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EDUCATION

University of Maryland School of Dentistry 2009-Present
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New York University College of Dentistry 2005-2009
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ABSTRACT:

Maxillary Sinus Morphology:
A Radiographic Retrospective Evaluation of Sinus Septa
in Caucasian and African-American Subjects

Kim-Thi Van-Dinh DDS, Masters of Science, 2012

Dissertation Directed by: Dr. Mark A. Reynolds DDS, PhD,
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Anatomic variations of maxillary sinus morphology including volume and septa impact the success of sinus augmentation procedures for dental implant placement. Anatomy has been investigated mainly with respect to age and gender; however, the effect of race has not been examined. The purpose of this study was to evaluate variations of maxillary septa sinus anatomy of African-American and Caucasian subjects, given differences significantly impact treatment success. This retrospective study examined consecutive computerized tomographic scans (CT) of patients scheduled for maxillary implant surgery at the University of Maryland School of Dentistry between 2009 to 2011. A total of 259 CT scans of 139 African-American and 120 Caucasian subjects were evaluated, of which, 62.5% of subjects (162/259) had identifiable septa. A total of 343 septa were identified in 518 sinuses (66.2%). Caucasians had more septa than African-Americans (1.56 compared to 1.09, p=0.006). The effect of gender was approaching significance (p=0.07). The adjusted mean number of sinus septa in female subjects was 1.48 compared to 1.17 in males. Sinuses were divided into three sections: anterior (premolars), middle (first and second molars), and posterior (third molar). In both the anterior and middle sections, race had a significant effect (p=0.033 and p=0.035). In the anterior, the adjusted mean number of septa for Caucasians was nearly

twice that of African-Americans (0.32 compared to 0.17). In the middle section, the adjusted mean for African-Americans was 0.57 compared to 0.79. With respect to the posterior section, only gender had a significant effect (p=0.008). Women had an adjusted average of 0.51 septa compared to men with a 0.29 average. The majority of septa were found in the middle segment (51.3%, 176/343), and 17.5% (60/343) were identified in the anterior segment. Sinus septa complicate Schneiderian membrane elevation therefore increasing likelihood of membrane perforation, a common complication of sinus augmentation procedures. The dentally relevant sinus segments contain the majority of sinus septa (68.8%) and have a direct impact on clinicians performing sinus augmentation procedures. Both race and gender impact maxillary implant treatment planning with a greater frequency of detectable septa in Caucasians and females when compared to African-American males.

Maxillary Sinus Morphology:
A Radiographic Retrospective Evaluation of Sinus Septa
in Caucasian and African-American Subjects

by
Kim-Thi Van-Dinh

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I . INTRODUCTION:

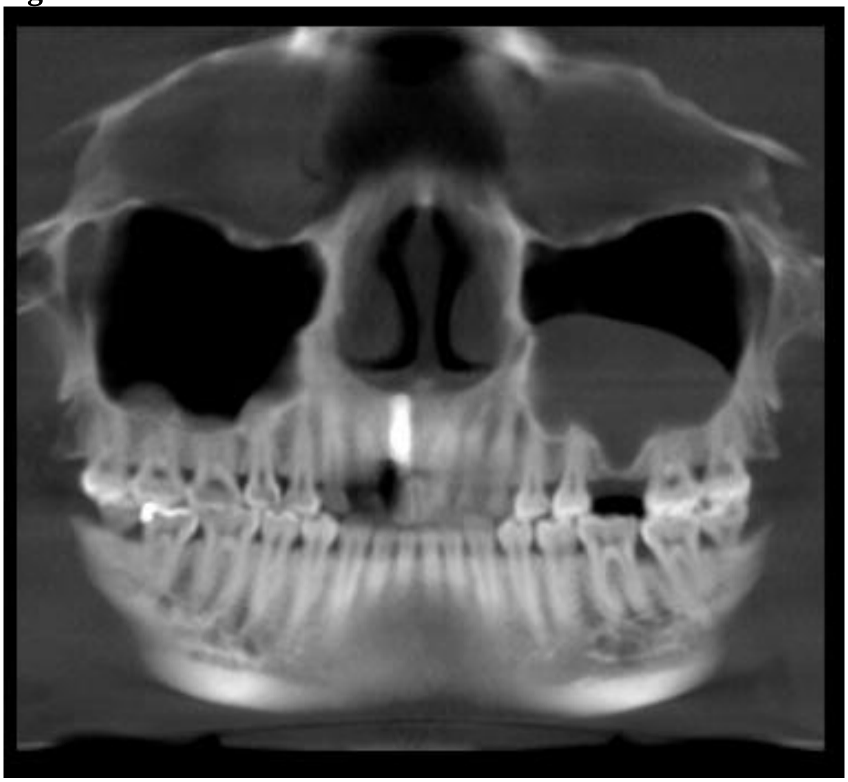
Maxillary molar teeth have some of the highest incidences of supporting bone loss and attrition due to anatomy and position in the arch. After loss of these molars, bone resorption results in decreased vertical and horizontal alveolar ridge dimension; progressive pneumatization of the sinuses also contributes to decreased ridge height. Sinus augmentation procedures have been widely utilized to restore patients with fixed prostheses by supplementing the alveolar ridge and allowing for dental implant placement even in the most severe cases of resorption. However, the presence of anatomic variations, such as septa, have been reported to increase the risk of membrane perforation during sinus floor augmentation procedures [1]. Also of concern is vascular damage, specifically to the posterior superior alveolar artery, upon accessing the sinus cavity through its lateral wall [2] as the maxillary blood supply is essential for preserving the vitality of the affected maxillary region, integration of the grafting material, and wound healing following sinus floor elevation [3]. In order to achieve a successful sinus augmentation for subsequent implant placement in patients, it is critical to appreciate any anatomical and morphological variation of the maxillary sinus between racial groups.

The maxillary sinuses were first discovered and illustrated by Leonardo Da Vinci in 1489; however, British surgeon Nathaniel Highmore was the first to describe the air cavity of the maxilla. Subsequently it is often referred to as the antrum of Highmore [4]. The maxillary sinus is the largest of the paranasal sinuses and the first to develop. During the 12th week of embryogenesis, it begins as an invagination of the ethmoid infundibulum in the middle meatus of the nasal cavity. At birth it expands by pneumatization into the developing alveolar process. Its growth rate parallels that of the maxilla and the developing dentition [5]. Antrum height development depends on an equilibrium of forces; the pressure exerted by the eye on the thin orbital floor, the pull of muscles that attach to or originate from the maxilla, and the eruption of teeth all have an effect on the resulting size of the maxillary sinus [6]. Its size is insignificant until the eruption of the permanent teeth. As teeth erupt into the oral cavity, the sinus becomes pneumatized and drops down into the space once occupied by tooth buds. Typically expansion of the sinus halts once all the permanent teeth have erupted; however, the removal of maxillary posterior teeth can cause further pneumatization of the sinus. At twelve years of age, the floor of the sinus typically corresponds to the floor of the nasal cavity. In adults, the roots of maxillary posterior teeth may protrude into the sinus cavity [6].

The maxillary sinus is pyramidal in shape with its base at the nasal wall and the apex extending into the zygomatic arch. It is bordered medially by the nasal cavity, superiorly by the orbital floor, and laterally by the maxilla, alveolar process, and zygomatic arch. Blood supply is from the anterior, middle, and posterior superior alveolar arteries and to a lesser extent the greater palatine arteries, branches of the maxillary artery. Venous blood drainage is through the pterygoid plexus. It is innervated by the anterior, middle, and posterior superior alveolar nerves, branches of maxillary division of the Trigeminal cranial nerve (CN V). The antrum is an air filled cavity lined by respiratory epithelium known as the Schneiderian membrane. It is continuous with nasal epithelium through the semilunar hiatus in the middle meatus of the nasal cavity. Mucous is secreted by the epithelium and any foreign material present in the sinus is moved out by the beating of cilia. The function of the maxillary sinus is not clearly defined. Many theories have been debated including decreasing the weight of the skull, protection against blows to the midface, phonetic resonance, warming and humidifying inspired air, and immunologic defense [4].

The floor of the sinus can contains one or more septa. Sinus septa were first described by Underwood in 1910; they are often referred to as Underwood's septa. He found that the sinus was frequently divided into 3 compartments that are often bordered by ridges corresponding to different periods of development of the dentition. The development of the anterior compartment occurs at the site of premolar eruption between 8 months and 2 years of age. The middle area corresponds to the location of the first and second permanent molars and growth occurs from 5 to 10 years of age. The posterior compartment develops during 16-30 years of age and contains the third molar region. Sinus septa form between adjacent teeth because as the tooth develops and the roots form, the sinus cavity expands and the antral floor follows becoming more concave [7]. This type of septa development is now referred to as primary or congenital; it occurs during growth of the midface. Secondary septa development was first described by Vinter. They are typically incomplete septa resulting from tooth loss and caused by irregular atrophy of the alveolar process and pneumatization of the sinus leaving bony crests. The sinus floor anterior and posterior to a septum is often at different levels. Since premolar teeth are typically retained longer than molar teeth, septa formation could be promoted by different phases of maxillary sinus pneumatization [8]. Earlier loss of molars results in further expansion of the sinus and the floor reaches a deeper level than in the premolar region where loss usually occurs later as seen in Figure 1. A septum can remain between the two zones of regression. Septa function to reinforce the floor of the sinus and develop as a result of stress transfer within the bone [4]. They seem to slowly resorb when teeth are lost due to decreased forces on the maxilla [9].

Figure 1: Panoramic Reconstruction from a CT Scan.



Reveals pathology in the left sinus and pneumatization of the antrum after the extraction of the maxillary left first molar. Compare the difference in the sinus floor between the left and right sinus. On the opposite side, the patient still has all the molars and the sinus floor is more or less at the same level.

Although variations in septa prevalence have not been thoroughly examined in literature, skeletal differences between racial groups have been well documented. African-Americans have larger teeth but exhibit less crowding than Caucasians. Burris attributed this to the fact that African-American maxillas are larger in both size and shape. Arch perimeter was 8% greater and the cross-sectional area of the arch was 19% greater in African-Americans compared to Caucasians [10]. Differences in bone density between the two races have also been widely documented. After adjusting for body mass, Pollitzer et al. found that blacks have greater skeletal calcium content and total body potassium. He attributed differences in body mass to be related to ethnicity [11]. Ettinger examined whether racial differences could be due to differences in bone metabolism and lifestyle and found that differences in bone mineral density could not be accounted for by clinical or biochemical variables. Adjusted bone density measurements were 4.5-16.1% higher for black than white men and were 1.2-7.3% higher for black then for white women [12]. Though these other skeletal differences have been demonstrated, differences in maxillary sinus morphology and anatomy between African-Americans and Caucasians of European decent have remained largely underreported in the literature.

In previous studies, anatomy and morphology of the maxillary sinus have been investigated, mainly with respect to age and gender, with the purpose of elucidating potential complications during augmentation and implant surgery. Anatomic variations including septa and size of the maxillary sinus have an effect on the success of sinus augmentation procedures. In Underwood's classic paper, he examined 45 dry skulls of European descent and found that 33.3% contained septa (30 septa found in 45 paired sinuses). A smaller number of maxillary sinuses in skulls originating from the Congo were evaluated and 3.8% of them contained septa (2 septa found in 26 paired sinuses). In a review by Maestre-Ferrin et al. 2010, the frequency of septa varied between 13 to 35% in all populations studied [13]. The prevalence of sinus septa reported has been as high as 69% in a study by van Zyl [14]. Table 1 summarizes a review of the literature with regards to septa prevalence using different methodology. Panoramic imaging has been used in the past to identify the presence of septa; however reported false diagnosis percentages range from 11.8-44.1%. Summarizing studies that use CT imaging for identification, 13-66.7% of sinuses contain septa. The majority of studies evaluate prevalence in subjects of Caucasian descent; there have been no reported studies on the differences between African-Americans and Caucasians. In addition to evaluations of sinus septa, sinus volume has also been investigated. Fernandes examined computed tomography scans of dried skulls of Zulu and European descent and found that European crania had significantly larger antral volumes than Zulu crania [15]. There is an inherent difference in the morphology of the maxillary sinus in African-Americans and Caucasians.

Table 1: Summary of Septa Prevalence, Location, and Percentage of False Diagnosis according to Different Specimen Analysis.

Author	Year	# subjects	Method	# septa	% pt	% sinus	Most f Location	False Diagnosis %	Para-meters
Underwood [7]	1910	45 cadavers	Anatomical	30	66.7	33.3			
Betts [16]	1994		Clinical			20			
Ulm [8]	1995	41 sinuses	Anatomical	13		31.7	anterior		>2.5mm
Lugmayr [17]	1996	200 sinuses	CT	26		13			
Krennmair [18]	1997	65 patients	Clinical + PAN	18		27.7		21.6	
		200 sinuses	CT	32		16			
Krennmair [19]	1999	61 patients	Clinical + PAN	17		27.8	anterior	21.3	
		41 cadavers	Anatomical	15		31.7			
		92 patients	CT	19		20.7			
Kasabah [20]	2002	68 sinuses	CT	24		35.9		26.5	
Velasquez-Plata [21]	2002	165 patients	CT	75		24	middle		>2.5mm
Kim [22]	2006	100 patients	CT	53		26.5	middle		>2.5mm
Gonzalez-Santana [23]	2007	30 patients	PAN + CT	15		25		11.8	

% pt refers to the prevalence based on the number of patients. % sinus refers to the prevalence based on the number of sinuses. Most f Location refers to the most common location of septa. False Diagnosis % includes false positives and false negatives. Parameters refers to inclusion criteria for minimum septa height.

Table 1 Continued: Summary of Septa Prevalence, Location, and Percentage of False Diagnosis according to Different Specimen Analysis.

Author	Year	# subjects	Method	# septa	% pt	% sinus	Most f Location	False Diagnosis %	Para-meters
Shibili [1]	2007	1024 patients	PAN	307	21.6				
Ella [24]	2008	40 cadavers	Anatomical		39				>4mm
		35 patients	CT						
Zijderveld [25]	2008	100 sinuses	Anatomical			48			
Gosau [26]	2009	65 cadavers	Anatomical	35		26.9			
Koymen [27]	2009	205 patients	CT	165	35.4	40.2			
Naitoh [28]	2009	15 cadavers	Anatomical + CT	12		37			>2mm
van Zyl [14]	2009	200 patients	CT	222	69	55.5			
Lee [29]	2010	236 sinuses	CT	58	27	24.6	middle		>2.5mm
Neugebauer [30]	2010	1029 patients	CT	814	47	39.5	middle		
Maestre-Ferrin [31]	2011	60 patients	PAN	32		53.3			
			Acetate CT	42		70			
			CT	40		66.7			
Park [32]	2011	200 patients	CT	111	37	27.7	middle	44.1	
Rosano [2]	2011	30 cadavers	Anatomical	20		33.3	middle		>3mm
Xu [33]	2011	40 patients	CT	43		53.8			

In addition to variations in the maxillary sinus as a result of racial differences, pathologic changes of the maxillary alveolus can occur as due to tooth loss, infection, trauma, and tumors or cysts. Following a posterior extraction in the maxilla, atrophy related changes cause the buccal plate to resorb more than the palatal bone. The amount of tissue resorption is greatest in the edentulous molar region compared to incisor and premolar regions [16]. Pneumatization of the maxillary sinus has been previously described as part of normal development; however, it can also be considered a pathological process when occurring after extractions. Once a maxillary posterior tooth is removed, the sinus expands occupying the space where the roots used to be. Resorption occurs both vertically and horizontally leading to inadequate bone height and width for the future placement of an endosseous dental implant [17]. Bone loss following extractions is attributed to osteoclastic activity of the sinus membrane and the loss of marginal bone. Changes due to chronic sinus infections include thickening of the Schneiderian membrane, a decrease in antral volume, and an increase in the bone thickness of the lateral wall [18]. Trauma related changes include those that occur as a result of midface fractures and unsuccessful extractions where the tooth is lodged in the sinus cavity. Rapidly growing tumors or cysts in the sinus cavity can expand beyond the bony confines of the sinus and invade adjacent structures like the orbit, nose, cheek, infratemporal fossa, and mouth [19]. Sinus morphology can be different within the same individual due to pathologic changes and depend on the resorption of the sinus floor due to premature tooth loss.

Restoring teeth lost in the posterior maxilla is challenging because of lack of bone volume and poorer bone quality. Numerous techniques for increasing the height of the maxillary posterior bone for the placement of dental implants have been described. Sinus augmentation, ridge onlay grafting procedures, distraction osteogenesis, and extrusion of teeth have been utilized to rebuild bone loss following extractions or due to periodontal disease. Although ridge onlay grafting can increase the maxillary bone height, there is also a decrease in the interarch distance. This procedure cannot be utilized in some patients. In those instances, gain in bone height from the apical aspect of the atrophic alveolar ridge would be ideal. Boyne and James first described the Caldwell-Luc sinus augmentation procedure in 1980. A window was created in the anterior wall to access the maxillary sinus floor. Graft material and autogenous marrow were utilized, and the ultimate goal was the placement of a blade type of implant [20]. Summers described another method of augmenting the maxillary bone height through a crestal approach with the use of osteotomes and bone [21]. This technique requires at least 5-6mm of remaining bone at the crest of the alveolus. Minimal drilling is needed and osteotomes are used to gradually widen the osteotomy. The objective is to conserve bone in the site and to selectively displace it upwards into the sinus. Often bone is added prior to infracturing the sinus floor with the osteotome. This method is believed to be less invasive than the traditional Caldwell-Luc approach since instruments never touch the membrane itself. Pressure is used to elevate the Schneiderian membrane. The resulting site will have increased bone density and height. Contraindications for this procedure include sinuses with an angled floor or septa. These situations make it more difficult to infracture the sinus floor because the osteotomes tend to be deflected from the desired direction. Regardless of the technique, maxillary sinus augmentation is a very predictable procedure. Various techniques have been described involving modifications in the lateral window, and various bone grafting materials have been utilized. The 1996 Consensus Conference on Maxillary Sinus Bone Grafting concluded that allografts, alloplasts, and xenografts, alone or in combination with autogenous bone, can be effective as bone substitute graft materials for sinus bone augmentation. They found a 90% success rate for implants placed in grafted sinuses and in function at least 3 years [22].

There are numerous approaches to maxillary sinus augmentation which require knowledge of sinus anatomy and variations to avoid any possible complications. The most common complications include perforation of the Schneiderian membrane, infection, and bleeding problems. Perforations during sinus augmentation procedures have been reported to be as high as 60% (45/75) [23]. Sinus septa have been reported to cause complications in elevating the membrane [20], but there are also studies that show the opposite. In a 2003 study, Kashabah and colleagues found that there was no relationship observed between the perforation and the presence of sinus septa. In all of the 118 subjects studied, no sinusitis or infections of the graft material were found despite perforations in 56% of the cases [24]. Contrastingly, Schwartz-Arad and colleagues found that 10% of sinus augmentation procedures had post operative complications including cyst formation and infection. They concluded that although membrane perforations correlated strongly with post operative complications, no associations were found between perforations and implant survival [25]. Typically if the perforation is small, a repair procedure can be performed. Fibrin and resorbable membranes have been utilized. If the perforation is large, block grafts have been considered in the past [9]. However in most cases with large perforations, the procedure is aborted and re-entered at a later date [6]. In addition to perforations, post operative infections can occur. The occurrence of post operative sinusitis is not related to membrane perforations but limited to patients with a history of preoperative sinusitis [26]. In is imperative to inform these patients of the increased risks; these patients require close follow up. Absolute contraindications for sinus augmentation procedures include maxillary sinus infection, severe chronic sinusitis, and tumors or pathologic growths in the sinus [27]. Relative contraindications include sinus floor convolutions, sinus septa, transient mucosa swelling, and narrow sinuses [9]. Bleeding problems during surgical procedures is another complication that can be avoided by identifying intraosseous vasculature in the lateral wall in CT scans. Large diameter vessels can be ligated to avoid intra and post operative complications [28]. Although sinus perforations are common, infections and other post operative complications are rare and can be avoided with careful surgical planning, ideal imaging, and detailed knowledge of sinus morphology.

The success of a sinus augmentation procedure is not solely dependent on avoiding post operative complications; success is related to consolidation of graft materials and osteointegration of implants. Since graft consolidation relies on adequate angiogenesis and migration of osteogenic cells from native bone, the remaining height of the alveolar ridge and buccopalatal dimension may have an effect on the therapeutic outcomes. Avila-Ortiz studied the relationship between the remaining alveolar bone height and the proportion of vital bone formation. Twenty-one sinuses were grafted with allograft material and core biopsies were taken at the time of implant surgery. They found no significant correlation between residual bone height and percentage of vital bone formation [29]. Avila also evaluated the relationship between the distance from the lateral to medial wall of the maxillary sinus and percentage of vital bone formation. Twenty-five subjects were treated and core biopsies were taken at the time of implant placement. A strong negative correlation was found; the percentage of vital bone formation after sinus augmentation procedures with allograft is inversely proportional to the buccal-palatal dimension of the sinus [30]. Although septa create difficulties in elevating the membrane, they can serve as an additional source of blood supply. Rough surfaced implants have a higher success rate than machined surfaced implants in grafted sinuses. Implants placed in particulate grafts had a higher survival rate than those placed in sinuses augmented with block grafts. Grafting entirely with autogenous bone or including autogenous bone as part of a composite graft did not affect implant survival. The survival rate of implants placed in sinuses augmented through the lateral window technique ranged from 61.7-100%, with an average of 91.8% [31]. Reported success rates are similar or better for implants in grafted sites compared to non-grafted maxillary bone [22].

Sinus augmentation procedures have frequently been utilized to restore patients with fixed prosthesis even in cases of severe resorption. The presence of anatomic variations, such has septa, have been reported to increase the risk of membrane perforation during sinus floor augmentation procedures. Differences in the morphology of the maxillary sinus between African-Americans and Caucasians of European decent have remained largely underreported in the literature; the purpose of the study is to evaluate the variations in anatomy of the maxillary sinus between African-American and

Caucasian patients, given that differences sinus morphology can significantly impact treatment planning as well as treatment outcome.

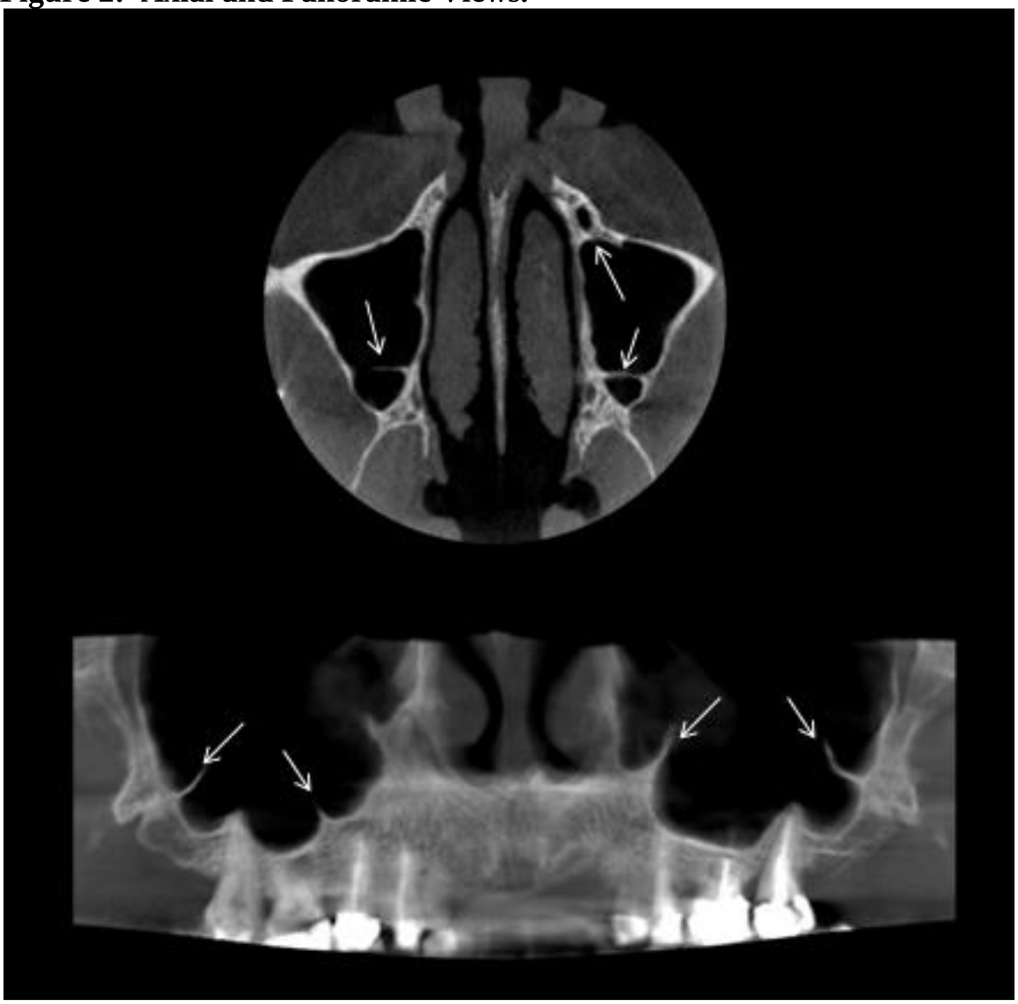
II. MATERIALS AND METHODS:

This retrospective study examined CT scans obtained on patients presenting for maxillary implant surgery at the University of Maryland School of Dentistry from 2009 to 2011. Records were reviewed based on treatment codes for maxillary computerized tomographic scans (D0310.0) and a total of 259 scans were identified on 139 African-American and 120 Caucasian patients. Since there were more female patients imaged than male patients, consecutively imaged patients were screened until a total number of 54 males of each race were identified. Subjects had undergone maxillary CT imaging prior to implant placement to replace lost or missing teeth due to caries or periodontal disease. Charts were accessed and reviewed to determine the race, age, and sex of the subject and to verify the presence of a pre-operative CT scan. CT scans were taken with 5-14mA and 84-120kV, and viewed with 1mm cross-sections. Data was analyzed from reformatted CT scans using Romexis software.

CT images were examined for the presence, location, and height of antral septa using axial planes as shown in Figure 2. The presence of septa was evaluated in axial cross-sections, and panoramic reconstructions were used to determine the height of septa (Figure 3). A baseline was drawn connecting the lowest mesial and distal points of the septum. The height of the septa was measured from the baseline to the highest peak of the sinus. The sinus cavity was divided into three parts consisting of an anterior (mesial to distal aspect of second premolar), middle (distal to second premolar to distal aspect of second molar), and posterior (distal aspect of second molar region). The prevalence of septa in each section was evaluated.

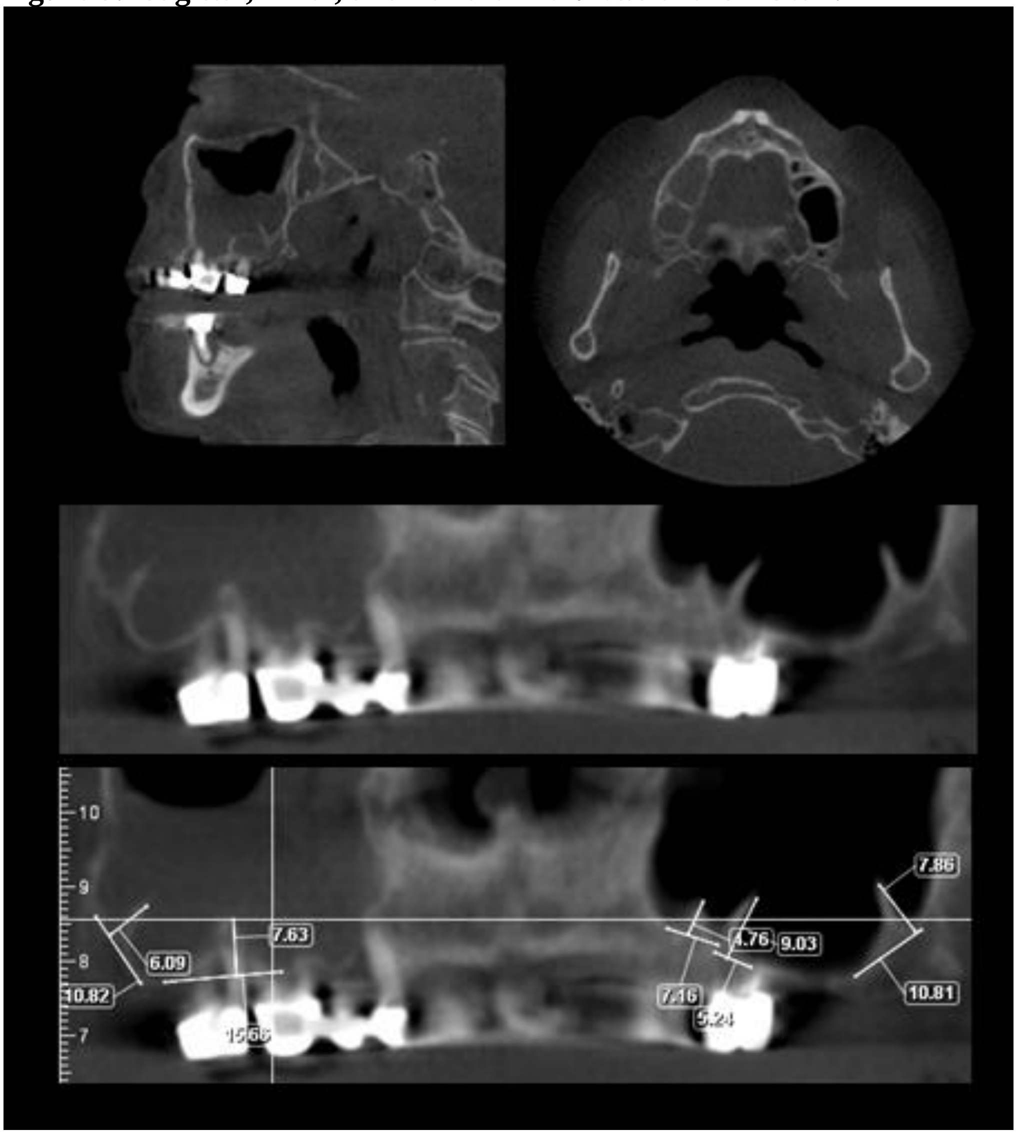
The scans were reviewed by two independent calibrated examiners to confirm findings. The primary dependent measure was the number of sinus septa. Secondary measures included the spatial location and height of septa. Data was submitted to statistical analysis using JMP software to do an analysis of variance.

Figure 2: Axial and Panoramic Views.



The axial view reveals that the left sinus is divided into three compartments by two sinus septa. At the same axial level, only one of the two septa on the right can be seen. The lateral septa on the left and right are in the third molar area and designated part of the posterior segment. The medial septa on the subject's right is found between the second premolar and the first molar; it is part of the middle segment. The medial septa on the left is in the premolar region thus part of the anterior segment.

Figure 3: Sagittal, Axial, and Panoramic Views of a CT Scan.



Axial and panoramic sections were evaluated for the presence of septa. The axial section reveals pathology associated with the right sinus. There are 2 septa on the subject's right and 3 septa on the left. The heights of the septa were determined by creating a baseline from the most apical aspects medially and laterally and measuring at a right angle from the baseline to the highest peak.

III. RESULTS:

CT scans from 259 subjects were evaluated for the presence, location, and height of septa. The age range for Caucasian subjects was 18-83 years old with a mean age of 60.0. African-American subjects ranged from 23-83 years old with a mean age of 56.6. Caucasian males comprised 45.0% (54/120) of the subjects, and African-American males comprised 38.9% (54/139). Table 2 summarizes the number of subjects in each group.

Table 2: Number of Subjects included in the Investigation.

	Males	Females	Total
Caucasian	54	66	120
African-American	54	85	139
Total	108	151	259

Of the 259 investigated subjects, 37.5% (97/259) showed no septa and 62.5% (162/259) had at least 1 septa. A total of 343 septa were found in 518 sinuses (66.2%). A summary of the findings is presented in Table 3. Caucasian patients had 186 septa; 37 in the anterior area comprising of the premolars, 95 in the middle area comprising the first and second molars, 54 in the posterior area comprising of the area of the third molars. There were less septa found in African-American subjects with a total of 157; 23 in the anterior, 81 in the middle, and 53 in the posterior. In both races, women had more septa than men; 111 compared to 75 in Caucasians and 108 compared to 49 in African-Americans.

Table 3: Total Number of Septa Categorized by Race and Location.

Caucasian				
	Anterior	**Middle**	**Posterior**	**Total**
Male	16	42	17	75 (40.3%)
Female	21	53	37	111 (59.7%)
Total	37 (19.9%)	95 (51.1%)	54 (29.0%)	186
African-American				
	Anterior	**Middle**	**Posterior**	**Total**
Male	10	25	14	49 (31.2%)
Female	13	56	39	108 (68.8%)
Total	23 (14.6%)	81 (51.6%)	53 (33.8%)	157

Statistical analysis of variance revealed a significant difference with respect to the presence of septa related to subject race (p=0.0061). The effect of gender was approaching significance. The combined effect of gender and race was not significant (Table 4). Caucasians were more likely to have sinus septa than African-Americans; the adjusted mean number was 1.56 compared to 1.09 (Table 5). Adjusted means were reported since there were a disproportionate number of subjects in each category. Although not statistically significant (p=0.07), women were more likely to have septa than men, the adjusted mean number was 1.46 compared to 1.17 (Table 6). When evaluating the septa height, there was no significant relationship with respect to gender, race, or the combined effect of race and gender (Table 7).

Table 4: Parameter Estimates for Number of Septa.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Race[AA]	-0.23	0.08	-2.77	0.003*
Gender[F]	0.15	0.08	1.79	0.07
Race[AA]*Gender[F]	0.03	0.08	0.34	0.73

Statistically significant results are indicated with an asterisk (*). There was a statistically significant difference in the number of sinus septa with respect to race. The effect of gender was only nearing significance.

Table 5: Adjusted Means Number of Sinus Septa by Race.

Level	Adjusted Mean	Std Error	Mean
AA	1.09	0.12	1.13
C	1.56	0.12	1.57

The adjusted mean number of sinus septa in African-Americans (AA) is 1.09 compared to 1.56 in Caucasians (C).

Table 6: Adjusted Mean Number of Sinus Septa by Gender.

Level	Adjusted Mean	Std Error	Mean
F	1.48	0.11	1.45
M	1.17	0.13	1.17

The adjusted mean number of sinus septa in female subjects is 1.48 compared to 1.17 in males.

Table 7: Parameter Estimates for Septa Height.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Race[AA]	0.80	0.67	1.18	0.25
Gender[F]	-0.58	0.67	-0.86	0.39
Race[AA]*Gender[F]	-1.11	0.67	-1.65	0.11

Results from statistical analysis revealing that neither race or gender were statistically significant.

When evaluating solely the anterior zone, there were significant differences only with respect to race (p=0.03). Caucasians had more septa in the premolar region; 0.32 compared to 0.17 septa found in African-Americans (Table 9). Gender and the combined effect of race and gender had no effect on the number of septa (Table 8). Analysis of the middle section revealed that there was a significant difference based on race (Table 10). Caucasians had more septa in the first and second molar region; 0.79 compared to 0.57 septa found in African-Americans (Table 11). The posterior section showed a significant difference only with respect to gender. Females had more septa in the third molar area than males; 0.51 for females and 0.29 in males (Tables 12-13).

Table 8: Parameter Estimates for Number of Septa in the Anterior Segment.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Race[AA]	-0.08	0.04	-2.14	0.03*
Gender[F]	-0.01	0.04	-0.26	0.79
Race[AA]*Gender[F]	0.00	0.04	-0.14	0.89

Results from statistical analysis revealed significant difference in the number of septa in the anterior region with respect to race.

Table 9: Adjusted Means Table for Race in the Anterior Segment.

Level	Adjusted Mean	Std Error	Mean
AA	0.17	0.05	0.16
C	0.32	0.05	0.32

The adjusted mean number of sinus septa in the anterior segment in African-Americans (AA) is 0.17 compared to 0.32 in Caucasians (C).

Table 10: Parameter Estimates for Number of Septa in the Middle Segment.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Race[AA]	-0.11	0.05	-2.11	0.04*
Gender[F]	0.05	0.05	0.97	0.33
Race[AA]*Gender[F]	0.04	0.05	0.77	0.44

Statistically significant results are indicated with an asterisk (*); There is significant difference in the number of septa in the middle region with respect to race.

Table 11: Adjusted Means Table for Race in the Middle Segment.

Level	Adjusted Mean	Std Error	Mean
AA	0.57	0.07	0.59
C	0.79	0.08	0.79

The adjusted mean number of sinus septa in the middle segment in African-Americans (AA) was 0.57 compared to 0.79 in Caucasians (C).

Table 12: Parameter Estimates for Number of Septa in the Posterior Segment.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Race[AA]	-0.04	0.04	-1.06	0.29
Gender[F]	0.11	0.04	2.66	0.01*
Race[AA]*Gender[F]	-0.01	0.04	-0.18	0.86

Statistically significant results are indicated with an asterisk (*); There is significant difference in the number of septa in the posterior region with respect to gender.

Table 13: Adjusted Means Table for Gender in the Posterior Segment.

Level	Adjusted Mean	Std Error	Mean
F	0.51	0.05	0.50
M	0.29	0.06	0.29

The adjusted mean number of sinus septa in the posterior segment in female subjects is 0.51 compared to 0.29 in males.

IV. DISCUSSION:

This retrospective study examined the prevalence, location, and height of maxillary sinus septa in 259 consecutive scans of Caucasian and African-American patients obtained for the surgical planning of dental implants. Previous studies have utilized panoramic radiographs for the detection of sinus septa and found the prevalence to range from 25-53.3% [32-35]. However, the percentage of false diagnosis has been reported to be as high as 44.1% [24, 32, 33, 36, 37]. Studies utilizing CT scans for positive identification of septa show the prevalence to be between 13% and 66.7% (Table 1). For accurate diagnosis and proper treatment planning, CT scans are useful for identifying maxillary sinus septa and for evaluating pathology in the sinuses.

The prevalence of sinus septa in the current study for all subjects was 66.2%. The percentage of patients with at least one septa was 62.5%. Similarly, van Zyl utilized 3-dimensional reconstructions for the identification of septa with no minimum exclusion criteria, and found that the prevalence was 66% [14]. The prevalence of sinus septa in studies which excluded septa less than 2.5mm-4mm in height ranged between 24-39% [8, 34, 38-41]. The current study reported a higher prevalence than previous reports. This difference may be attributable to dissimilar inclusion criteria. In addition, CT scans enabled more accurate identification of sinus septa compared to panoramic images. Clinically, Zijderveld found sinus septa in 48% of subjects treated [42]. There is a large range of reported findings across all methods used. Methodology can influence the identification of sinus septa.

In this study, Caucasians were more likely than African-Americans to have septa in the sinus floor. Caucasian subjects had a prevalence of 77.5% and African-Americans had a prevalence of 56.5%. Statistical analysis revealed that the mean number of septa for Caucasians was 1.56 compared to 1.09 in African-Americans (p=0.006). The effect of gender was nearing significance (p=0.07). The data revealed a trend that women were more likely than men to have maxillary sinus septa. The adjusted mean number of sinus septa in female subjects was 1.48 compared to 1.17 in males. Since septa function to reinforce the floor of the sinus and develop as a result of stress transfer, one can surmise that prevalence is related to bone density. Ettinger found that black men and women had higher adjusted bone mineral densities than their Caucasian counterparts [12]. In addition, Caucasian and Asian women were most likely to have osteoporosis. Traditionally, Caucasians have lower bone density when compared to African-Americans and women have lower bone density than men. In this study, a higher prevalence of maxillary sinus septa was found for Caucasians and women. Future studies can examine the relationship of bone density to the presence of septa.

In both the anterior and middle sections, race had a significant effect on the number of sinus septa identified (p=0.033 and p=0.035). In the anterior, the adjusted mean number of septa for Caucasians was nearly twice that of African-Americans; 0.32 compared to 0.17 (Tables 8-9). In the middle section, the adjusted mean for African-Americans was 0.57 compared to 0.79 (Tables 10-11). The effect of gender or the combined effect of race and gender did not have a significant effect on the number of sinus septa found in the anterior and middle sections (Tables 8, 10). Bone density difference between races and premature loss of molar teeth may have affected the study results.

With respect to the posterior section, only gender had a significant effect ($p=0.0083$); there was no effect for race or combined effect of race and gender. Women had more septa than men: 0.51 septa in the posterior zone compared to men with a 0.29 average (Tables 12-13). It is unclear why the anterior and middle sections were affected by race while the posterior section was affected only by gender. When looking at the overall differences, gender was approaching statistical significance. It is only in the posterior section that it reached statistical significance. Premature loss of third molars may not largely influence the site since many are removed or impacted. Primary septa are typically associated with the roots of teeth, and secondary septa result from premature loss of teeth. Septa in edentulous areas can be either primary or secondary in nature. Septa develop as a result of stress transfer on the bone, and occlusal forces in the posterior zone are much heavier than forces in the anterior and middle. That may explain why gender differences are only found in the posterior zone. Again, bone density and occlusal force differences could influence the number of septa that develop.

The majority of septa were found in the middle segment (51.3%, 176/343) which supports the findings of Velasquez-Plata, Kim, Lee, Neugebauer, Park, and Rosano. Ulm and Krennmair found that septa were most frequently present in the anterior segment. Variations in study subjects and differences in inclusion criteria, measurement methods, and imaging modalities may have caused the diverse findings across studies. There may also be some variation between edentulous and fully dentate patients. 68.8% of septa were found in the anterior and middle sections (236/343) which impacts clinicians since that is the area most often involved in sinus augmentation procedures. Perforations of the Schneiderian membrane during sinus augmentation procedures are the most common complication. The presence of septa can make elevation of the membrane more difficult. Septa in the anterior region can be managed by creating two windows and elevating the membrane separately in the two compartments. Septa in the middle region are often fractured to enable elevation of the membrane more posteriorly. Although perforations have not been shown to influence the osteointegration of dental implants, large perforations can delay treatment if the procedure needs to be aborted. Smaller tears can be repaired which will not increase treatment time, but will increase material costs to the surgical procedure. Contrastingly, septa may have a slight advantage to sinus augmentation and implant placement because they are mainly composed of cortical bone and implant placement can engage denser bone and have increased primary stability. In addition, septa can act as an additional source of blood supply allowing for faster bone formation and consolidation of graft materials.

Limitations of the current investigation include a disproportionate amount of female subjects. Subjects were selected based on treatment codes of consecutively imaged patients which resulted in the inclusion of higher numbers of females in both Caucasians and African-Americans. In addition, information regarding smoking status and systemic diseases was incomplete. Smoking is more likely to have an effect on the thickness of the Schneiderian membrane rather than the presence of septa but diseases such as osteoporosis and hyperparathyroidism can affect bone density and may have an effect on septa formation. There are also limitations associated with Romexis imaging software. Measurements of septa heights were made from a baseline to the highest point and depending on the sharpness of the structures on the CT scan, there may be some measurement errors. Furthermore, there was no information on when teeth were lost;

therefore, no correlations could be made regarding time elapsed since tooth loss and heights of septa.

V. CONCLUSION:

Differences in the morphology of the maxillary sinus between African-Americans and Caucasians of European decent have remained largely underreported in the literature. The purpose of the study was to evaluate the variations in anatomy of the maxillary sinus between African-American and Caucasian patients, given that differences in sinus morphology can significantly impact treatment planning as well as treatment outcome. A total of 343 septa were identified in 518 maxillary sinuses (66.2%) which corresponded to 62.5% of subjects (162/259). The prevalence in African-Americans was 56.5% compared to 77.5% in Caucasians. Caucasians had more septa than African-Americans (1.56 compared to 1.09, p=0.006). The effect of gender was approaching significance (p=0.07); women tended to have more septa than men. The adjusted mean number of sinus septa in female subjects was 1.48 compared to 1.17 in males.

In the both the anterior and middle sections, race had a significant effect (p=0.033 and p=0.035). In the anterior, the adjusted mean number of septa for Caucasians was nearly twice that of African-Americans (0.32 compared to 0.17). In the middle section, the adjusted mean for African-Americans was 0.57 compared to 0.79. With respect to the posterior section, only gender had a significant effect (p=0.008). Women had an adjusted average of 0.51 septa compared to men with a 0.29 average. The majority of septa were found in the middle segment (51.3%, 176/343) and 17.5% (60/343) were found in the anterior. Thus, 68.8% of all sinus septa were found in the area most often involved in sinus augmentation procedures. It is important to obtain 3-dimensional imaging for proper surgical planning since panoramic images can have false diagnoses up to 44%. Perforations of the Schneiderian membrane are the most common complications encountered; sinus septa can make elevation of the membrane more difficult. Appropriate pre-surgical treatment planning requires an in depth knowledge of the anatomy and morphology of the sinus with CT scan imaging to prevent surgical complications due to aberrant structures in the sinus. This investigation confirms the existence of regional differences in maxillary sinus floor morphology. Both race and gender impact maxillary implant treatment planning with a greater frequency of detectable septa in Caucasians and females when compared to African-American males.

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