethnic model are the corresponding coefficients for the ethnic groups Asian, Caucasian, and Hispanic; Asian, C and H are the indicators for the specific ethnic group.

In the fitted model, $\beta_3$=0.373, exp(0.373)=1.452, meaning that the odds of having septa relative to being normal for Asian patients is 1.452 times that for African American patients; $\beta_4$=0.39, exp(0.39)=1.477, meaning that the odds of having septa relative to being normal for Caucasian patients is 1.477times that for African American patients; $\beta_3$ =0.655, exp(0.655)=1.925, meaning that the odds of having septa relative to being normal for Hispanic patients is 1.925 times that for African American patients.

*Example of Calculation of fitted value:*

$$log \frac{\pi_1}{1-\pi_1} = \beta_{ie} + \beta_3 Asian + \beta_4 C + \beta_5 H$$

*For African American group,* $log \frac{\pi_1}{1-\pi_1} = \beta_{ie} = -0.538$

$$\pi_1 = \frac{exp(g_i(x))}{1+exp(g_i(x))} = \frac{e^{-0.538}}{1+e^{-0.538}} = 0.369$$

For Asian group,

$$\pi_1 = \frac{exp(g_i(x))}{1+exp(g_i(x))} = \frac{e^{-0.538+0.373}}{1+e^{-0.538+0.373}} = 0.459$$

For Caucasian group,

$$\pi_1 = \frac{exp(g_i(x))}{1+exp(g_i(x))} = \frac{e^{-0.538+0.39}}{1+e^{-0.538+0.39}} = 0.463$$

For Hispanic group,

$$\pi_1 = \frac{exp(g_i(x))}{1+exp(g_i(x))} = \frac{e^{-0.538+0.656}}{1+e^{-0.538+0.656}} = 0.529$$

Similar calculations can be performed in age and gender model if needed. The model fitting results are shown below:

Regression with Gender

|  | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | -0.302 | 0.107 | -2.835 | 0.005 |
| GenderM | 0.177 | 0.155 | 1.145 | 0.252 |

**Table 13: Regression analysis with gender.**

The intercept term is significant. However, the factor gender is not significant. The likelihood test p-value is 0.252. This test indicates that gender factor is not important in predicting incidence rates of septa.

Regression with Age

|  | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | -0.199 | 0.099 | -2.014 | 0.044 |
| Age2 | -0.049 | 0.158 | -0.312 | 0.755 |

**Table 14: Regression analysis with age.**

The intercept term is significant. However, the factor age is not significant (p-value is 0.755). The likelihood test p-value is 0.7554. This test indicates that age factor is not important in predicting incidence rates of septa.

| Summary of Lack of Fit analysis | | | |
|---|---|---|---|
| Model | Residual Deviance | df | p-value |
| 1(Age) | 15.399 | 14 | 0.3514 |
| 2(Gender) | 14.184 | 14 | 0.4361 |
| 3(Ethnicity) | 9.6154 | 12 | 0.65 |

| Summary of Likelihood Test | | | | | |
|---|---|---|---|---|---|
| Model | Residual Deviance | df | Deviance dif | df | p-value |
| 1(Age) | 15.399 | 14 | 0.097 | 1 | 0.7554 |
| 2(Gender) | 14.184 | 14 | 1.312 | 1 | 0.252 |
| 3(Ethnicity) | 9.6154 | 12 | 5.881 | 3 | 0.1176 |
| 0(only intercept) | 15.496 | 15 | | | |

**Table 15: Summary of lack of fit analysis and likelihood test.**

**CHAPTER 4**
**DISCUSSION**

Previous studies on various population subsets have reported the prevalence of sinus septa in the range of 18.3 to 66.7%. (Table 11) The prevalence of sinus septa is in range (44.56%) with other studies that have previously addressed the topic with cadaver studies, and direct clinical measurements, CBCT studies, and panoramics (table 11).

Underwood (1910) described the first 45 skulls he examined, 30 contained more or less well-developed septa between a quarter and half an inch in height. More frequent on the left side than the right (about in the proportion of 3 to 1). And 26 skulls of Negroes from the Congo varying age from 5 years to middle age, only 2 showed septa and both on left side.

Ulm (1995) examined 41 edentulous maxilla, 31.7% with at least 1 septum were present. 26.8% showed one septum, and 4.9% exhibited 2 septa. Most septa were located between second premolar and first molar. The mean height of the septa was 7.9 mm with the highest septum height of 17 mm. Most septa presented in frontal orientation (buccopalatal plane, transverse).

Krennmair (1999) studied using different examination methods, cadaver, direct clinical measurements, and CBCT. 27.8% (17 of 61) patients who underwent sinus augmentation showed false diagnosis (in 21.3% cases) using panoramic radiographs. In cadaver (anatomic) study, 31.7% (13 of 41) maxilla had 15 antral septa (36.6%) on the sinus floor, 26.8% had one septum and 4.8% had 2 septa. 11 septa in anterior portion, 2 in the middle and 1 in the posterior. With CBCT analysis, 28.5% of 42 complete edentulism and 50 partial edentulous). Analysis of the completely or partially dentate maxilla (n = 50) showed fewer septa. 70% of the septa were located in the anterior maxillary portion.

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Mean height of septa is 8.6 $\pm$ 3.5 mm in panoramic radiograph, 7.9 $\pm$ 4.2 mm in anatomically measured, 7.7$\pm$3.8 in CBCT complete edentulism, 12.2 $\pm$ 7.5 in partial edentulism/complete dentate.

Shibli (2007) evaluated 1024 panoramic radiographs. 21.58% presented with maxillary septa. 8.4% showed septa presented bilaterally. No statistical significant regarding of age and gender.

Ella (2008) studied 150 sinuses from 40 male cadavers, and 35 randomized patients by anatomical dissection and computed tomography. 61% showed no septa present or had septa < 4 mm. 39% showed bony septa with 7 incomplete, 1 complete and 20 symmetrical septa.

Rosano (2010) studied 60 sinuses from 30 human cadavers with age 59 to 90 years. Septa definition is > 3 mm in this study. 33.3% presented with incomplete septa. All located in the anterior-lateral wall and were either sagittal or transverse. 30% in anterior region, 40% in middle, and 30% in posterior region. Mean septa height of 8.72 mm with range 3.7-18.4 mm.

In other direct measurements studies, Jensen & Greer (1992) showed 56.7% of 26 patients presented with sinus septa. Zijderveld (2008) showed 48% of 100 patients presented with sinus septa during maxillary sinus floor elevation.

In CBCT studies, Lugmayr (1996) showed 13.7% in 200 patients presented with sinus septa. Kasabah (2002) showed prevalence of 35.9% in 68 patients. Velásquez-Palata (2002) studied 156 patients (106 women and 50 men with age ranging from 24 to 86 years). 75 septa were found in 312 maxillary sinuses (24%) which corresponded to 32.7% of patients. Completely edentulous patients presented with 33.3% of total septa

and 66.7% of septa were identified in partially edentulous patients. 24% septa were located in anterior region, 41% in the middle and 35% were in posterior region. Height of septa ranges from 0 to 15.7 mm (mean 3.54 mm) in posterior (lateral) region, middle area ranged from 0 to 17.3 mm (mean 3.14 mm), and anterior (medial) region ranged from 0 to 20.6 mm (mean 7.59 mm).

Kim (2006) studied 100 patients (41 women and 59 men, with mean age of 50 range from 19 and 87 years). The prevalence of one or more septa per sinus was found to be 26.5%, 31.76% 22.61% in overall study population, the edentulous, and non-atrophic/dentate maxillary segments. 25.4% were located in anterior region, 50.8% in the middle region, and 23.7% in the posterior region. The heights of septa varied among different areas. Mean heights were 1.63, 3.55, and 5.46 in lateral, middle and medial areas respectively. This study did not discuss the orientation of the septa.

González-Santana (2007) studied 30 patients (60 sinuses). 20% of sinuses and 25% of patients had septa. The septa were located as follows: 2 anterior, 11 middle, and 4 posterior. Heights were between 2.5 and 6 mm long.

Selcuk (2008) studied 330 paranasal sinuses of patients presenting with sinonasal complaints to ENT. 20.3% anteriorly and 2.5% posterior localized maxillary sinus bony septa. The position was frequently vertical at anterior, and horizontal at posterior. This study found significant correlation between the anteriorly localized maxillary sinus septa and Infraorbital fissure enlargement. The study mention the presence of mucosal pathology was significant in patients with maxillary sinus septa.

Lee (2010) study exclude cases presenting any sinus pathological changes. 236 maxillary sinuses in 204 patients were analyzed. The mean age of the patients was 50.9

years. 20.9% of 204 patients presented with pathologic findings. Sinus septa were present in 24.6% of 236 maxillary sinuses and 27% of patients. Septa were found in 27.3% in anterior, 50% in the middle and 22.7% in the posterior region.

Maestre-Ferrin (2011) studied 30 patients (17 women and 13 men, with a mean age of 50.9 years). In 60 maxillary sinuses, panoramic radiographs showed 53.3% prevalence and CT showed 66.7%. Most septa (60%) located in the middle region of the maxillary sinuses, 22.5% in the posterior region and 17.5% in the anterior region. The mean height of the septa was 4.78 mm.

Neugebauer (2010) evaluated 1029 scans. Septa were found in 47% of patients, and 33.2% sinuses. There was no statistical difference in prevalence with respect to age, sex or side. Most patients with septa showed one septum in one sinus (24.6%); 13.7% showed 1 septum in each sinus. Other combination up to 3 septa were found in 8.7% of patients. Septa were most commonly located in the first molar region, followed by second molar region and the canine region. The orientation of septa is 25.3% in sagittal and 74.7% in transverse.

Park (2011) studied 200 patients. 111 septa presented in 400 maxillary sinuses (27.7%), which corresponded to 37% of patients. 22.5% were located in the anterior, 45.9% in the middle and 31.5% in the posterior region. The directional orientation analyses showed that 106 septa were buccopalatal, 4 were sagittal and 1 was transverse type. Mean heights were 7.78 and 7.89 in the right and left sinuses respectively.

Shen (2012) studied 423 Taiwanese patients with 216 women and 207 men, mean age 53.65 years). 30% subjects had sinus septa and 20.45 % of sinuses. 22.93% presented with multiple septa. Most frequent location is in the region of first and second molar. The

prevalence was not related to tooth loss (edentulous, partially edentulous or dentate maxillary segments. Logistic regression analysis showed that men were significantly more likely to have septa than were women.

Pommer (2012) systemic review and meta-analysis of prevalence, location and morphology of maxillary sinus septa. He concluded that septa were present in 28.4% of 8923 sinuses investigated. Prevalence was significantly higher in atrophic sinuses compared with dentate maxillae. Septa were located in premolar, molar and retromolar regions in 24.4%, 54.6%, and 21% respectively. Orientation of septa was transverse in 87.6%, sagittal in 11.1% and horizontal in 1.3%. Septa height measured 7.5 mm on average. Complete septa were found in only 0.3%. O4.2% presented with multiple septa in one sinus and 17.2% in bilateral septa. Septa diagnosis using panoramic radiographs yielded incorrect results in 29% of cases.

Li (2013) studied 424 patients from the Jiangsu region in China using CBCT. 44.81% subjects had sinus septa, 21.23% had multiple sinus septa, and 20.52% had bilateral septa. The prevalence was not related to age, gender, or the presence or absence of teeth. Septa were most commonly located in the middle of the maxillary sinus. Mean height of the septa was (5.90±3.65) mm in the right sinus, and (5.54±2.87) mm in the left sinus. Mean length of septa was (8.15±2.40) mm in the right sinus and (7.88±2.73) mm in the left sinus.

Orhan (2013) studied 272 patients which included 242 adults and 30 children. 58% of the subjects had septa, which corresponded to 3.2% of completely edentulous (CE), 53.9% septa of edentate and 3.8% septa of the mixed dentition. Septa were most commonly located in the middle region of the maxillary sinus (69.1%). Septa was found

to be higher in partially edentulous patients than dentate and CE patients. There were no statistically significant differences in terms of gender or age.

Rancitelli (2015) studied the relationship between the prevalence of the septum and the thickness of the schneiderian membrane. Of the 228 maxillary sinuses studied, 38.1% had sinus septa. Mean height of primary and secondary septa was 5.5 mm and 3.4 mm respectively. Medium thickness of mucosa was 0.85 mm. When measured closer to the septa, it was 1.8 mm. This study concluded that presence of septa may result thickening of the schneiderian membrane.

Gandhi (2015) studied 210 cadaveric heads in formalin. He concluded that septa were presents in 28.1% of the specimens, and 55.9% of the specimens were in the middle region of the maxillary sinus cavity. Septa were more common in edentulous than dentate jaws. This study did not evaluate the orientation of the sinus septa.

Bornstein (2016) studied 213 patients with 126 women and 86 men, mean age 53.8 years). 66.5% subjects and 56.5% of sinuses had sinus septa. 61.8% had coronal orientation, 7.6% had axial orientation, and 3.6% had sagittal orientation. Most frequent location is in the region of first and second molar.

Sakhdari (2016) cross-sectional study of the prevalence, height, and location of maxillary sinus septa. He concluded that 44.8% of 946 sinuses investigated had at least 1 septa, 36.8% had 1 septa in their right sinus, 27.4% had 1 septa in their left, and 35.8% of the sinuses had septa in both sides. Septa were located in the middle of the sinus cavity in 35.1% of the subjects. The most common septa found was the mediolateral septa (59.2%). In terms of the prevalence of the septa, there was no statistically significant differences in terms of gender or the right or left sinuses.

Teleghani (2017) evaluated 300 CBCT images of Iranian subjects for the prevalence, location, and size of the sinus septa. He concluded 44% of the patients had septa. Location of the septa was equally found in the anterior, middle, and posterior part of the sinus cavity. The average height was $3.6 \pm 1.56$ mm.

This study evaluated different parameters described from previous articles such as age, ethnicity, gender, septa orientation, and sinus location. None of the above article evaluated prevalence of sinus septa in term of ethnicity. Previous studies found sinus septa commonly located in the middle region corresponding to first and second molar region. This study found septa most commonly located in premolar regions (43.4%) following by molar (42.03%) and retromolar (14.6%). In term of septa orientation, vertical is most common following by transverse and horizontal is rare, which is different from previous study indicate transverse was the most common direction. The study agree with complete septa was rare and single septum is more common finding than multiple septa.

Presence of sinus septa may increase the risk of Schneiderian membrane perforation during sinus elevation surgery. The perforation of the Schneiderian membrane may be associated with the development of maxillary sinusitis.

Sinus elevation technique was first described by Tatum. The two approaches for sinus elevation are transcrestal approach of sinus augmentation or lateral window approach (SALW). The presence of septa complicates the sinus window preparation and increase the risk of membrane perforation. Accurate diagnosis with CBCT scans before surgery enables the surgeon to plan any necessary modifications to the SALW procedures. Such modifications vary based on the location and height of the septa.

Sinus are commonly divided into 3 sections; the anterior, middle and posterior regions. Surgeons sometimes can elevate over the septum if the height is minimum. However, when the tall septa are found in the anterior third, the surgery is modified to create 2 distinct windows; one in the front of the septum and one distal to it (Figure 8, Misch, 1993).



**Figure 8: Sinus augmentation surgery modified to create 2 windows**

When the septum is located in the middle third, the 2 window approach is not as feasible due to limited direct vision. The recommended technique involves making one window anterior to the septum, elevating the membrane from that window above the apex of the septum and onto the other side of it extending approximately 1-2 mm. Using a firm pulling action towards the anterior, one can fracture the apical portion of the septum, and proceed with elevating Schneiderian membrane distally or mesially as needed. (Figure 9, Misch, 1993).

**Figure 9: Sinus augmentation surgery modified by fracture of the apical portion of the septum**

If the septum is located in the posterior third of sinus, it is usually distal to the last implant position. Sinus septum can be treated as posterior wall with utilizing single window approach and elevate membrane and place graft toward the anterior to the septum.

Membrane perforation is the most common complication encountered during sinus augmentation surgery. Small perforations less than 5 mm can be repaired with folding of the membrane or resorbable collagen membrane alone. In case of large perforations (>10 mm), surgery is generally aborted.

| Studies | N= | Septum definition | Prevalence of septa (Sinus) | Prevalence of septa (Subjects) | No. Septum/sinus 1 | No. Septum/sinus >1 | Location Anterior | Location Middle | Location Posterior | Orientation | Mean height (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cadavers** | | | | | | | | | | | |
| Underwood 1910 | 45 | NS | N/A | 33.0% | | | | | | | |
| Ulm et al. 1995 | 41 | > 2.5 mm | 31.7% | N/A | 84.6 | 15.4 | 73.3 | 19.9 | 6.6 | Most (T) | 7.9 |
| Krennmair et al. 1999 | 41 | NS | 18.3% | 31.7% | 84.6 | 15.4 | 73.3 | 26.6 | 0 | NA | 7.9 |
| Ella et al. 2008 | 40 | NS | N/A | 39.0% | | | | | | | |
| Rosano et al. 2010 | 30 | > 3 mm | 33 % | N/A | 100 | 0 | 30 | 40 | 30 | 70 (S) 30 (T) | 8.72 |
| **Surgical/Clinical Studies (Direct Clinical Measurements) (P): Patients, (S): Sinuses** | | | | | | | | | | | |
| Jensen & Greer. 1992 | 26 (P) | NS | N/A | 57.6% | | | | | | | |
| Krenmair et al. 1997 | 65 (P) | NS | N/A | 27.7% | | | | | | | |
| Krenmair et al. 1999 | 61 (P) | NS | N/A | 27.8% | NA | NA | 70.5 | 29.4 | 0 | NA | 8.6 |
| Zijderveld et al. 2008 | 100 (P) | NS | N/A | 48.0% | | | | | | | |
| **CT/CBCT** | | | | | | | | | | | |
| Lugmayr et al. 1996 | 200 (P) | | 13.7% | N/A | | | | | | | |
| Krennmair et al. 1997 | 200 (P) | | N/A | 16.0% | | | | | | | |
| Krennmair et al. 1999 | 42 CE (P) | | N/A | 28.5% | N/A | N/A | 68.4 | 31.6 | 0 | N/A | 7.7( CE)/ 12.2( PE) |
| Krennmair et al. 1999 | 50 PE (P) | | N/A | | | | | | | | |
| Kasabah et al. 2002 | 68 (S) | | 35.9% | N/A | | | | | | | |
| Velásquez-Plata et al. 2002 | 156 (P) | > 2.5 mm | 24% | 32.7% | 98.4 | 1.6 | 41 | 35 | 24 | NA | 3.5 (L), 5.9 (m), 7.6 (M) |

**Table 16: Studies summarizing the orientation, prevalence, and location of the sinus septa**

| Studies | N= | Septum definition | Prevalence of septa (Sinus) | Prevalence of septa (Subjects) | No. Septum/sinus 1 | >1 | Location Anterior | Middle | Posterior | Orientation | Mean height (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kim et al. 2006 | 100 (P) | > 2.5 mm | 26.5% | 38% | 97.5 | 2.5 | 25.4 | 50.8 | 23.7 | NA | 1.6(L), 3.6 (m), 5.5(M) |
| González-Santana et al. 2007 | 30 (P) | | 20% | 25% | | | | | | | |
| Selcuk et al. 2008 | 330 (P) | | 22.8% | N/A | | | | | | | |
| Lee et al. 2010 | 204 (P) | > 2.5 mm | 24.6% | | 92.6 | 7.4 | 27.3 | 50 | 22.7 | N/A | N/A |
| Maestre-Ferrin et al. 2011 | 92 (P) | > 2.5 mm | 66.7% | | N/A | N/A | 17.5 | 60 | 22.5 | N/A | 4.78 |
| Neugebauer et al. 2010 | 1029 (P) | NS | 33.2 | | N/A | N/A | 22.5 | 59.2 | 17.7 | 25 (S) 75 (T) | 11.7 (S), 7.3 (T) |
| Park et al. 2011 | 200 (P) | > 3 mm | 27.7% | | N/A | N/A | 22.5 | 45.9 | 31.5 | 3.7 (S) 96.3 (T) | 7.8 |
| Shen et al. 2012 | 423 (P) | NS | 24% | | N/A | N/A | 16 | 54 | 27 | NA | NA |

| Panoramic (P): Patients, (S): Sinuses | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kasabah et al. 2002 | 68 (S) | NS | 44.1% | | | | | | | | |
| Shibli et al. 2007 | 1024 (P) | NS | 21.6% | | | | | | | | |

**Table 16: Continued.**

# CHAPTER 5
## CONCLUSION

Incidence of septa was found in 44.56% of the scans. The age, gender, ethnicity factors are not statistically significant. Septa height has a mean of 5.26 mm (range of 1.2 to 22.30 mm). Most common orientation of septa is vertical following by transverse. Horizontal orientation is rare. Most of the septa are incomplete. Only 0.01% presented with complete septa. Most common location is second premolar and anterior region, which is different from most study (molar and middle region). Single septum (28.38%) is more common than multiple septa (7.28%).

With 360 females and 320 males studied, 22.50% of females and 22.03% of male with evidence of septa. There was no statistically significant relationship observed between gender and prevalence of sinus septa.

The prevalence of sinus septa for the groups Caucasians, African Americans, Asians and Hispanics is as follows 27.79%, 8.67%, 4.12%, and 3.53%. The ethnicity factor as a group is no statistical significant.

There were 413 patients younger than 60 year old and 267 subjects older than 60. The prevalence of maxillary sinus septa was 27.35% and 17.21% for the groups < 60 year old and ≥ 60 year old. There was no statistically significant difference.

Based on these findings, it is recommended that prior to sinus augmentation surgery, CBCT scans should be carefully evaluated for the septa location and height since 44.56% have variations to prevent surgical complication such as perforations.

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## Certification of Approval for a Project Involving Human Subjects

| | |
|---|---|
| Protocol Number: | **20906** |
| PI: | **SUZUKI, JON** |
| Review Type: | EXEMPT |
| Approved On: | 03-Jan-2013 |
| Approved From: | |
| Approved To: | |
| Committee: | A1 - MEDICAL INTERVENTION |
| School/College: | DENTAL SCHOOL (0700) |
| Department: | DENTAL:PERIDONTOLOGY (07140) |
| Project Title: | Prevalence, location, and morphology of maxillary sinus septa in patients of Temple University Kornberg School of Dentistry |

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The IRB approved the protocol **20906**.

If the study was approved under expedited or full board review, the approval period can be found above. Otherwise, the study was deemed exempt and does not have an IRB approval period.

Before an approval period ends, you must submit a "Continuing Review Progress Report" to request continuing approval. Please submit the form **at least 60 days before the approval end date** to ensure that the renewal is reviewed and approved and the study can continue.

Finally, in conducting this research, you are obligated to submit modification requests for all changes to any study; reportable new information using the Reportable New Informaiton form; and renewal and closure forms. For the complete list of investigator responsibilities, please see the Policies and Procedures, the Investigator Manual, and other requirements found on the Temple University IRB website: http://www.temple.edu/research/regaffairs/irb/index.html

Please contact the IRB at (215) 707-3390 if you have any questions.