A CONE BEAM ANALYSIS OF THE MAXILLARY BONY CANAL

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DECLARATION

I declare that *A Cone Beam Analysis of the Maxillary Bony Canal is* my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Mariam Bedford : ………………………………………………………………..

August 2013 : …………………………………………………………………

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ABSTRACT

Aim: To determine the prevalence and diameter of the maxillary endosseous canal which carries the anastomosis of the infra alveolar artery (a branch of the posterior superior alveolar artery) and the infra- orbital artery.

Material and methods: Data was analysed from one hundred archived cone beam computed tomography (CBCT) images. The presence of the endosseous anastomosis in the lateral sinus wall was identified by utilising axial views. The vessel diameter was also measured in those images where the canal was identified.

Results: The maxillary bony canal was identified in 49 (49%) of 100 maxillary sinus. 14 (14%) presented on the right hand side, 10 (10%) presented on the left hand side, 25 (25%) had a bilateral presence with a remaining 51 (51%) which cannot be identified on the imaging. From the 49 canals that were identified, 5 canals had a diameter that was 2-3mm wide, 19 canals had a diameter that was 1-2mm wide and the remaining 25 had a diameter that was less than 1mm.

Conclusion: A sound knowledge of the maxillary sinus vascularity is essential as severe bleeding can occur due to damage of the intra-osseous branch during sinus augmentation procedures. CBCT analysis is required as a pre-requisite for the pre-planning stages during implant treatment to prevent complications such as haemorrhage, sinus perforations or associated vascular anomalies that may arise.

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INTRODUCTION

Special care is needed to avoid invading vital anatomic structures during surgical procedures. Dental professionals are accustomed to the traditional dental imaging modalities such as panoramic radiography and intra oral radiography during the pre-surgical planning phase utilising both the analogue and digital radiographic methods. However, cone beam computed tomography (CBCT) is based on the concept of multiplanar imaging and has the ability to generate images in different planes.

The sinus floor represents the danger zone for dental implants (Nimegean *et al*. 2008). Knowledge of the maxillary arterial blood supply is important during sinus augmentation procedures. Vascular anastomosis perforates the floor of the maxillary sinus and provides a potential site for the spread of disease (Abrahams *et al*. 2000). There are several vessels that supply the maxillary sinus which must be taken into consideration because of the potential risk of haemorrhage. Anatomic variations of the maxillary artery and its concurrent anastomoses may also occur. Variations in the maxillary sinus such as septa, has been known to increase perforations of the Schneiderian membrane during sinus augmentation procedures (Lee *et al*.2010).

This study will provide clarity on the features of the intra osseous canal as well as the relevance for practical clinical application in that no literature is available regarding visualization of these two arteries using CBCT (Sato 2010).

The maxillary artery together with the superficial temporal artery, are both terminal branches of the external carotid artery (Otake *et al*.2010). It enters through the pterygomaxillary fissure in an anterior, medial and superior direction. The maxillary artery supplies the mandible, maxilla, and muscles of mastication, palate, nose, teeth and the dura mater of the cranium. The maxillary artery can thus be further classified into three parts which is based on the relationship to the lateral pterygoid muscle (Kim *et al*. 2010). It has a mandibular section which is located posterior to the lateral pterygoid muscle, a pterygoid section which may run deep or superficial to the lateral pterygoid, and a pterygopalatine section located in the pterygopalatine fossa. Various morphologic classifications exist based on the branching of the third part of the maxillary artery. The branches of the third part comprise of five arteries namely the posterior superior alveolar artery (PSAA), infraorbital artery (IOA), descending palatine artery (DPA), artery of the pterygoid (VA) canal and sphenopalatine artery (SPA).

Branching patterns of the posterior superior alveolar artery and infraorbital artery display two distinct patterns. The first type shows that both these arteries branch directly from the MA. In second variant, these two arteries originate from a short branch of the maxillary artery (Park *et al.* 2012, Kim *et al.* 2010). The maxillary artery is the most vulnerable anatomical structure during craniomaxillofacial procedures (Kim *et al*. 2010). The primary blood supply to the sinus is derived from the anastomoses of the dental branch of the posterior superior alveolar artery (PSAA), known as the alveolar antral artery (AAA) and the infraorbital artery (IOA), both being branches of the maxillary artery. The maxillary bony canal contains the intra osseous anastomoses between the alveolar antral artery (AAA) and the infraorbital artery (IOA).

Variation in the arterial system has been well documented within the literature. Lydia *et. al*. (2013) reported that 30.5% of cases passed superficially, 69.5% passed deep to the lateral pterygoid. Normal branching of the third part of the maxillary artery occurs at the height of the posterior lateral aspect of the maxillary sinus. The maxillary artery can be classified into four types based on the branching patterns of the sphenoplatine artery (SPA) and the descending palatine artery (DPA) which has proven to be similar in the Morton and Khan Classification (Figure 1) (Park *et al*. 2012).

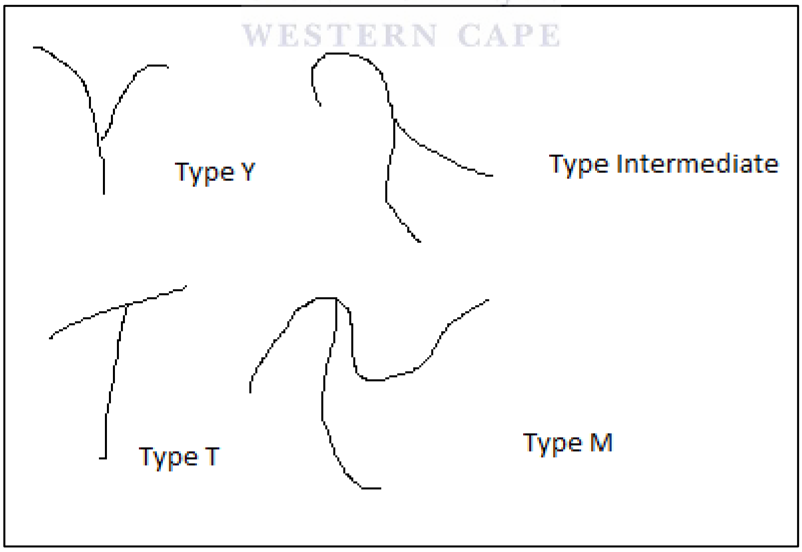


Figure 1 Morphologic classification of the Maxillary artery based on contours of the third portion

Morton and Khan classified the morphology of the third portion of the maxillary artery based on the contour pattern (Park *et al.* 2012) which are type Y, intermediate and type M. Morton and Khan also established that the various branching patterns were located in the middle third with occasional extension to the upper third of the posterolateral antral wall (Kim *et al.* 2010). According to Park *et al*. (2012), it can be classified into five types namely type Y, intermediate, T, M, and other. The branching patterns of the third part of the maxillary artery were generally similar throughout the literature.

Variations in the literature reported that the accessory meningeal artery may arise as a branch of the middle meningeal artery (Otake *et al.* 2010). The inferior alveolar artery was given off by the maxillary artery before the origin of the middle meningeal artery. In some cases both arteries arose directly from the 2nd part of the maxillary artery and intra alveolar artery arouse before the middle meningeal artery (Otake *et al.* 2010).

The maxillary sinus, also known as the antrum of Highmore, is the largest of the paranasal sinus cavities. The maxillary sinus resides within the maxillary bone and is pyramidal in shape (Rosano *et al.* 2009) with the base adjacent to the nasal wall and the apex pointing to the zygoma. The size of the maxillary sinus is not clinically relevant until eruption of the permanent dentition (Woo 2004). If the maxillary sinus is average in size, it would be on the same level with the floor of the nose. The sinus can thus be classified as large if it extends below this level (Nimegean *et al*. 2008). The size of the maxillary sinus increases with age as well as by the presence of an edentulous area (Gosau *et al*. 2009).

Septa are walls of cortical bone found within the sinus. They arise from the either the inferior or lateral walls of the sinus. They are described as having an inverted gothic arch shape and have the potential to further subdivide the sinus into two or more cavities. It is important to identify these structures radiographically as the placement of the lateral window during sinus augmentation is based on the presence of these structures. The prevalence of septa is neither gender related nor age specific (Mardinger *et al.* 2007)

The maxillary bony canal is located on the inner surface of the maxilla. The bony canal follows a concave arch course with the first molar area being the most inferior site (Mardinger *et al*. 2007). Sato *et al*. (2010) described the bony canal structure surrounding the PSAA using CBCT in 19 cadavers and classified them into three types namely canal-like, ditch-shaped tunnel and fragmented. Sato *et al*. (2010) reported the ditch-shape tunnel structure to be the most common (67, 6%) of all images observed. The varied appearance of the bony canal has been observed using both CT (53%) and CBCT (71.4%) (Sato *et al*. 2010).

Yoshida *et al.* (2010) reported that the anastomoses can be located at a height of 23-26mm above the alveolar ridge. Rosano and colleagues (2011) identified this anastomoses at a distance of 18.9 mm to 19.66 mm from the alveolar crest. They also reported a mean vertical distance of 29mm above the alveolar crest with a canal diameter of 1mm in 53%,1- 2 mm in 40.4% and 2-3 mm in 4.3%of cases examined.

According to Mardinger *et al.* (2007), the canal diameter is directly related to the age of the patient. Older patients have wider canal diameters. No correlation was found with gender, sinus position or presence/absence of teeth.

LITERATURE REVIEW

Maxillary sinus augmentation was initially described by Tatum in 1976 and subsequently published in 1980 (Woo, 2012). Today, sinus floor elevation is one of the most commonly performed preprosthetic surgeries in the dental arena.

Earlier methods used to determine the size of the maxillary sinus include directly reporting from the dissection of cadavers, examining radiography of living patients as well as by computed tomography. Numerous studies conducted on cadavers have indicated the presence of the anastomoses of the PSAA and IOA located in the lateral wall of the sinus with a prevalence of 62.2%.

Previous studies reveal that the intra osseous vascular canal has been identified in the lateral wall of the antrum in more than 50% of CT images that were examined (Mardinger *et al.* 2007). Sato *et al.* (2010) reviewed literature examining CT images with a prevalence of 53%, 55% and 71.4% respectively. Flanagan *et al. (*2005) reported that the maximum diameter of the PSAA externally was 2mm at the posterior superior alveolar foramen and an approximate value of 1.6mm at the infrazygomatic crest. These measurements are indicative that bleeding can occur when the artery becomes damaged.

Recent forms of measurement include immunohistochemistry, microscopic and macroscopic observations, and CBCT. Recently CBCT has provided more highly accurate data when compared with physical measurements (Yoshida *et al*. 2010). CBCT provides vital, three-dimensional information about the morphology of the maxillary sinus utilising lower radiation levels. No literature is available regarding visualization of the branching patterns of these two arteries using CBCT together with a macroscopic analysis (Sato *et al.* 2010).

Sato *et al*. (2010) reported that numerous blood vessels and nerves form complex fibres which can be observed near the floor and the upper wall of the maxillary sinus. The presence of CGRP-positive fibres distributed along the posterior superior alveolar artery (PSAA) indicates the capacity for vascular regulation, vasodilation and vasoconstriction. CGRP is released by nociceptive sensory nerves. The number of positive CGRP fibres changes during vasodilation. They pose the greatest surgical risk during sinus augmentation (Sato *et al.* 2010).

Excision of this arterial anastomoses is not threatening due to the small vessel size. Hemostasis is achieved by a reactive contraction. Hemostasis must be done spontaneously or by the application of pressure from a humidified gauze pack. Electrocautery must be avoided to prevent perforation of the Scheiderian membrane. Healing may also be compromised which could affect the remodelling of the graft. (Rosano *et al.* 2009).Post-operative pain and inflammation can occur in the maxillary sinus following surgical treatment or implant placement. Pain along the PSAA is also related to variations within the sinus anatomy (Sato *et al.* 2010).

According to Rosano *et al.* (2011), the intraosseous and extraosseous anastomoses of the PSAA and IOA form a double arterial arcade which supplies both the lateral wall of the sinus as well as parts of the alveolar process. The infra alveolar artery contributes to the sinus membrane located in the anterolateral aspect .The presence of this bony canal is important during sinus floor augmentation procedures and may lead to vascular impairment, intense bleeding, visual obstruction and perforation of the Scheiderian (sinus) membrane (Mardinger *et al.* 2007). Elian *et al*. (2005) highlighted the importance in determining the potential complications that may arise in relation to compromise of the vessels specifically on the lateral sinus wall. In the event that the alveolar crest has undergone severe resorption, the vessel is usually located closer to the alveolar crest than reported values in the literature. The artery was closer to the alveolar crest in the region of the first molar with an average distance of 13.5mm.

The **AIM** of this study is to:

Determine the frequency and characteristics of the maxillary bony canal located on the lateral border of the maxillary sinus.

The **OBJECTIVES** are:

To investigate the prevalence of the maxillary bony canal utilising CBCT records from an archived patient database.

To study variation in the maximum diameter size of the intra-osseous canal.

If present, determine if they are bilateral or unilateral.

METHOD and MATERIALS

<u>Study sample</u>

A sample of 100 pre-operative cone beam records were analysed from CBCT patient records that presented for placement of posterior maxillary dental implants at the Oral Health Centre, Faculty of Dentistry, University of the Western Cape, Tygerberg Campus. The first one hundred implant patient records were selected from the database. A selection of 100 patient records would yield 95% confidence limit of +/-0.10 whereas a sample size of 50 would have a width of +/-0.14. These values are based on current prevalence figures of a 60% frequency.

<u>Inclusion criteria</u>

Any patients requiring a CBCT as part of pre-planning stage for the placement of implants.

<u>Exclusion criteria</u>

Any patient with abnormalities of the mid –facial region including the maxillary sinus e.g.malignancies, fractures, etc.

Study design

This is a retrospective cross sectional study of 100 cone beams records utilising the New Tom VGI EXPERT suite. This specific software configuration allows all tasks which include scanning such as primary volumetric, secondary and 3D imaging reconstruction, report creating and printing.

Radiological Interpretation

CBCT records will be analysed by one observer with experience of examining CBCT images and will be noted on a separate form (Appendix 1) to indicate the prevalence.

The maximum diameter will be measured by two observers and then compared. These two values will be added together and then used to calculate the mean.

Data record

100 CBCT records were selected from the CBCT database.

Each patient record, which was selected, has a unique folder number.

The folder will then be allocated an individual record number which will be used as the first index data set.

This index data set will be kept separate and used to ensure confidentiality as well as a cross reference.

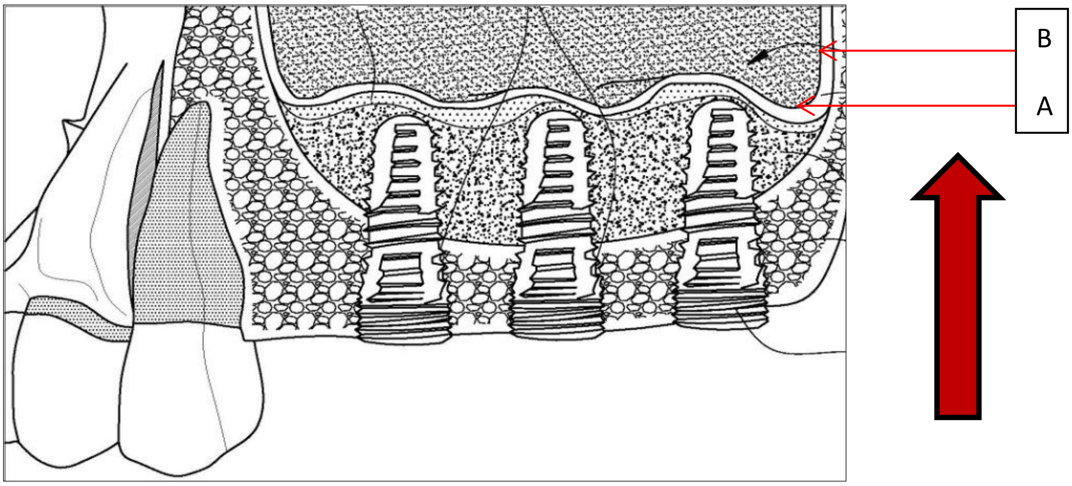
The second index data set would then contain the allocated record number together with ten axial views of each patient.

These axial views will be selected from the original CBCT record and saved in the second index data

The selected axial view will start at the floor of the maxillary sinus and be measured in increments of 1mm.

The ten axial views will be measured from inferior to superior (as indicated in figure 2).

Axial Views inferior to superior direction



A – Floor of the maxillary sinus

B –1mm incremental measurement

Figure 2 Incremental measurements to be made

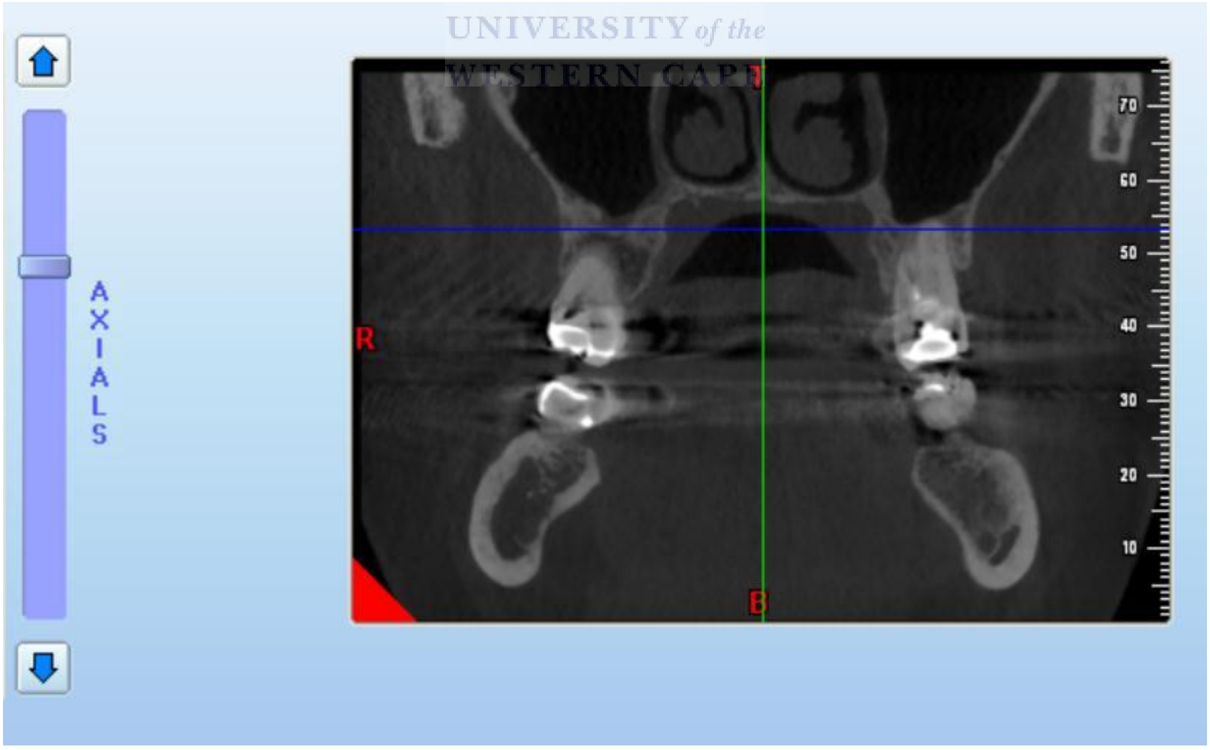


Figure 3 Baseline for initial measurements

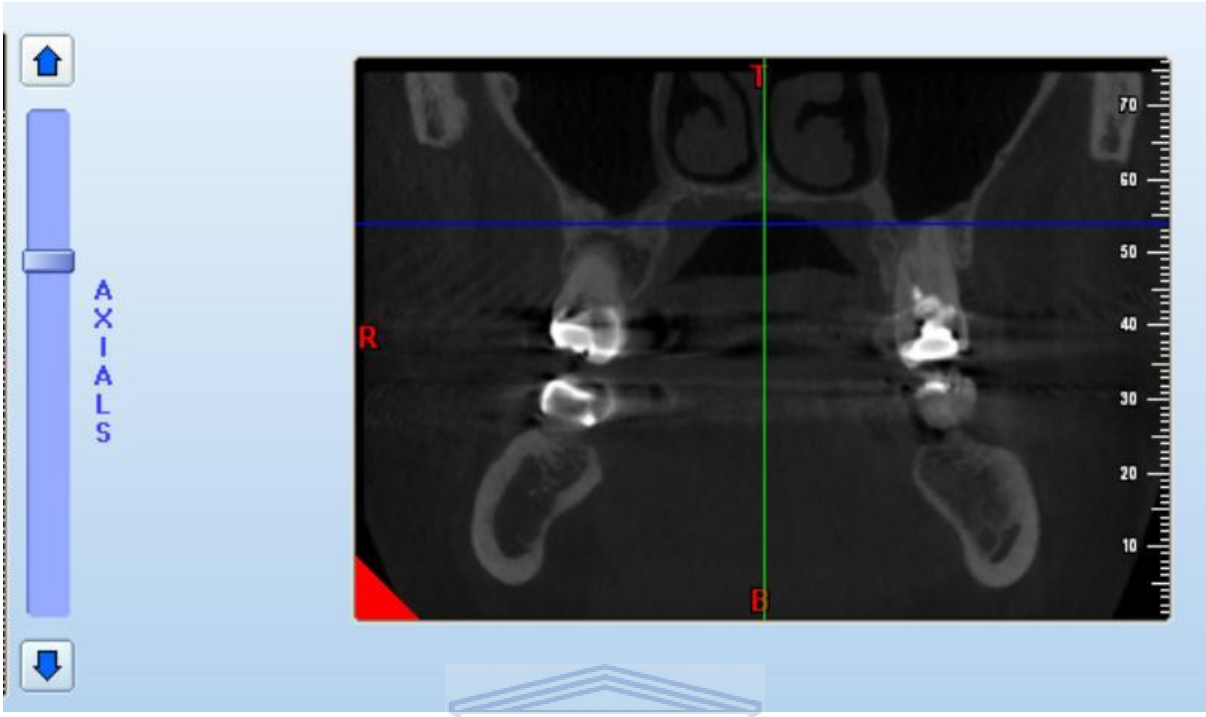


Figure 4 Incremental measurements made on CBCT

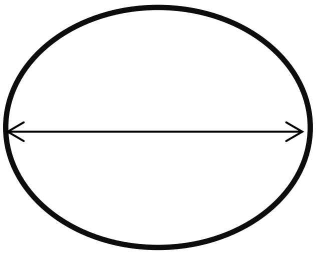


Figure 5 Diagram indicating maximum diameter

This applies for both left and right sides.

Data will then be recorded on Form A (Appendix 1).

Upon completion, data will be entered into statistic software for analysis.

Data Analysis

Data will be analysed by entering the statistics into the Epi-Info Version 3.4.3 database which is statistic software for public health professionals.

Data will be analysed using descriptive statistics such as the observer prevalence with a 95% confidence limit. The mean would also be calculated for the maximum diameter in descriptive analysis of data.

Ethical Clarity

Permissions to access the records were obtained from the Head of the Department of Maxillofacial Radiology and Diagnostics. Patient confidentiality was maintained by the creation of an index data set which links the patient folder number to the allocated record number. Consent was not to be obtained because the records are archived.

No conflict of interest was declared.

RESULTS AND DATA ANALYSIS

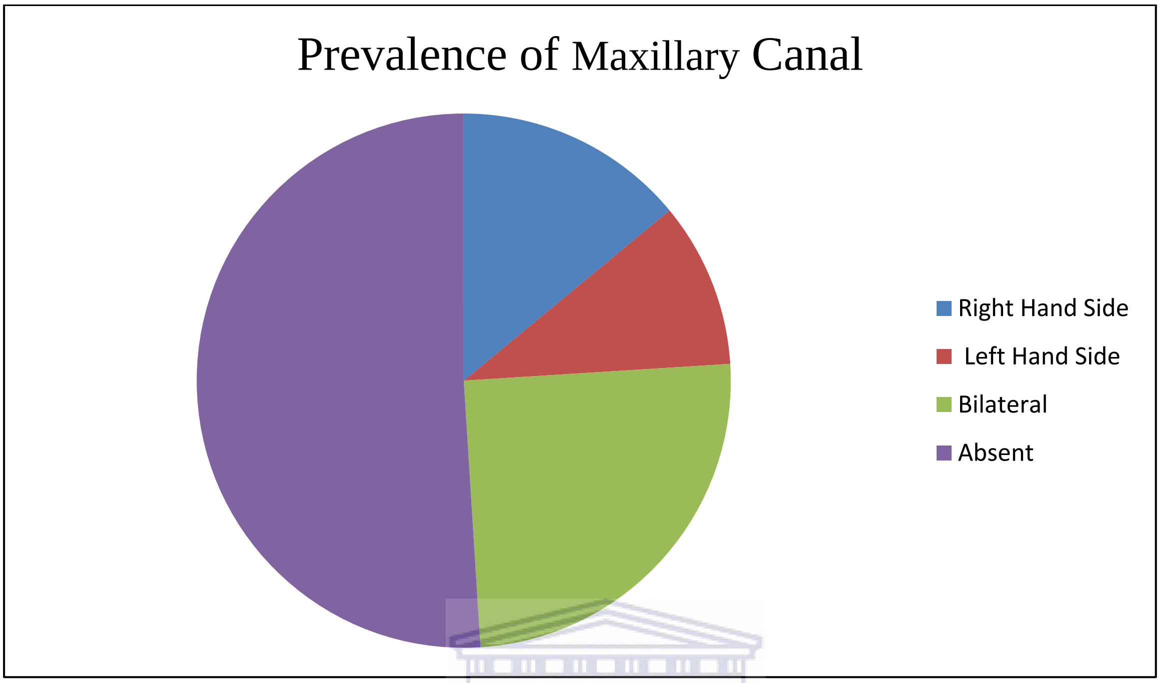


Figure 4 Prevalence of the maxillary canal in 100 patient records

The figure above indicates the following:

14% prevalence on the right hand side with a confidence interval of 7, 9% to 22%.

10% prevalence on the left hand side with a confidence interval of 49% to 17, 6%

25% presented bilaterally with a confidence interval of 16, 9% to 7%

51% had complete absence thereof with a confidence interval of 40.8% to 61.1%

Previous results show a detection rate of 52.9% (Woo, 2004). Mardinger *et al*. (2007) detected a prevalence of 55%. Kim *et al.* (2008) had a detection rate of 67.5%. Elian *et al.* 2005 stated that although the vessel is only evident in 53%, it is present 100% of the time. Woo *et al*. (2004) detected the canal in 54.8% which is similar to the expression in previous studies.

DIAMETER

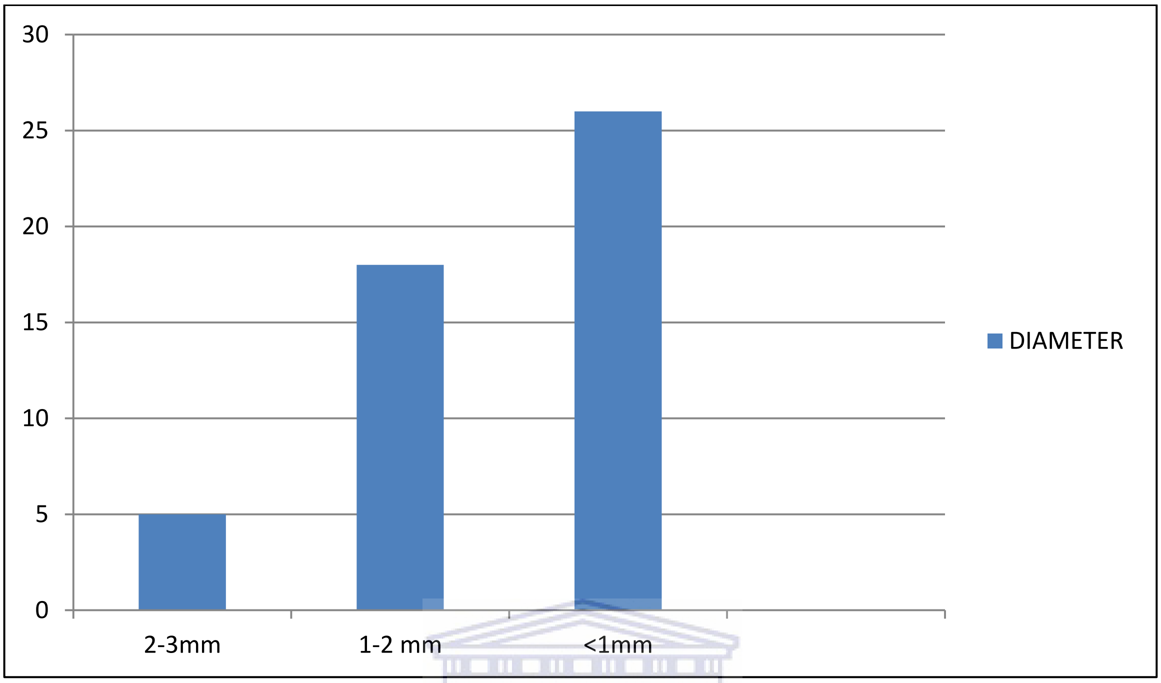


Figure 5 Number of cases

The diameter readings were calculated according to the diameter size found in the forty nine patients who presented with the canal either bilaterally or unilaterally. The following results were found:

- 2-3mm category : 5 (10.2%)
- 1-2mm category : 18 (36.7%)
- <1mm category : 26 (53. 1%)

Guncu *et al.* 2011 reported that mean diameters were 1.6mm in origin, with a range of 1.2mm to2.7mm. When a mean was calculated for each sinus, 4.9% of the vessels had a diameter of < 2mm. Mardinger et al. (2007) reported that 6.7% of the vessels examined had a vessel of >2mm. This may explain why there is a very low incidence of bleeding.

AGE DISTRIBUTION

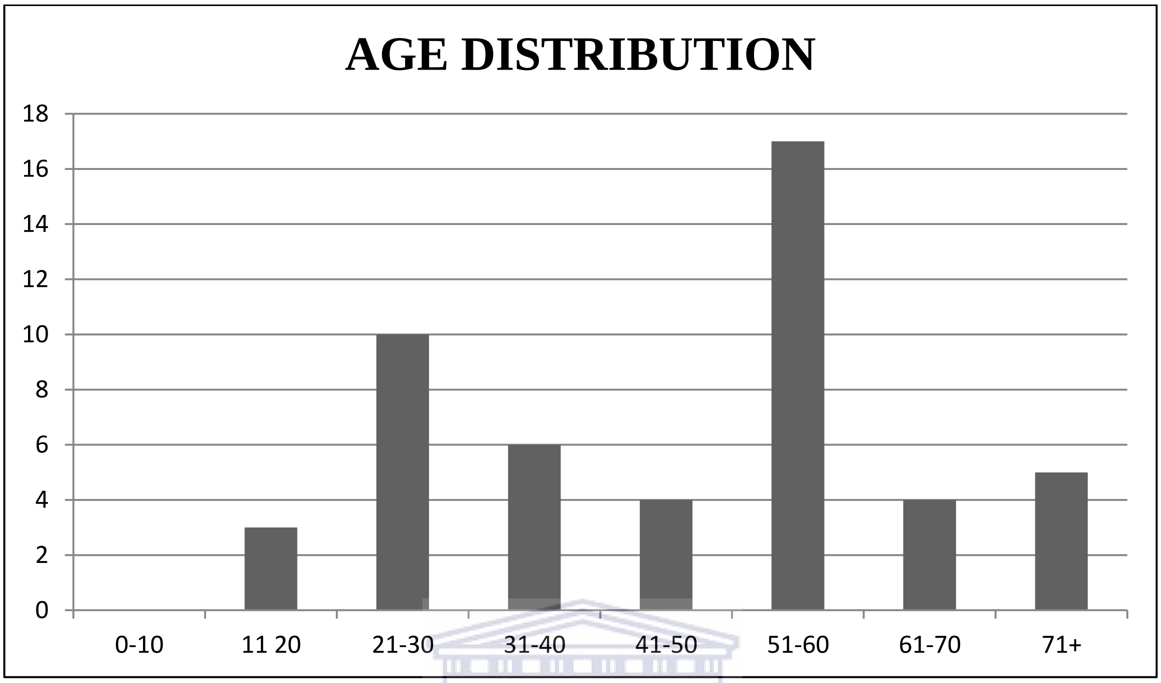


Figure 6 Number of cases

The age distribution was calculated in the forty nine patients who presented with the canal either bilaterally or unilaterally. The following results were found:

- 0-10 category : no patient under 10 had a CBCT done
- 11-20 category : 3 patients
- 21-30 category : 10 patients
- 31-40 category : 6 patients
- 41-50 category : 4 patients
- 51-60 category : 17 patients
- 61-70 category : 4 patients
- 71+ : 5 patients

GENDER DISTRIBUTION

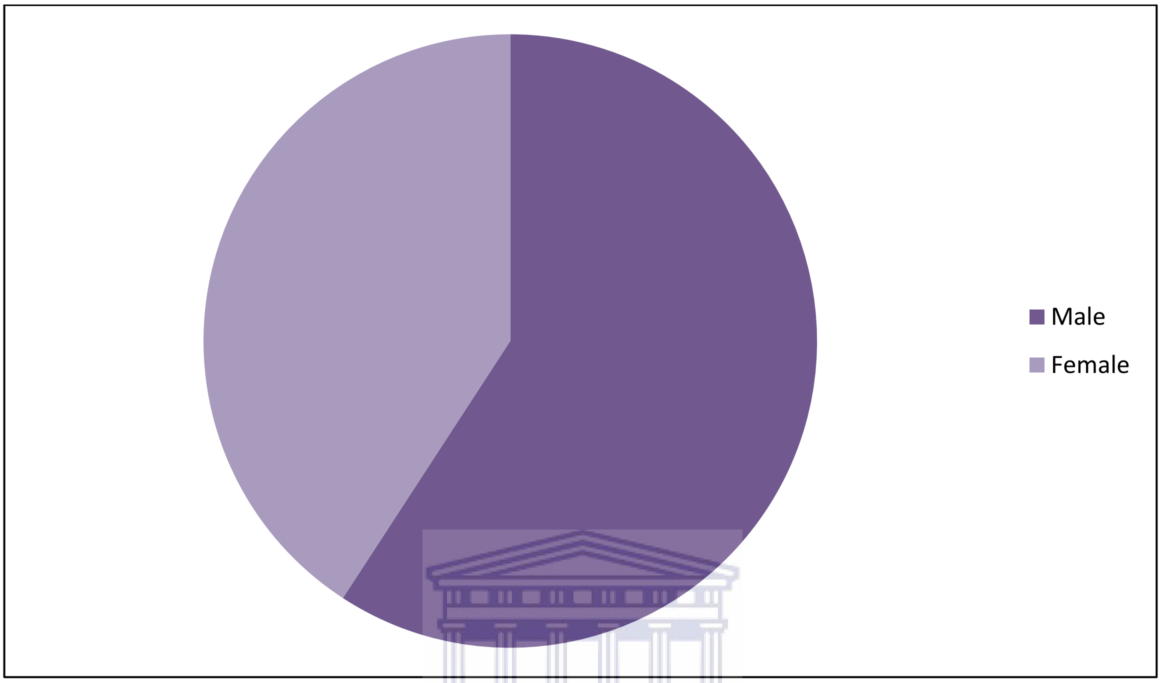


Figure 7 Males versus female ratio

The gender distribution was calculated in the forty nine patients who presented with the canal either bilaterally or unilaterally. The following results were found:

- Total number of males : 29 patients (58%)
- Total number of females : 20 patients (42%)

In previous studies, the detection rate was 66.7% for males and 50% in females, but the difference was not statistically significant (Woo, 2004).

DISCUSSION

According to this study, a maxillary canal was identified in 49% of examined CBCT patient records. The results do correlate with previous studies mentioned in the literature. According to Mardinger *et al*. (2007), a study done by Traxler in 2007 found a 100% presence which means that an undetected bony canal in a CT does not exclude its absence, but is rather indicative of its small diameter. The distance of this anastomoses runs a concave course with distances which range between 5mm and 29mm to the alveolar crest (Mardinger *et al.* 2007). *S*olar *et al.* reported distances to be between 17mm and 23mm. The differences between these two studies are most likely due to the smaller number of cases examined in the study conducted by Solar *et al. (*1999).

Variations only exist in the position and diameter of the canal (Mardinger *et al.,* 2007). However the following parameters have also been discussed and compared in previous studies which may have an effect in detecting the canal as well as relate to characteristics of this anatomical landmark. They are:

<u>Gender</u>

Mardinger *et al*. (2007) could not find a difference between men and women in the diameter of the canal.

<u>Age range</u>

According to Elian *et al.* (2005), the vessel diameter is reduced in older patients. Mardinger *et al.* (2007) contradicts this statement stating that diameter of the artery did not change according to age. Mardinger *et al. (*2007) discovered a relationship but found the diameter to be wider in older patients.

<u>Dentate versus edentulous specimens</u>

Several theories have been suggested to explain alveolar crest atrophy. These include functional upload, ischemia, pressure and local inflammation. According to Nimegean *et al.* 2008), three subantral classes (SAC) were discussed based on the average height of the available bone in the edentulous maxilla as well as the age of edentulism. They are:

SAC 1 : Bone height 10mm with no edentulism older than five years

SAC 2 : Bone height 5-10mm with edentulism5-10 years old without prosthetic treatment

SAC3 : Bone height 0-5mm with edentulism more than ten years old without prosthetic treatment.

In the event that the alveolar ridge is severely resorbed, there is a likelihood that the anastomosing vessel will be in closer proximity to the alveolar crest than the reported value of 16.4mm (Elian *et al*., 2005) and 16.9mm (Mardinger *et al*., 2007).However, such data can be misleading because the height of the residual bony ridge, the class of maxillary atrophy and the presence of teeth plays a pivotal role in determining the location of this vessel (Rosano *et al*., 2011). According to Woo *et al*. (2004), the posterior superior alveolar anastomosis is shorter in edentulous groups compared to non-edentulous groups. This then confirms that the more resorbed the ridge, the higher the violation risk of this vessel during augmentation procedures. Extreme caution must be exercised when the residual ridge height is <3mm (Rosano *et al.*, 2011).The clinical challenge is further exacerbated by post extraction ridge resorption associated with increased pneuamatization creating proximity to the antral floor (Toffler *et. al.,* 2009).

Radiographic findings that may pose problems for the surgeon are the presence of septa, thickening of the sinus membrane, pathosis such as acute rhinosinusitis or evidence of neoplastic disease. There is limited knowledge with regard to the mean thickness and dimension of the sinus membrane. No guidelines have been established for the assessment and classification of mucosal findings in the maxillary sinus (Janner *et al*., 2011).

<u>Presence of septa</u>

Maxillary sinus septa are walls of cortical bone which is located in the maxillary sinus. Clinically, they may be present in varying forms or shape, and may arise from with the lateral or inferior sinus wall. Sinus septa can further be described as primary or secondary. Primary septa arise from the development of the maxilla (congenital). Secondary septa develop from the irregular pneumatisation of the sinus floor followed by subsequent tooth loss and do not exceed 2.5mm (Gosau *et al.,* 2009).

Therefore, it can be concluded that septa above teeth are regarded as primary and those above an edentulous ridge are regarded as primary or secondary. However, septa above an edentulous ridge can only be distinguished clinically as primary or secondary if previous radiographic records are available. Previous studies have reported that these septa are more prevalent in atrophic edentulous areas as compared to a non-atrophic site (Beretta *et al.*, 2012).

However, in the posterior region of the maxilla, the anatomical variation of the sinus septa is diverse in prevalence and location irrespective of the nature of the ridge (atrophic, non-atrophic, dentate, and edentulous) (Lee *et al.*, 2010). Septa deserve attention because they have the potential to mimic periapical disease (Serkerci *et al*., 2013). Septa can hamper the preparation and elevation during sinus procedures.

Several authors have studied the prevalence of septa. Underwood (1910) found 30 septa in 90 sinuses which demonstrated 33% prevalence. Ulm *et al*. (1995) demonstrated a 28.3% prevalence rate; Krenemair (1999) detected 16% prevalence. Mardinger *et al*. (2007) demonstrated a 24.6% prevalence which agrees with previous studies.

Knowledge about the precise location and morphology of the septa is essential in determining the surgical approach .Septa with a height of 2mm do not warrant additional treatment (Neugebauer *et al*., 2010).

Pathogical conditions

There are certain conditions which may alter the size of the sinus which may either enlarge or reduce sinus volume. These conditions may alter the normal anatomy of the sinus. One has to be aware of these conditions and their pathologic processes if present.

Enlargement of sinus is usually due to the presence of a mucocele/ pneumatocele which may lead to mucous or air trapping. Concurrent enlargement of the sinus leads to enlargement of the face associated with elevation of the orbital floor (*Lawson et al*., 2008).

However, sinus reduction encompasses a wide range of developmental, congenital, iatrogenic, traumatic, neoplastic or systemic conditions. Amongst these, only the disorders which affect the normal anatomic structure and actual bony configuration will be discussed.

TABLE 1: Conditions which may alter maxillary sinus anatomy and their pathogenesis

ENLARGEMENT	
Mucocele	Mucous Trapping
Pneumatocele	Mucous Trapping / Air trapping
REDUCTION	
Developmental Hypoplasia Silent Sinus Syndrome	 Nonaeration Atelectasis
Congenital Syndromal	 Non development
Iatrogenic Post Caldwell Luc Procedure Irradiation	 Osteogenesis Arrested development
Traumatic Zygoma, Maxilla Orbit Fractures	 Displaced bone, Fat Herniation
Neoplastic Tumours Fibro-osseous Odontogenic Lesions	 Mass ingrowth, invasion Abnormal bone growth All displacement, Infiltration
Systemic Hematologic Endocrine Osteopetrosis	 Marrow proliferation Non development Bone production

- *Congenital*

Although complete aplasia of the maxillary sinus is rare, it does not imply that it cannot occur. Maxillary sinus hypoplasia (MSH) is well documented clinical condition and has three subtypes. They are;

MSH Type I which is characterised by the presence of mild to moderate hypoplasia, presence of a normal uncinate process, a well-defined infundibulum with varying mucosal thickening.

MSH Type II is characterised by the presence of a hypoplastic uncinate process together with an ill-defined/absent infundibular passage. There is considerable sinus hypoplasia and total opacification of the sinus.

MSH Type III displays extreme hypoplasia together with an absent uncinate process. The profound nature of the sinus hypoplasia is only noted as a shallow cleft along the lateral nasal wall.

Sydromal etiologies of MSH can be classified as either due to a lack of development from failure of the midface to grow and obliteration of sinus cavities as a result of osteosclerosis. There are over 100 forms of craniofacial dystoses and the more common ones include Treacher Collins syndrome, Apert syndrome, Crouzon syndrome and Binder Syndrome.

<u>Silent Sinus Syndrome</u>

Silent sinus syndrome is clinically asymptomatic. The patient present with spontaneous enopthalmos.Radiographically, the syndrome appears with a “shrunken” sinus, remodelling of the orbital floor, demineralization and bowing of the sinus walls creating an atelectatic sinus (Lawson and Lin, 2008)

- *Neoplastic – Malignant, benign, odontogenic lesions, fibro-osseous disease*

Malignant neoplasm arising in the maxillary sinus is principally the squamous cell carcinoma. This specific tumour proliferates and “fills” the cavity. The adjacent walls are destroyed and invaded. In the case that the tumour is advanced, the sinus appears non-recognizable. If the tumour arises from the maxillary alveolar bone, the sinus floor is only destroyed. In the event that the sinus develops from within the sinus cavity, the tumour growth is then multidirectional. The hallmark sinus of malignancy is usually the appearance of an irregular appearing sinus due to loss of the bony walls and nasal soft tissue.

Benign tumours are extremely uncommon. Primary benign tumours usually behave like an odontogenic lesion and may distort the sinus. In the case of an osteoma or an inverted papilloma, the production of an intracavity mass can lead to expansion of the sinus. The presence of a pseudotumour, which is the only exception, is clinically characterised by the presence of chronic inflammation which produces extensive destruction and distortion.

Odontogenic lesions result in encroachment of the sinus with resultant displacement of the sinus wall on of the affected side. If inflammatory in nature, the antral floor is elevated. In the case of developmental cystic conditions such as a dentigerous or keratocyst, the posterior and lateral sinus walls are displaced. Due to their non-invasive nature, they can create a "duplicate sinus" (Lawson and Lin, 2008).

Fibro -osseous disorders may be classified as Pagets Disease, fibrous dysplasia or ossifying lesions (osteoma, ossifying fibroma). These conditions alter normal bone by replacing the normal medullary bone and in doing so; alter the normal architecture by obliteration of the sinus cavity.

- *Traumatic lesions*

May include midfacial fractures which may alter sinus shape.

- *Iatrogenic*

This encompasses disruption of the sinus by surgical procedures such as the Caldwell- Luc procedure as well as endoscopic surgery in paediatric patients.

- *Systemic - Hematologic, Endocrine, Osteopetrosis*

Hematologic conditions can lead to the formation of Maxillary Sinus Hypoplasia (MSH) which could either decrease sinus volume or cause total obliteration thereof.

Endocrine disorders such as hypoparatyhroidism as well as acquired hypopituarism have been associated with MSH. Alteration in the release of growth hormone may decrease the ability of the growth centres in the face to develop to their full potential (Lawson and Lin, 2008).Osteopetrosis is characterised by the replacement of normal medullary bone with resultant sinus obliteration

Maxillary Sinus Variations and Abnormalities

Maxillary sinus abnormalities are usually incidental findings on radiographic images. However, failure to detect these sinus abnormalities is usually due to the limited ability and experience of the clinician /radiologist when interpreting volumetric images as well as negligence when undertaking visual systematic scrutiny (Rege .2012).

According to Rege *et al*. (2012), great variability in the prevalence of incidental findings in the maxillary sinus was found when using multiplanar images. CT scanning studies had an abnormality prevalence rate of 30% and CBCT images reported a prevalence ranging from 24.6% to 56.3% (Rege *et al.* 2012). Discrepancy in abnormality rates can be multifactorial such as dissimilarity in the sampling size, variations in the diagnostic criteria and interpretation of the image. Climate amongst different geographical areas may also play a role.

The degree of extension of the maxillary sinus into the alveolar process is variable. (Serkerci *et al*. 2013) According to Rege *et al.* (2012), sinus abnormalities were more frequent in males. Patients were all order than 12 years of age because formation of the maxillary sinus is still incomplete. Certain sinus abnormalities such as opacification are usual common findings in early childhood stages and usually not indicative of sinus disease.

There is no consensus in the literature on the amount of mucosal thickening which is considered to be abnormal. Previous studies have suggested measurements which range from 2mm to 6mm. 3mm is considered to be the reference point (Rege *et al*. 2012)

The Schneiderian membrane

The Schneiderian membrane is attached to bone which borders the maxillary sinus. It is characterised by a periosteum which is covered by a layer of pseudociliated stratified respiratory epithelium. This epithelial layer serves as a protective barrier for the sinus cavity. Serum-mucosa glands are located directly underneath the epithelial layer. The normal thickness of this membrane varies from 0.13mm to 0.5mm but can become thickened due to inflammatory or allergic phenomena (Testori *et al.* 2013).This membrane is freed during the sinus lift procedure and can be damaged due to overfilling, infection or perforation (Ardekian and Mactei, 2006).

Perforation is a well-documented phenomenon which is likely to occur at the sharp angle and ridge line, septa and spines (Ardekian and Mactei, 2006). Membrane perforation most often occurs on the lateral sinus wall.

The Valassis and Fugazzotto classification (Class I to V) is based on both the position and extent. Class I and II can be easily repaired while Class II to V being more difficult. The classification is as follows:

Class I : Perforations are sealed off due to folding of the membrane and is usually located next to the osteotomy site.

Class II : Occurs most frequently when in-fracture design of the osteotomy is employed. The perforations are located in the mid-superior aspect of the osteotomy which extends in a mesio-distal direction.

Class III : These perforations are usually located at the inferior border of the osteotomy at both the mesial and distal ends. This is usually the most common form of membrane perforation.

Class IV : These perforations are rare and usually occur in the central two thirds of the osteotomy site and pose a clinical challenge.

Class V : Is usually a pre-existing area of exposure of the sinus membrane which is due to a combination of excessive antral pneumatisation together with severe ridge resorption.

It has therefore been concluded that the presence of small residual alveolar bone height is more likely to result in membrane perforation which is largely due to the technical difficulties when freeing the membrane from the lateral wall. Also, factors affecting membrane perforation are often at times mainly anatomical occurring in 7-35% of cases (Meleo *et al*. 2012).

Comparison of cone beam and other techniques

In the field of dental implantology, assessment of the surrounding alveolar bone and dentition is largely dependent on two dimensional imaging modalities which include both digital and conventional radiography.it is evident that panoramic radiography cannot illustrate the width of the bucco-lingual alveolar ridge or the angle for the placement of future dental implants.

Intraoral periapical (IOPA) and panoramic radiographs are not accurate in revealing true ridge morphology specifically defects located in the labial cortical plates (Arora *et al.* 2013). Periapical radiography is limited because information is two dimensional. Interpretation becomes difficult in the posterior maxillary region where the roots of the teeth overlap as well as the presence of anatomic structures (maxillary sinus, zygomatic buttresses) are present.

Panoramic radiography cannot be eliminated in cases without complications when the number of future implants is considerably low (Georgescu *et al*. 2010). Panoramic imaging as a two dimensional imaging modality possesses limitations in the assessment of the implant site alone. Pathologies in the maxillary sinus are often over projected such and cannot determine a three dimensional architecture (Mohan *et al*. 2011).

Methods used in the past for implant programs had limited use and only allowed bi-dimensional and inexact analysis (Georgescu *et al.* 2010). It is for this reason that three-dimensional modalities have proven to be superior in detecting change in the maxillary sinus (Neugebauer *et al*. 2011) recent radiographic imaging such as Computed tomography (CT), magnetic resonance imaging (MRI) and CBCT have become necessities in adequate assessment of the jaws

- Computed Tomography (CT)

CT is a form of digital imaging that enable the differentiation and quantification of hard and soft tissues. Initially, CT has revolutionized bone analysis and treatment planning. CT creates a three dimensional reconstruction of any anatomical area of interest in an axial, sagittal and frontal planes.

Medical CT utilises a fan-shape beam which acquires individual image slices with a number of rotations. Each slice requires a separate scan and reconstruction. CT imaging is very often non-isotrophic which implies that the resolution is not equal for all three directions in space.

The resolution of one slice can be less than 1mm. the spaces between the various slices are usually within the range of one millimetre or more (Neugebauer *et al.* 2011).

CT has several advantages when compared to the traditional imaging modalities such as orthopantomography and intra-oral radiographs (Testori, 2013). CT scanning allows for the precise evaluation of numerous anatomic components which may reveal any irregularities. However, CT analyses are more prone to artefacts due to the metallic nature of the dental materials.

Recently, CT guided surgery allows the clinician to measure with great precision, the location of anatomic structure and dimension of the underlying bone. Bone densities are easily identified as well as the fabrication of a precise surgical guide

- Magnetic Resonance Imaging

MR images are based on the application of electromagnetic fields and radiofrequency waves which are believed to be harmless to the body making it biologically safe. All data acquired is from the concentration of hydrogen atoms in the body. MR allows for the formation of representative images only of the structures formed in the layers of pre-selected images and pre-orientated in space. It is possible to scan each plane of interest without further reconstruction of the image.

MR provides a high resolution image of the implant site. It produces an image which gives three dimensional information on the spatial relationship of important structures. MR provides good definition of detail which allows for complete flexibly in the alignment of the image slices. This allows the operator to move the acquisition plan as appropriate.

Another advantage of MR imaging in implantology is the use of a permanent magnet of 0.2 Tesla. This produces a lower noise produced by the scanners due to the reduced vibration forces acting on the magnetic coil gradient. The application of using a low-field MR with a 0.2 Tesla means cost is reduced. All relevant structures are well displayed.

However, additional studies are deemed necessary to determine the technical advantages of resonance at lower magnetic fields compared to those of CT. MR images in comparison to CT is so exact that it even shows clot formation in the empty alveolus. For future application of MR, the use of open low intensity magnetic field scanners could ultimately reduce costs and extend the use of this technique without exploitation of the few scanners that are available for the study of serious disease (Pompa *et al*. 2010).

- Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) was first described in the year 1998 Janner et al., (2011) and has since become a popular technique utilised for diagnosis and treatment within the dental arena. Janner et. al. (2011) reported that it has already become an "established dental tool" for endodontics, dental trauma, periodontal disease, implantology, furcation and implant surgery, orthodontic planning, TMJ analysis, airway study (sleep apnea), tumours of the jaws and cephalometric analysis.

CBCT utilises the application of a fixed x-ray source and detector and a rotating gantry. The scanner rotates around the patients head from 160 degrees to 360 degrees. This obtains 600 distinct images (160-1024 depending on the type of system used). A cone=shape beam is used and acquires a volume of the complete field of view in a single rotation of which one scan is sufficient to produce a complete 3D reconstruction with sub-millimetre resolution.

CBCT provides a three dimensional image and can provide vital information about morphology. CBCT offers increased precision lower radiation doses to the patient. CBCT has several advantages some of which are listed below (Mohan 2012):

- Rapid scan time as compared to normal panoramic radiography
- Complete 3D reconstruction when taken at any angle
- Beam collimation limits radiation to area of interest.
- Patient radiation dose is five times less than normal CT
- Image resolution ranges from 0.4mm to as low as 0.076mm voxel
- The data projected provides images in axial, sagittal and coronal planes
- Volumetric datasets allow for multiplanar reconstruction
- 3D volume rendering is made possible by either the direct or indirect technique
- Patient positioning is made easy by means of the three positioning beams
- Reduction in image artefacts

It has been reported that CBCT provides diagnostic accuracy of 61%, Digital radiography 39% and conventional radiographs 44%. It was also found that CBCT systems provided intra-and interobserver agreement higher than that of conventional radiographs .According to Hu *et al*. (2012), digital panoramic radiography can be used during the pre-surgical planning in the mandible, but cannot be used in the maxilla when evaluation of a structure in a bucco-lingual location is required. CBCT provides information about the bucco-lingual relationship which cannot be obtained from digital panoramic radiography.

CBCT has limitations such as specific artefcats, limited volume and the lack of soft tissue information (Lana et.al. 2011).

CONCLUSION

It is important to have a comprehensive knowledge of the maxillary artery and its distribution in order to avoid intraoperative bleeding. Variations occur in the position, diameter and length of the canal. The studies confirm that a small diameter of an intra-bony canal does not exclude existence, but may be the reason that it is not detected. (Mardinger *et al*. 2007).

If damage to the bony vessel < 2mm, the clinical significance is barely relevant. However, if the transection of the AAA with a diameter of > 2mm is likely to produce spontaneous bleeding, vision impairment and membrane perforation. Haemorrhage from this artery may displace the graft material due to a "washing effect". This is due to the associated blood pressure thereby reducing/compromising the Schneiderian membrane after sinus elevation and lead to subsequent production of hematomas in the cheek area which creates ideal conditions for bacterial growth and consequent infection.

As with emerging imaging modalities, CBCT scanners has been both criticised and acclaimed. The technology is limited by lack of user experience as well as the availability of the small body of related literature (Mohan *et al*. 2011). The application of CBCT is still limited due to the inferior quality when compared to CT (Mohan et al. 2011).CBCT is an essential tool in both implant selection and placement (Mohan et al. 2011). CBCT thus follows the principles of radiation protection to reduce radiation to "as low as reasonably achievable" (ALARA principle).It can therefore be concluded that CBCT imaging is recommended as a valuable pre-surgical diagnostic tool to evaluate the maxillary sinus for augmentation procedures (Pompa et al. 2010).

It is therefore clinically important for dental specialists to be aware of the localisation of the anastomoses in order to prevent vascular complications that can arise from surgical procedures in an anatomically demanding area. Both radiologists and dental specialists must be familiar with the normal anatomy in this area as well as anatomic changes that may occur after surgery (Abrahams *et al*. 2000). Parameters such as the existence of a large diameter anastomoses, the dimension of the lateral wall of the maxillary antrum, the nature of the sinus membrane and presence of maxillary septa must also be noted.

Therefore, my research is relevant because knowledge of the maxillary arterial supply is of utmost importance when placing posterior maxillary implants which may involve sinus augmentation. Although accidental laceration of the vessels is not life threatening, visualisation may be impaired which will compromise the procedure. Preservation of this anastomosis is also important in supporting bone graft neoangiogenesis, its concomitant relationship with the sinus membrane especially when the diameter is constant.

RECOMMENDATIONS

Future studies should include histological studies for a better understanding of the maxillary sinus and anatomy. Evaluation of the advanced CBCT techniques such as computer assisted implant surgery studies should be done.

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APPENDIX 1

Form 1 : CBCT Analysis

Observer 1 : ………………………………………………………………………

Legend - Canal Presence

1 Right Side Present
2 Left side present
3 Present bilateral
4 Absent

Record Number	Canal Presence	Maximum Diameter (mm)
1		
2		
3		
5		
5		
6		
7		
8		
9		
10		
100		

Total : …………… mm

Canal Presence : Apply the legend code and determine

Maximum Diameter : Average of values