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Abstract

Title of Thesis: Maxillary Sinus Morphology: A Radiographic Retrospective Evaluation of the Posterior Superior Alveolar Artery in Caucasian and African-American Subjects

John B. Fontana, III, Master of Science, 2012

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Maxillary sinus floor augmentation using a lateral window approach is commonly used to increase the alveolar bone available in the edentulous maxilla for dental implant placement. Although this grafting procedure is generally considered safe and predictable, intra-operative complications can involve anatomic variations related to sinus septa and vasculature. Morphologic variations in the maxillary sinus have been documented in Caucasians but not African Americans. The purpose of this retrospective study was to compare the anatomic location and diameter of the posterior superior (PSAA) alveolar artery in African-Americans and Caucasians. Computerized tomographic images of 219 patients (108 African American and 111 Caucasian) permitted radiographic assessment and morphometric comparison of the PSAA. The primary dependent measure was radiographic diameter of the PSAA. Secondary dependent measures included the vertical distance of the PSAA to both the crest of the alveolar ridge and the inferior-most aspect of the maxillary sinus. The association of race and gender to the dependent measures was assessed using an analysis of covariance, adjusting for body mass index. The prevalence of the artery differed significantly between African-Americans (72.2%) and Caucasians (43.2%). Mean artery diameter did not differ significantly between African-Americans and Caucasians (1.29 mm ± 0.05, 1.24 mm ± 0.06, respectively), when adjusted for BMI. Diameter of the PSAA exhibited a significant positive association with BMI ($p \leq 0.05$). The mean distance from the PSAA to alveolar crest was significantly lower for Caucasian females than Caucasian males (13.30mm ± 1.15, 17.79mm ± 1.05, respectively), whereas no gender difference was found in African Americans. The more prevalent and potentially larger caliber PSAA in African-Americans and the more inferior position of the artery seen in Caucasians women must be taken into consideration when attempting maxillary sinus floor augmentation via a lateral approach.

Maxillary Sinus Morphology: A Radiographic Retrospective Evaluation of the Posterior Superior Alveolar Artery in Caucasian and African-American Subjects

By
John B. Fontana, III

Thesis submitted to the faculty of the Graduate School of the
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DEDICATION

To my mother and father, John and Ellen Fontana, and brother, Steven Fontana, whose own dedication to the field of dentistry has been a constant inspiration for me.

To Drs. Mark A. Reynolds, Mary-Beth Aichelmann-Reidy, and all of my co-residents for their invaluable guidance and input, without which this work would not be possible.

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I. INTRODUCTION

The decrease in bone volume following tooth loss or extraction is one of the primary considerations when planning tooth replacement using dental implants (Albrektsson, Branemark et al. 1981). A long history of edentulism commonly has a negative impact on the volume of bone present due to subsequent resorption leaving inadequate space for dental implant placement. Surgery to augment the edentulous space may be necessary to prepare for proper implant placement, though rehabilitation of the edentulous maxilla presents significant challenges such as poor bone quality, severe resorption, and pneumatization of the maxillary sinus (Misch 1987; Garg and Quinones 1997; Wallace and Froum 2003). Fortunately, several treatment options exist to overcome inadequate bone volume. Maxillary sinus floor augmentation, either with simultaneous or delayed implant placement is one of the more common procedures to replace missing maxillary posterior teeth. The lateral approach, one of the two techniques available for sinus floor augmentation, may be employed for simultaneous or delayed implant placement (Lindhe, Lang et al. 2008).

The main indication for maxillary sinus floor augmentation via the lateral approach is a reduced residual bone height, which cannot accommodate standard implant placement. (Pjetursson, Tan et al. 2008). This approach has been shown to be a predictable method to increase the volume of bone for the purpose of implant placement (de Lange, Tadjoedin et al. 1997; Nkenke and Stelzle 2009; Avila-Ortiz, Neiva et al. 2011). The lateral window technique has proven to be predictable and highly successful, providing direct access and visibility to the sinus; however, various complications may result, both intraoperatively and postoperatively (Katranji, Fotek et al. 2008).

A number of investigators have reported surgical complications encountered during lateral sinus floor augmentation which include, but are not limited to: sinus membrane perforation, antral pathoses such as sinusitis or mucocele formation, and oroantral communication (Low 1995; Cho, Wallace et al. 2001; Maksoud 2001; Chan and Wang 2011). Another major complication is bleeding within the surgical field associated with the interruption of a large vessel within sinus wall. In a study by Ella and co-workers (2008), the vascular supply of the maxillary sinus including all major blood vessels was outlined because of the potential risk of intraoperative bleeding during sinus augmentation surgery. More often than not, many of these complications are related to preexisting pathologies and variations in sinus anatomy (Chan and Wang 2011).

For the surgeon, being well versed in general or basic vascular anatomy may not be sufficient enough to prevent and manage complications that arise during augmentation surgery, given the potential for such large morphologic variations between patients. Anatomic variation has been demonstrated between individuals of different age, race and gender. With respect to sinus morphology, Fernandes and associates (2004) reported that European crania had significantly larger maxillary sinus volumes than Zulu crania. Chinese individuals were shown to have smaller sinus volumes and thicker bones compared to Caucasians (Lu, Pan et al. 2011). Pertinent to this discussion is the variation seen in vascular morphology between individuals of different races. For example, Wong and co-workers reported Blacks and Hispanics had larger retinal arteriolar and venular calibers than did Caucasians and Chinese after adjusting for systemic conditions and social parameters (2006).

While variation of either vascular anatomy or sinus anatomy with relation to race has apparently been demonstrated, little to no information is available on racial differences of maxillary sinus vascular anatomy, particularly the posterior superior alveolar artery (PSAA), of the maxillary sinus itself. This study specifically investigated variation of the prevalence, location and diameter of the posterior superior alveolar artery when comparing African-Americans and Caucasians of European descent.

II. LITERATURE REVIEW

Residual vertical bone height in the posterior maxillary region is often reduced, and limits standard implant placement (Lindhe, Lang et al. 2008). This reduction in ridge height is the result of crestal bone resorption accompanied by sinus pneumatization (Hupp, Tucker et al. 2008).

Tallgren demonstrated significant, long-term continual resorption of the maxillary residual ridge following tooth loss (2003). Pietrokovski, reported the course of bone remodeling following tooth extraction was characterized by an overall loss of ridge volume with reduction in both an apical and palatal direction and more pronounced resorption with multiple missing teeth (Pietrokovski and Massler 1967; Pietrokovski 1975; Pietrokovski, Sorin et al. 1976). It is this pattern of resorption that complicates implant placement, especially in light of the concomitant pneumatization of the sinus at the superior aspect of the ridge.

Pneumatization, or an increase in volume of the maxillary sinus, like the other paranasal sinuses, occurs for varied reasons including: spontaneous mucocele drainage, inflammatory processes, abnormal secretion of sex and growth hormones, or valve-like obstructions which allow for drainage of mucous without equilibration of air pressure (Trimarchi, Lombardi et al. 2003). Urken and co-workers (1987) first classified the different conditions in which sinuses increase in size, leading to abnormal pneumatization. These three categories can be described as the hyper-(pneumatized) sinus, pneumosinus dilatans (PSD), and the pneumocele. The hypersinus is defined as a large sinus that does not extend beyond its normal boundaries and demonstrates neither thinning nor erosion of its bony walls. PSD refers to an aerated, abnormally expanded sinus with outwardly displaced bony walls of normal thickness. Conversely, the pneumocele, like PSD, describes an aerated, abnormally expanded sinus but with thinning of the bony walls. Of most concern to the oral implantologist, however, is the pneumocele which commonly results in decreased alveolar bone height limiting bone available for an otherwise uncomplicated implant placement.

Several treatment options have been proposed to compensate for these morphologic limitations, including placement of short implants, angled placement of implants to avoid entrance into the maxillary sinus, and even placement of extra-long zygomatic implants which traverse the maxillary sinus antrum, anchoring into the lateral aspect of the zygomatic bone (Lindhe, Lang et al. 2008).

Additionally, there are two common procedures to facilitate implant placement by augmenting the residual bone height by way of sinus floor augmentation: the lateral approach (originally referred to as the Caldwell-Luc technique or lateral window technique) and the crestal approach, also referred to as the transalveolar osteotome technique (Lindhe, Lang et al. 2008). The crestal approach was first described by Tatum (1986), but is more commonly known as the transalveolar approach and uses osteotomes as reported by Summers (1994). In this procedure, a concave-tipped osteotome instrument is used to shave bone from the inside of a prepared implant osteotomy and tapped inward to ultimately elevate the bony sinus floor with the intact membrane. Bone grafting material may be added under the membrane after elevation of the sinus floor to further augment the space for an implant. This procedure involves less risk and trauma than methods which were previously described and can elevate the sinus floor by several millimeters in most patients.

Lateral maxillary sinus augmentation (lateral window) is an effective and common procedure performed to increase bone height for implant placement in an atrophic posterior maxilla. The main indication for this approach over the alternative transalveolar approach is a reduced residual bone height, which allows for neither standard implant placement nor placement of implants in combination with minor sinus floor elevation (Pjetursson, Tan et al. 2008). This procedure was first published by Boyne and James (1980), where a bony window was created at the lateral aspect of the sinus and a space was enlarged between the Schneiderian membrane and the sinus walls where grafting material may be placed. A decade later Chanavaz (1990) further described the protocol for lateral augmentation surgery, describing it as a procedure which is intended to elevate the membranous floor of the sinus cavity separating it from its lateral connections with or without its inferior bony attachments. The space is then filled in with bone and biomaterials, usually with the simultaneous insertion of an implant.

A histomorphometric analysis of bone graft biopsies obtained after sinus augmentation by Galindo-Moreno et al. (2010) demonstrated significant vital trabecular bone in intimate contact with graft particles and highly satisfactory clinical outcomes with the use of a combined bovine bone and allogeneic bone grafting material. A variety of graft materials can be used in sinus augmentation procedures. A systematic review comparing survival and condition of implants placed in sinuses previously augmented with autogenous bone to those with bone substitute demonstrated no evidence to support one material over another (Nkenke and Stelzle 2009). In a systematic review, Pjetursson et al. (2008) reported a mean graft failure of 1.9% following a metanalysis of 48 studies of sinus floor elevation all with a variety of graft materials: autogenous block grafts, autogenous particulate grafts, bone substitutes and combinations. Furthermore, implants placed in conjunction with sinus floor augmentation demonstrated a 3-year survival of 90.1%. In sum, lateral augmentation in conjunction with implant placement using varied graft types has proven highly successful and provides direct access and visibility to the sinus (Katranji et al. 2008).

However, many intraoperative and postoperative complications may occur following maxillary sinus floor augmentation surgery including: Schneiderian membrane perforation, massive bleeding from the bony window or the sinus membrane, hematoma, wound dehiscences, infection, injury of the infraorbital neurovascular bundle and implant migration into the maxillary sinus. In a 2008 systematic review by Pjetursson et al, the most frequently encountered surgical complication was perforation of the Schneiderian membrane with a mean prevalence 19.5%. Extensive bleeding from the bony walls of the sinus may result from damage to the blood vessels near the bony wall and periosteum (Traxler, Windisch et al. 1999). Of great concern is damage to the PSAA upon accessing the sinus cavity through its lateral wall (Rosano, Taschieri et al. 2011). 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 (Solar, Geyerhofer et al. 1999). A case report by Lee (2010) reported intraoperative laceration of the PSAA during the creation of the lateral window during a lateral approach for sinus floor augmentation. This resulted in prolonged, pulsatile hemorrhage which was ultimately resolved through appropriate intraoperative management. Knowledge of the vasculature is imperative for the prevention and management of untoward events. Therefore, both normal vascular anatomy and its variations in the maxillary sinus are necessary to prevent these complications for sinus augmentation surgery.

The maxillary sinuses are the largest of the paranasal sinuses and the first of five to develop embryonically, beginning in the third month of development as pouching of the ethmoid infundibula (Blitzer, Lawson et al. 1991). After birth, the maxillary sinus expands by pneumatization into the developing alveolar process and extends anteriorly and inferiorly from the base of the skull. Portions of the alveolar process become further pneumatized by the remaining vacancy of erupted teeth (Anon, Rontal et al. 1996). Sinus expansion normally ceases after the eruption of the permanent teeth but can progress further subsequent to the removal of posterior teeth, occupying the alveolar process (Harorh and Bocutoglu 1995).

Anatomically, the maxillary sinus has been described as a four sided pyramid encased completely within the maxillary bone, the base of which is located medially, forming the lateral nasal wall. The apex extends laterally as the zygomatic process of the maxilla. The roof of the sinus also forms the floor of the orbit and the floor of the sinus serves as the base of the alveolar process. Posteriorly the maxilla declines into the maxillary tuberosity at the most posterior point of the alveolus. Lastly, it extends antero-laterally to the bicuspid region.

The surface lining of the sinus is primarily comprised of a mucous-secreting, respiratory, pseudo-stratified, ciliated, columnar epithelium. The main function of the cilia is to aid in drainage of mucous from the sinus due to the more superior location of the sinus opening, or osteum. The cilia move mucous produced by the epithelium as well as any foreign material toward the osteum and into the middle meatus of the nasal cavity (Hupp, Tucker et al. 2008). The epithelial layer covers a loose, highly vascular connective tissue followed by the periosteum which lies against the bony walls. Collectively, the epithelium, connective tissue and periosteum are referred to as the Schneiderian membrane (Lindhe, Lang et al. 2008).

The Schneiderian membrane is vascularized by way of anastamoses from vascular channels traveling through the bony walls of the sinus. Major vascular supply to the maxillary sinus is provided mainly from the maxillary artery via the infraorbital artery, the anterior, middle and posterior superior alveolar branches, and to a lesser extent, the anterior ethmoidal and superior labial arteries. The greater and lesser palatine arteries and the sphenopalatine artery deliver blood to the sinus floor, penetrating the bony palate and ramifying within the medial, lateral, and inferior walls. Lastly, the posterior and lateral walls of the sinus receive blood from tributaries of the posterior superior alveolar artery. Sensory innervation of the maxillary sinus is provided by the anterior, middle and posterior superior alveolar nerves which are branches of the maxillary division of the trigeminal nerve (Solar, Geyerhofer et al. 1999; Lindhe, Lang et al. 2008; Newman, Takei et al. 2012).

An understanding of the potential variation in sinus anatomy is crucial to successful surgical outcomes and avoidance of complications. 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. For instance, maxillary sinus volume was shown to decrease with older age and increase with alveolar bone loss (Cho, Kim et al. 2010). Neiva et al. investigated lateral sinus in Caucasian skulls, reporting a lateral wall thickness of 0.91 mm with a statistically significant greater thickness in males (2004). Finally, maxillary sinus septa also demonstrated a wide anatomical variation in prevalence, size, location, and morphology when examined in a Korean population (Kim, Jung et al. 2006). In a review by Maestre-Ferrin et al. (2011), the frequency of septa varied between 13 to 35% in all populations studied. Differences in maxillary sinus morphology have been reported based on gender and age but there is likely a potential for racial differences owing to documented skeletal differences between racial groups (Burris and Harris 2000; Fernandes 2004; Lu, Pan et al. 2011).

The focus of this study is not related to the skeletal morphology of the maxillary sinus, but to its vascular component, specifically the dental branch of the posterior superior alveolar artery as interruption of this vessel during surgical access may result in significant hemorrhage (Mardinger, Abba et al. 2007; Ella, Sedarat et al. 2008). The posterior superior alveolar artery divides into two branches shortly after its origin from the maxillary artery; the terminal or gingival branch supplies the mucoperiosteum in the molar and premolar region and the dental branch. This branch, in a double arterial circle arrangement with the infraorbital artery, is responsible for the blood supply to the membrane at the buccal aspect of the maxillary sinus and the local oral mucosa (Solar, Geyerhofer et al. 1999; Traxler, Windisch et al. 1999). Traxler et al. (1999) and Rosano et al. (2009) demonstrated intraosseous anastamoses between the dental branch of the posterior superior alveolar artery and the infraorbital artery in 100% of cadaveric specimens. However, radiographic evaluations by Mardinger et al. (2007) and Elian et al. (2005), using CT scans, detected the posterior superior alveolar artery only within

50% of the subjects. Kim et al. (2011) evaluating two hundred CT scans from a Korean population reporting a mean detectable prevalence of the PSAA to be 52% with a mean diameter 1.52 mm for this total population. Females in this report, however, demonstrated a significantly less frequent artery detection and smaller vessel diameter when the artery was present. The average distance from the inferior border of the PSAA to the alveolar ridge crest was 15.45 mm in the second molar area, but no significant differences were found for gender or age.

Vascular anatomy differences between genders have been observed in other studies. For instance, carotid artery diameter was shown to be smaller in women even after adjusting for body and neck size, age, and blood pressure (Krejza, Arkuszewski et al. 2006). In a report by Wong et al. (2006), not only was there a significant difference in retinal arteriolar caliber found between males and females, but blacks and Hispanics also demonstrated larger arteriolar and venular calibers than did whites and Chinese after adjusting for systemic conditions and social parameters (2006). African-Americans as a group have larger common carotid artery lumen diameters than Caucasians as measured by M and B-mode ultrasonography (Ruan, Chen et al. 2009). Levy et al. (1978) compared black hypertensive subjects to white hypertensive subjects and found renal blood flow to be significantly less in black subjects. The aforementioned reports suggest vascular differences exist between races and these differences may also be present in the maxillary sinus.

Currently, there has been no published data regarding race and maxillary sinus vascular anatomy. Given the evidence for differences in systemic vascular morphology between races, this study was undertaken in order to specifically assess differences in the vascular morphology of the posterior superior alveolar artery between African-Americans and Caucasians of European decent.

III. MATERIALS AND METHODS

This retrospective study evaluated the PSAA using computerized tomographic (CT) images obtained on consecutively imaged patients presenting at the University of Maryland School of Dentistry over a 36 month period (January 1, 2008 to December 31, 2011). Patient imaging records were reviewed upon identification of treatment codes D0360 (Cone Beam ct -craniofacial data capture) or D0360.1, upper (Cone Beam ct - single arch (maxillary)) within dental records. Paper charts were accessed and reviewed to determine the race, age, and sex of the subject and to verify the presence of a CT scan and to ultimately establish a total sample of 219 scans on 108 African American and 111 Caucasian patients. The corresponding 219 CT scans taken with a 15cm diameter field of view at 5-14 mA and 84-120mV were analyzed in 1 mm sections from reformatted CT scans using Romexis software. Scans of patients with a history of sinus augmentation surgery, maxillary orthognathic surgery, scans of unacceptable or non-diagnostic quality and scans that did not capture a superior-inferior field from the level of the alveolar crest to the infraorbital artery were excluded.

The PSAA was recorded as present or absent on sectional CT images in the area between the second premolar and the second molar. The maxillary first molar was also scored as present or absent. Measurements were made using the measurement function of the Romexis software program including radiographic vessel diameter of the PSAA as measured in a medio-lateral orientation (Figure 1) as well as the vertical distance of the vessel from its inferior border to the most inferior aspect of the maxillary sinus (Figure 2). The distance from the inferior border of the PSAA to the buccal alveolar crest was also measured (Figure 3).

Figure 1. PSAA Diameter. Coronal section of a CT scan in the area of the maxillary first molar shows the location and diameter PSAA in a medio-lateral orientation (D).

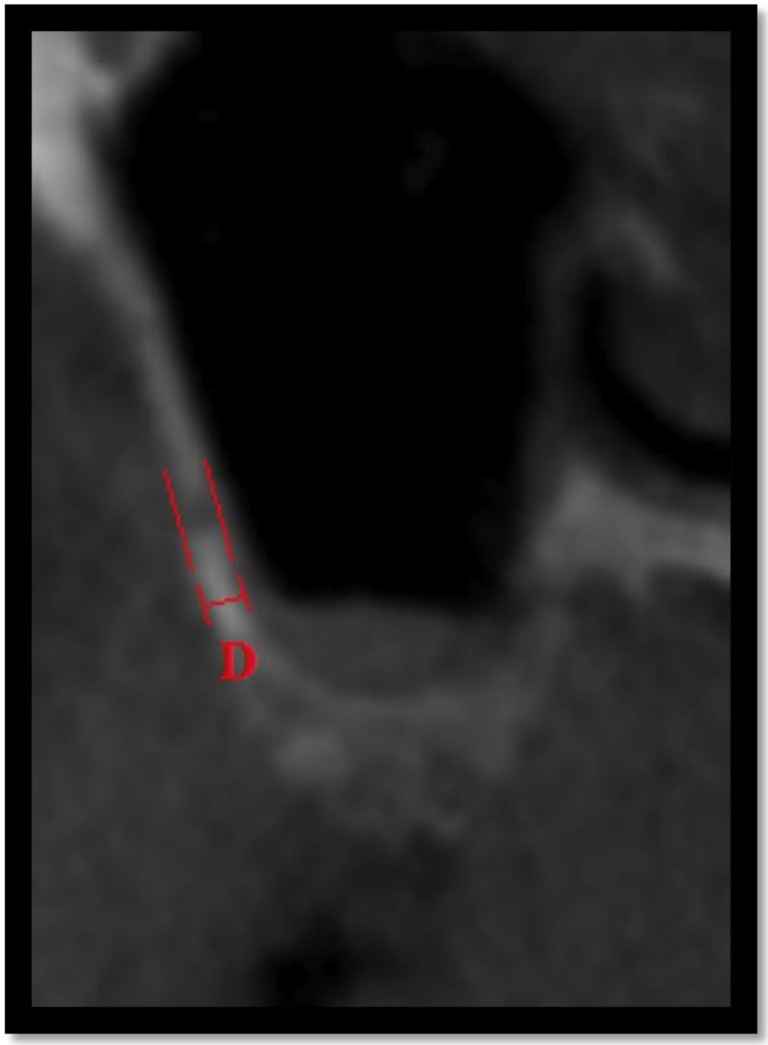


Figure 2. Distance from Maxillary Sinus Floor. Vertical distance (F) from the inferior border of the PSAA to the floor of the maxillary sinus.

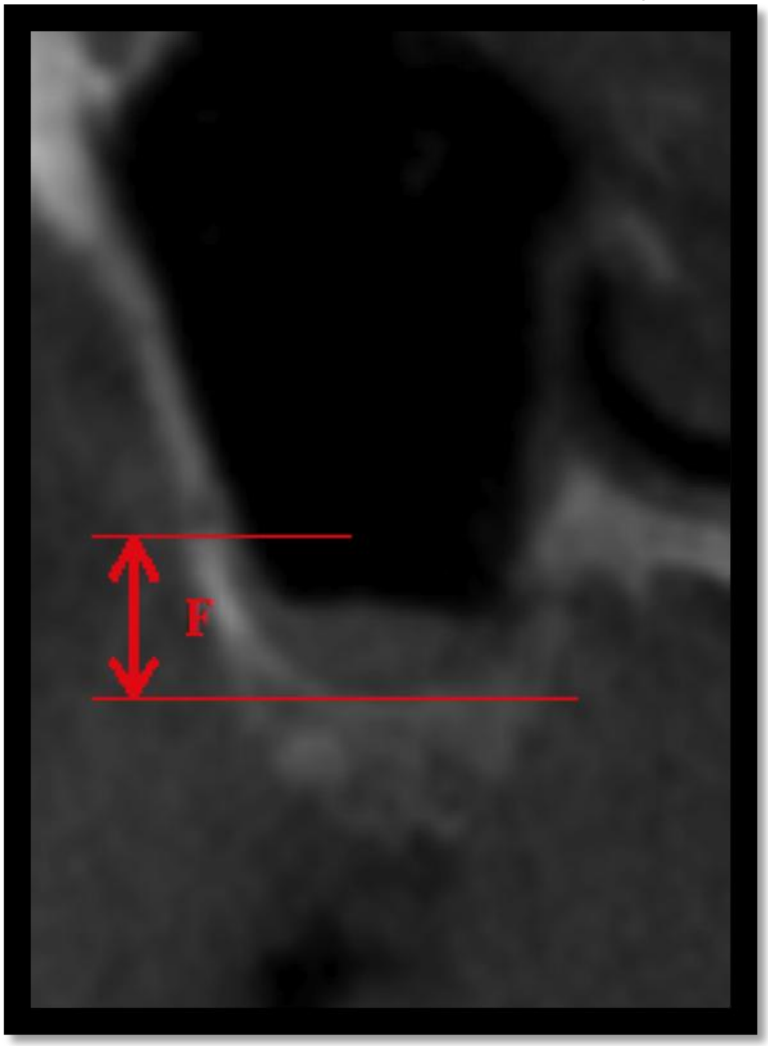
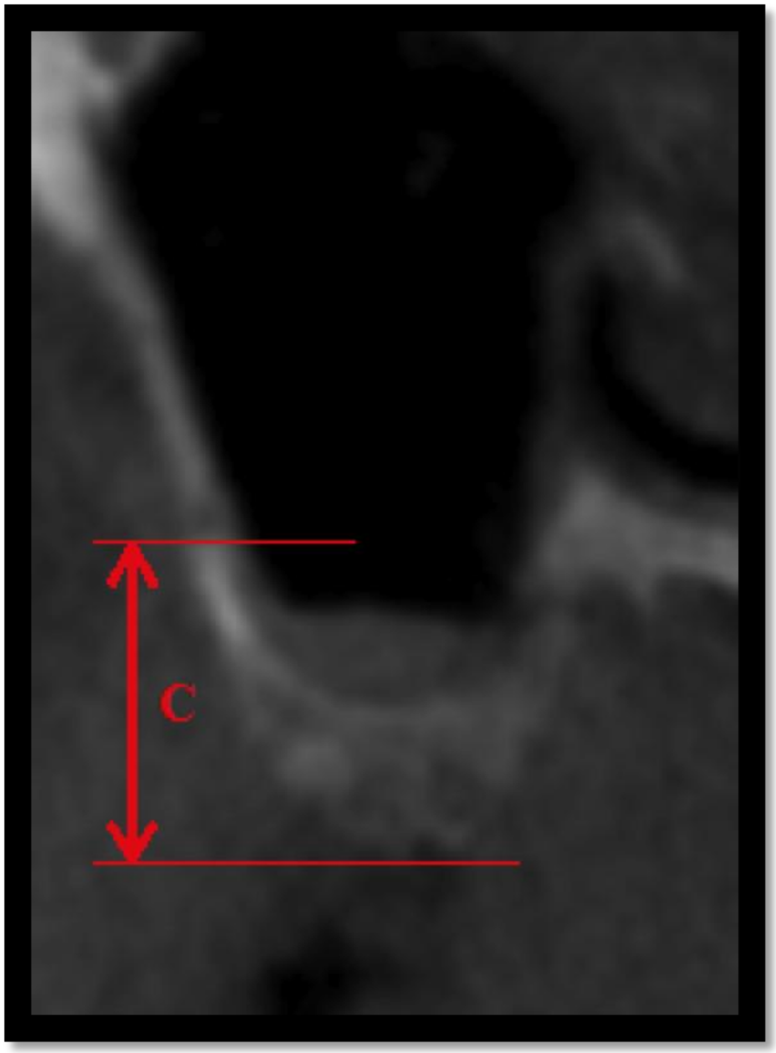
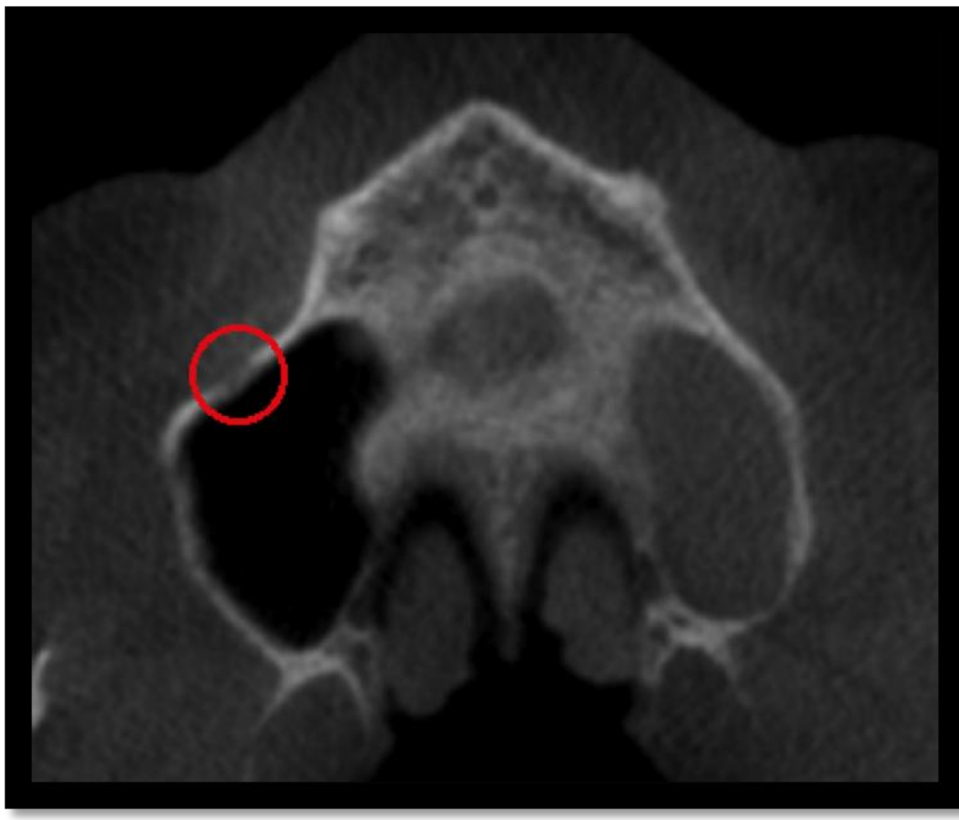


Figure 3. Distance from Alveolar Crest. Vertical distance (C) from the inferior border of the PSAA to the crest of the alveolar ridge.



To differentiate between the artificial defects and the PSAA in the reconstructed images, cross-sectional and axial views were compared to verify the location of the PSAA and measurements were made after confirmation of its continuity on proximal axial views (Figure 4). Paper and electronic charts were also reviewed in order to

Figure 4. Verification of PSAA. Axial view verifying presence of the PSAA (circled).



determine height, weight, body mass index (BMI), and specific medical history including hypertensive status, history of smoking, diabetic status and history of hypercholesterolemia.

The primary dependent measure was radiographic diameter of the PSAA. Secondary dependent measures included vertical distances of the posterior superior alveolar artery to the crest of the alveolar ridge and the inferior-most aspect of the maxillary sinus. The association of race and gender to the primary and secondary dependent measures was assessed using an analysis of covariance, adjusting for BMI, and post-hoc comparisons were indicated using a Tukey HSD test (JMP Version 10.0, SAS Institute, Inc., Cary, NC). Statistical significance was set at an alpha level of 0.05.

IV. RESULTS

A total of 219 CT scans on 108 African-American and 111 Caucasian patients were included for examination in this study. The African-American group consisted of 68 female (63%) and 40 male (37%) subjects, whereas the Caucasian group consisted of 54 female (49%) and 57 male (51%) subjects. Subjects ranged in age from 18 to 83 years, with a mean of 57.8 ± 13.4 years. Of the patient-related variables--namely, smoking, hypertension, diabetes, hypercholesterolemia, and BMI--only BMI was retained as a covariate in the final analysis. The absence of the maxillary first molar was not a significant covariate in the analysis of the secondary outcome measures.

The overall prevalence of the PSAA was 57.5%. Table 1 presents the prevalence of the PSAA in relation to race and gender. The radiographic prevalence of the PSAA was significantly higher in African-American subjects than Caucasian subjects (72.2% versus 43.2%, respectively; $p < 0.05$). No significant difference in prevalence was found between males (60.8%) and females (54.9%).

Table 1. Radiographic Prevalence of Posterior Superior Alveolar Artery

Race	Sex	N	Prevalance (%)
African-American	F	68	64.7
	M	40	85.0
Caucasian	F	54	42.6
	M	57	43.9

PSAA diameters for each group are listed in Table 2. The average diameter of the PSAA for all subjects was 1.26 ± 0.03 mm, ranging from 0.25 to 2.25 mm. The mean diameter of the PSAA was significantly smaller in females than in males (1.17 mm vs.

1.37 mm), when controlling for BMI ($p \leq 0.05$). The mean diameter in PSAA did not differ significantly between African-American and Caucasian subjects (1.29 mm versus 1.24 mm, respectively), when controlling for BMI. Diameter of the PSAA exhibited a significant positive association with BMI ($p \leq 0.05$).

Table 2. Radiographic Diameter of the Posterior Superior Alveolar Artery

Race	Sex	N	Mean ± Standard Error (mm)
African-American	F	68	1.15 ± 0.07
	M	40	1.43 ± 0.07
Caucasian	F	54	1.19 ± 0.09
	M	57	1.29 ± 0.09

The mean distance from the inferior boarder of the PSAA to the crest of the alveolar ridge was 17.83 ± 5.93 mm, ranging from 7.04 to 36.00 mm. The absence of the first molar failed to show a significant association with distance between the PSAA and the alveolar crest (ChiSquare = 1.7, $p > 0.05$). The mean distance from the inferior border of the PSAA to the alveolar crest exhibited a significant association with gender ($t = -2.44$, $p \leq 0.05$) and race ($t = 3.57$, $p \leq 0.005$); however, the distance showed a differential relationship between men and women in relation to race, as reflected in the significant race by gender interaction ($t = 1.95$, $p \leq 0.05$). Post-hoc comparisons revealed that the mean distance from the PSAA to alveolar crest was significantly lower for Caucasian females than Caucasian males, whereas no gender difference was found in African Americans (Table 3).

African-Americans and Caucasians exhibited a similar mean distance from the PSAA to the floor of the maxillary sinus. Males, however, demonstrated a significantly greater distance from the PSAA to the floor of the maxillary sinus than did females (Table 4).

Table 3. Distance of the Posterior Superior Alveolar Artery from the Maxillary Alveolar Crest

Race	Sex	N	Mean ± Standard Deviation (mm)
African-American	F	68	18.96 ± 0.73
	M	40	19.45 ± 1.14
Caucasian	F	54	13.30 ± 1.15
	M	57	17.79 ± 1.05

Table 4. Distance of the Posterior Superior Alveolar Artery from the Maxillary Sinus Floor

Race	Sex	N	Mean ± Standard Error (mm)
African-American	F	68	8.67 ± 0.62
	M	40	9.90 ± 0.99
Caucasian	F	54	7.32 ± 0.64
	M	57	9.38 ± 0.94

V. DISCUSSION

This retrospective study examined the prevalence, diameter, and vertical location of the posterior superior alveolar artery in 219 consecutive scans of 111 Caucasian and 108 African-American patients. The importance of considering the vascular system of the maxillary sinus when employing sinus surgery, particularly lateral approach sinus floor augmentation relates to potential intraoperative complications (Solar, Geyerhofer et al. 1999; Traxler, Windisch et al. 1999; Rosano, Taschieri et al. 2011). Studies by Elian et al and Mardinger et al investigated the prevalence and distance from the inferior border of the artery to the alveolar crest using CT scans (Elian, Wallace et al. 2005; Mardinger, Abba et al. 2007). Kim and co-workers also utilized CT scans to evaluate PSAA prevalence, diameter and position, but considered variation between age and sex. Kim reported statistically significant difference in prevalence and diameter between genders but no difference relative to age (2011). The study by Kim et al., however, did not take into account racial differences as the study population was solely Korean. The present study, unlike previous studies, was designed to examine variations in prevalence, diameter and vertical position of the PSAA based on race and gender.

The mean detectable radiographic prevalence of the PSAA in this study was slightly greater but consistent with the findings of others. Kim et al. (2011) and Mardinger et al. (2007) found an average artery prevalence of 52% and 55% respectively whereas the mean prevalence in this study was 57.5%. The slightly higher detection rate could be attributed to differences in the sample population in this study which consisted of two races whereas the other reports contained subjects of one race or otherwise unspecified. The mean artery detectability for African-Americans was relatively high at 72.2% and in the Caucasian group it was detectable in 43.2%.

Of important note, is the inability to detect a bony canal in a CT scan does not represent an absence of the artery altogether, but rather an artery that is too small to detect using this radiographic method (Elian, Wallace et al. 2005; Mardinger, Abba et al. 2007; Kim, Ryu et al. 2011). This is clearly made evident by anatomical studies by Traxler et al. (Traxler, Windisch et al. 1999) and Rosano et al. (Rosano, Taschieri et al. 2009) who found the PSAA in cadavers 100% of the time.

The mean diameter of the PSAA for the entire study population was 1.26 mm and ranged from 0.25-2.25 mm. This mean diameter is slightly smaller than that reported by Kim et al. in 2011, who found a mean diameter of 1.52 mm. No significant differences in PSAA diameter were found in this study between races after adjusting for BMI. This finding was not expected as variations in systemic vascular anatomy have been reported demonstrating larger vessel size in African-American groups. Wong et al. (Wong, Islam et al. 2006), Ruan et al. (Ruan, Chen et al. 2009) and Levy et al. (Levy, Talner et al. 1978) demonstrate these differences, particularly with respect to larger vessels and vessel lumens in African-American populations. The publication by Ruan et al. in 2009, also established through a multivariate analysis that body mass index, mean arterial pressure, heart rate, and carotid intima media thickness were independent predictors of common carotid artery lumen diameter.

In this study, a statistically significant positive correlation was detected between BMI and diameter. A limitation encountered in the study of artery diameter was the measuring capability of the imaging software used, as the program would not allow measurements smaller than 0.79 mm and measurements larger than this value were at random, set intervals. Thus, the measurement tool could only be used as a scale and the actual artery diameter estimated to the nearest 0.25 mm increment. As previously stated, prior reports also hypothesize that detection of the PSAA on a CT scan is dependent upon its size (Elian, Wallace et al. 2005; Mardinger, Abba et al. 2007; Kim, Ryu et al. 2011). Therefore, the assumption that a significantly greater prevalence of the arteries on CT scans in the African-American population represents an overall greater diameter might be valid.

The measurements made from the crest of the ridge to the inferior boarder of the PSAA indicated a statistically significant greater vertical distance in African-Americans than Caucasians as well as in males than in females after adjusting for BMI. These results are in contrast to Kim and co-workers' findings, who found no difference in vertical height of the artery between males and females. The greater distance demonstrated in this study for males, however, would be logical assuming that males, on average, exhibit a greater height and weight.

The measurement from the inferior boarder of the PSAA to the floor of the maxillary sinus yielded no significant differences between groups. This measurement was taken in attempts to establish a new method of vertical distance measurement. At this point in time however, it cannot be used as such, as it did not statistically match the findings of the already utilized crest to artery distance, nor is it entirely clinically relevant.

Important clinical implications can be derived from the results of this study given some of the fundamental differences seen between the racial groups. The more prevalent

PSAA, and therefore possibly larger diameter size, found in African-American subjects may indicate that the likelihood of intraoperative and postoperative hemorrhages is higher in this group. The same is true for males who demonstrated a greater artery diameter. This is not to say that more caution should be exercised when operating on patients of these groups since an undetectable artery does not indicate an absent artery. Therefore, it may be considered that some arteries in Caucasian and female groups simply cannot be referenced, and subsequently avoided, during surgery. The more inferiorly located PSAA in the Caucasian group is also clinically significant in that a more superior preparation of the lateral window in these patients may increase the likelihood of encountering and possibly severing the artery. Therefore, depending on the desired length of the implant to be placed, a preparation of the lateral window that is closer to the crest of the alveolar ridge should be considered.

Whatever the race or gender of our patients, performing CT scans before maxillary sinus floor augmentation provides valuable information about the anatomy of the sinus including the location of blood vessels. Careful evaluation of this information, identifying both vascular and hard and soft tissue structures must also be employed. In this manner, intraoperative and postoperative complications can be successfully avoided, and if necessary, appropriately managed.

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