

CHAPTER ONE: INTRODUCTION

1.1 Introduction

With the growing need for rehabilitation of the edentulous anterior maxilla, the anatomy of this region has become very important; this is especially with implant procedures where the dental implant may interfere with the incisive canal and its contents. It is further reported that more care must be taken with females and younger patients during the immediate implant placement (at the mid-root level of maxillary central incisor) due to the root proximity to incisive or nasopalatine canal (Mardinger *et al.*, 2008).

It can be safely stated that the interference between dental implant and incisive canal and its contents may jeopardize a successful implant placement. This interference actually may cause non-osseointegration of implant or lead to sensory dysfunction. Therefore it is important to evaluate and consider the presence of incisive canal and its morphology (size and shape) prior to surgical procedures to avoid any complications (Mraiwa *et al.*, 2004).

To avoid the risk of injury to the incisive canal and its contents, a study was undertaken to determine the position and morphology (size and shape) of the incisive canal amongst Malaysians who ethnically belonged to the Malay and Chinese ethnicity groups.

1.2 Statement of problem

The incisive canal and its opening, the incisive foramen is in close proximity to the upper central incisor. Any surgical procedure in this area may cause damage to the neurovascular bundle in the canal. It is therefore necessary to determine if there are any significant anthropological variations of these structures and whether these variations are useful for forensic applications.

1.3 Aim of this study

To determine the location and morphology of the incisive canal and foramen of the Malaysian Malays and Chinese.

1.4 Objectives

1. To obtain the mean dimensional measurements of the incisive canal structures, anterior maxillary bone thickness and the incisive foramen location.
2. To determine and compare incisive canal length and width between the Malays and Chinese.
3. To measure and compare the incisive foramen diameter and nasal foramina diameter between Malays and Chinese.
4. To measure and compare maxillary bone thickness anterior to the incisive canal between the Malays and Chinese.
5. To determine and compare the incisive foramen location between the Malays and Chinese.
6. To classify and compare incisive canal according to its direction between the Malays and Chinese.
7. To classify and compare canal according to the number of channels in the middle portion between the Malays and Chinese.
8. To determine the effects of advancing age on the dimensions of the incisive canal and related structures.

1.5 Rationale

There was no such study on this subject in Malaysia.

1.6 Null hypothesis

There are no variations in the location and morphology of incisive canal and foramen amongst the Malays and Chinese.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

There are many anatomical structures in the maxilla which are of interest to dentists, oral maxillofacial surgeons, and otolaryngologists performing procedures in these areas (e.g. administration of local anesthesia, dental implant placement, orthognathic Le fort I osteotomies and sino-nasal surgeries) (Howard-Swirzinski K *et al.*, 2010). The understanding of the anatomy of those structures (size and morphology) is very important to avoid complications during such procedures.

Implant surgery in the anterior maxilla is often challenging. This is because of the difficulty to find a perfect compromise between the biomechanical, aesthetic and phonetic demands and anatomical limitations in this area (Mraiwa *et al.*, 2004).

2.2 Development and anatomy of incisive canal

Sedler (2004), Moore *et al.* (2008), Snell (2008), Ellis (2006), Sinnatamby *et al.* (2006), Avery *et al.* (2002) and Nanci *et al.* (2008) described the palatogenesis as follows:

During human embryological, the palate is built from two primordia: the primary palate and the secondary palate. The critical period of palate developmental process is from the end of the sixth week until the beginning of the ninth week.

2.2. 1. Primary palate

The developmental process of the primary palate (median palatine process) begins early in the sixth week from the deep part of the intermaxillary segment of maxilla. Initially, this segment is a wedge-shaped mass of mesenchyme between the internal surfaces of the maxillary prominences of the developing maxillae. The primary palate forms the

premaxillary part of the maxilla which represents only a small part of the adult hard palate.

2.2. 2. Secondary palate

In the sixth week of development two shelf-like structures from the maxillary prominences develop as outgrowths. These palatine shelves are directed obliquely downward on each side of the tongue. With time the jaws develop and the tongue becomes relatively smaller and moves inferiorly. In the following seventh and the eighth weeks, the lateral palatine shelves elongate and ascend to reach the horizontal position, superior to the tongue where they fuse in the median plane to form the secondary palate.

During the ninth week the nasal septum begins to develop from the internal part of the merged medial nasal prominences in downward growth pattern until fused with the palatal processes. The bone gradually develops by intramembranous ossification in the primary palate, forming the premaxillary part of maxilla. At the same time, the bone extends from the maxillae and forms the hard palate. The line of fusion of the lateral palatal processes is indicated by the median palatal raphe. Anteriorly, between the primary and secondary palates the incisive foramen is the midline landmark for the incisive canal (Knecht *et al.*, 2005).

The incisive canal is often seen in radiographs and it varies greatly in width and length (Cohen, 2006). This incisive canal, is a long slender structure present in the midline of the bilateral maxilla (Jacob *et al.*, 2007; Standring, 2005). The incisive canal is located about 12-15 mm from the anterior nasal spine, close to the septum (Scortecci *et al.*, 2001). The incisive canal ranges in length from 4 to 26mm and is related to the maxillary bone height (Misch, 1999).

The incisive canal connects the roof of the oral cavity with the floor of nasal cavity. The inferior part of the incisive canal is a continuation of the funnel-shaped incisive fossa and the incisive foramen, and the superior (nasal) part is divided into 2 foramina (the nasopalatine foramen or the foramen of Stensen) by the nasal septum in the nasal floor (Jacob *et al.*, 2007; Standring, 2005). Occasionally, two additional minor canals are seen (foramina of Scarpa), which may transmit the nasopalatine nerve (Mraiwa *et al.*, 2004).

The incisive canal has a Y-shape, caused by fusion of the right and left incisive canal with the anterior palatine canal to form common incisive canal (Fig 2.1) (Ennis *et al.*, 1967).

The incisive foramen, the inferior opening of the incisive canal is located in the midline just palatal to the central incisors and directly beneath the incisive papilla. Incisive foramen diameter ranges from 2mm to 1 cm (Ghom, 2008). The plane of the incisive foramen is oval-shaped and faces

the posteroinferior side (Cohen and Burns, 2002; Song *et al.*, 2009). The position of incisive foramen on the radiograph may vary from just above the crest of the alveolar ridge to the level of the apices of the central incisors. This is caused because of anatomic variations and vertical angulations of the canal (Frommer, 1996).

2.3. Incisive Canal as a passage

The importance of the incisive canal is expressed because it acts as a passage for some blood vessels and nerves.

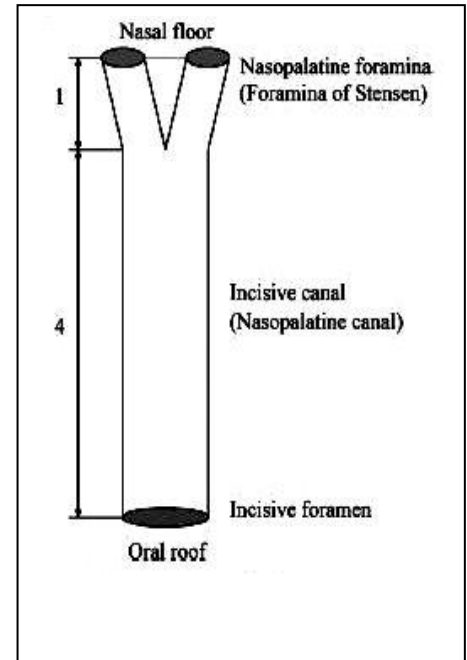


Figure 2.1: Diagram of the normal incisive canal and associated terms. The dividing level of the incisive canal is the upper fifth. Figure adapted from: Song W. C., Jo D. I., Lee J. Y., Kim J. N., Hur K. S., Kim H. J., Shin C. and Koh K. S (2009). Microanatomy of incisive canal using three dimensional reconstruction of microCT images : An ex vivo study . Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 108:583-590.

2.3. 1. Blood vessels

Two terminal branches of maxillary artery are communicated in the incisive canal; these branches are the nasopalatine artery and the greater palatine artery, both of them being branches of the third part of maxillary artery (Singh, 2003).

Moor *et al.* (2010), Anand (2009), Singh (2009), Snell (2008), Ghosh (2007) and Tank (2009) described the maxillary artery and its branches as following:

Maxillary artery is the larger terminal branch of the external carotid artery. It starts behind the neck of mandible and is divided into three parts based on its relation to the lateral pterygoid muscle.

First part (mandibular):

Course: Proximal to lateral pterygoid muscle; runs horizontally, deep to neck of condylar process of mandible and lateral to stylomandibular ligament. Five branches arise from this part:

1. Deep auricular artery.
2. Anterior tympanic artery.
3. Middle meningeal artery.
4. Accessory meningeal artery.
5. Inferior alveolar artery.

Second part (pterygoid):

Course: Adjacent to lateral pterygoid muscle; ascends obliquely anterosuperiorly, medial to temporalis muscle. Four branches arise from this part:

1. Masseteric artery.

2. Deep temporal arteries.
3. Pterygoid branches.
4. Buccal artery.

Third part (pterygoidpalatine):

Course: Distal to lateral pterygoid muscle; passes between heads of lateral pterygoid and through pterygomaxillary fissure into pterygopalatine fossa. Six branches arise from this part:

1. Posterior superior alveolar artery.
2. Infra-orbital artery.
3. Artery of pterygoid canal.
4. Pharyngeal branch.
5. Descending palatine artery.

This one descends through palatine canal and is divided into a greater palatine artery and lesser palatine artery. The greater palatine artery goes along the hard palate. During its course it supplies mucous membrane, hard palate glands, and gingiva before it ends in small vessels, ascends through the incisive foramen and anastomose with the nasopalatine artery.

6. Sphenopalatine artery.

When the sphenopalatine artery enters the nasal fossa through the sphenopalatine foramen, it is divided into branches of which one of them is the nasopalatine artery.

The nasopalatine artery is the larger and the longer branch which runs downward and forward in the groove on the vomer then enters the incisive canal in small vessels (Singh, 2003; Lang, 1989 and Standring, 2005).

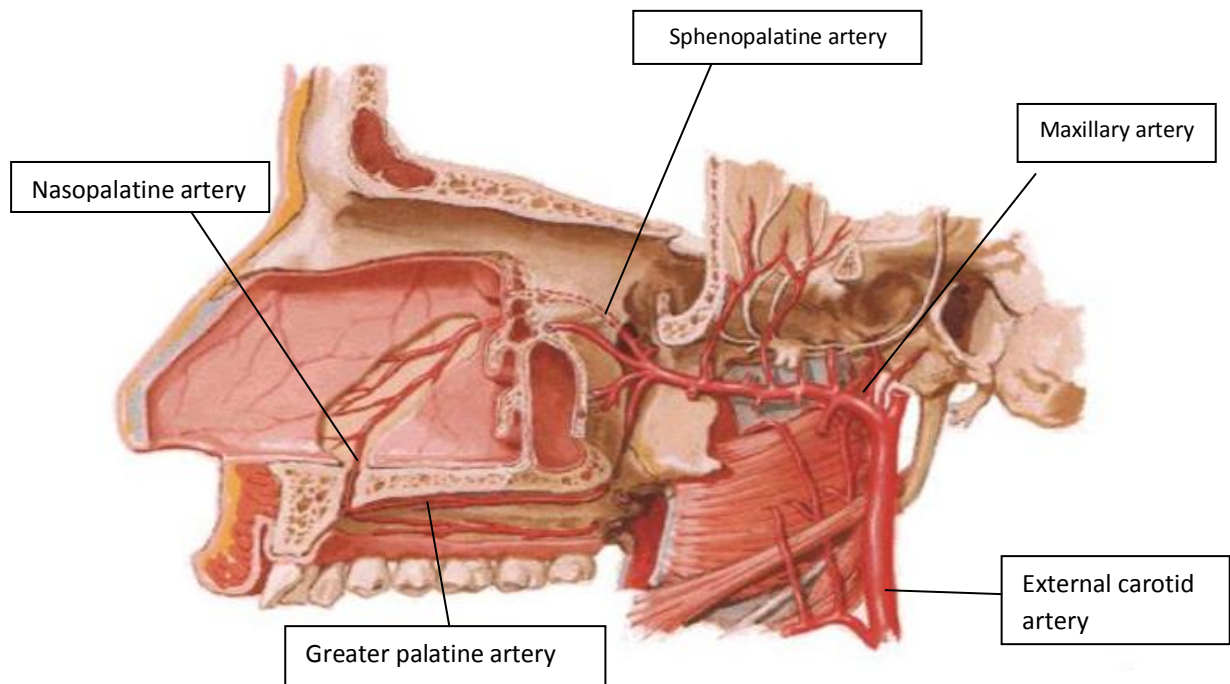


Figure 2. 2: Maxillary artery; nasopalatine artery and greater palatine artery. Figure adapted from: Hansen J. T. (2009). Netter's Clinical Anatomy. 2nd edn. Chapter8: pp.395.

2.3. 2.Nerves

The nasopalatine nerve joins together with the greater palatine nerve in the incisive canal. Both of them are branches of the maxillary nerve.

The maxillary nerve is the second division of trigeminal nerve that leaves the middle cranial fossa through foramen rotundum, and is purely sensory (Anand, 2009; Drake *et al.*, 2010 and Ellis, 2006).

When the maxillary nerve reaches the pterygopalatine fossa, it gives three branches:

- a. Zygomatic nerve.
- b. Posterior superior alveolar nerve.
- c. Ganglionic (communicating) branches

The last one (pterygopalatine ganglion) provides 4 sets of branches;

- c. 1. Orbital branches.
- c. 2. Palatine branches.

c. 2. A. Greater palatine nerve: this nerve enters the mouth through the palato-maxillary canal and divides in the roof of the mouth into branches in the hard

palate and extends forward nearly to incisor teeth. During its passing in the mouth it supplies the glandular structures and mucous membrane of the hard palate before it joins with the nasopalatine nerve in the incisive canal.

c. 2. B. Lesser palatine nerves.

c. 3. Nasal branches

From the sphenopalatine foramen the nasal branches enter the nasal cavity where they are divided into two postero-superior branches, namely:

c. 3. A. Posterosuperior lateral nasal branches.

c. 3. B. posterosuperior medial nasal branches:

These branches supply the nasal septum during its travel to the roof of the nasal cavity.

The longest one of these nerves is called nasopalatine nerve. It is directed downward and forward on the nasal septum toward the anterior palatine canal. It descends downward to enter the mouth through the incisive canal and ends in several filaments, which are distributed to the papilla behind the incisor teeth (Sharpey *et al.*, 1867; McMinn, 2005; Snell, 2008 and Ghorpada, 2006).

c. 4. Pharyngeal branch.

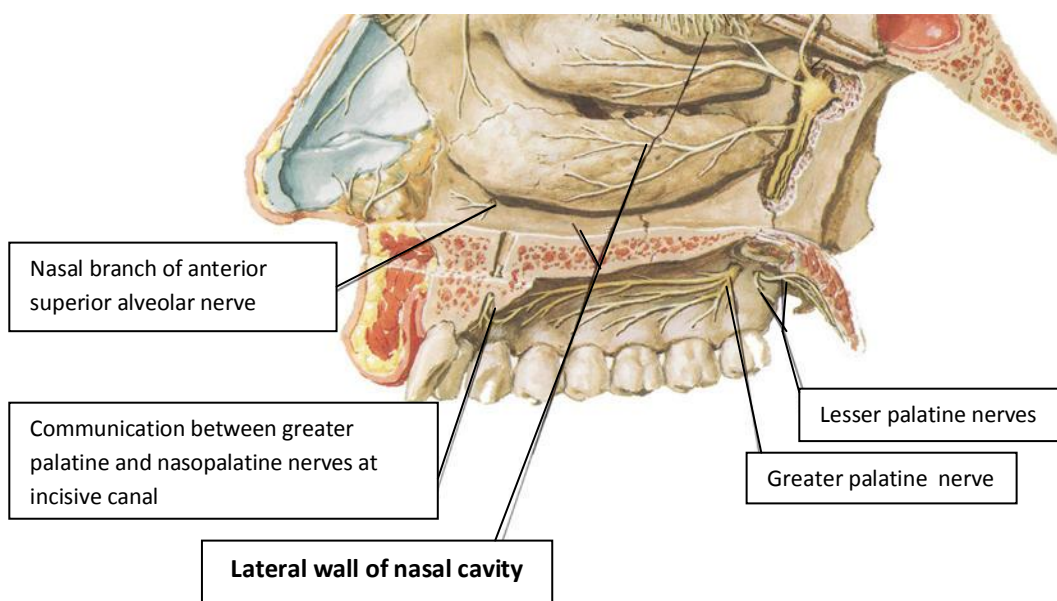


Figure 2. 3: Communication between greater palatine and nasopalatine nerves at incisive canal. Figure adapted from: Netter F. H. (2006). Atlas of Human Anatomy. 4thedn. Chapter 1: pp36-50.

So injection of the anesthetic solution into the incisive foramen will achieve anesthesia in the incisors, anterior of maxilla or lower nasal septum and nasal floor (Song *et al.*, 2009). Furthermore, the nasopalatine nerve is most easily damaged when implants intrude into the incisive canal (Peñarrocha *et al.*, 2009 and Jacobsen, 2008). The cutting of nasopalatine neurovascular bundle may be necessary when operating on a highly resorbed anterior maxilla or when there is a wide incisive canal. This is not of much concern, since sensation in the anterior third of the palatine mucosa is recovered within 2 to 3 months. This is possible due to the compensatory action of the branches of the greater palatine nerves (Annibali *et al.*, 2009 and Baart *et al.*, 2008).

2.4. Displacement of the incisive foramen in conjunction with implant placement

Anatomic limitations are always a consideration for implant placement. Most consist of the sinus floor, mandibular canal, bone ridge concavity, and an extensively resorbed alveolar process. With the increasing need for rehabilitation of the edentulous maxilla by means of osseointegrated implants, pre-operative evaluation of the incisive canal region has regained attention (Kraut and Boyden, 1998; Cavalcanti *et al.*, 1999; Artzi *et al.*, 2000). It is a well accepted fact that in the post-extraction phase (Carlsson *et al.*, 1967; Atwood *et al.*, 1962), the high resorption rate of the maxilla could jeopardize the surgical osteotomy preparation and prosthesis retention. With progressive bone loss, the alveolar crest may approach important anatomic structures resulting in undesirable outcomes.

2.5. Classification of incisive canal

Song *et al.* (2009) classified the incisive canal according to the number of channels in at its middle portion and according to its direction and course as the following:

2.5. 1. According to the number of channels in the middle portion

It is believed that the incisive canal comprised of a single channel almost throughout its length, except just beneath the superior opening. However, based on 2D cross-section images and 3D reconstruction, it appears that there can be up to 4 channels at the middle level. In most cases this channels are separated completely from each other by a bony septum, but in some cases the separation is incomplete.

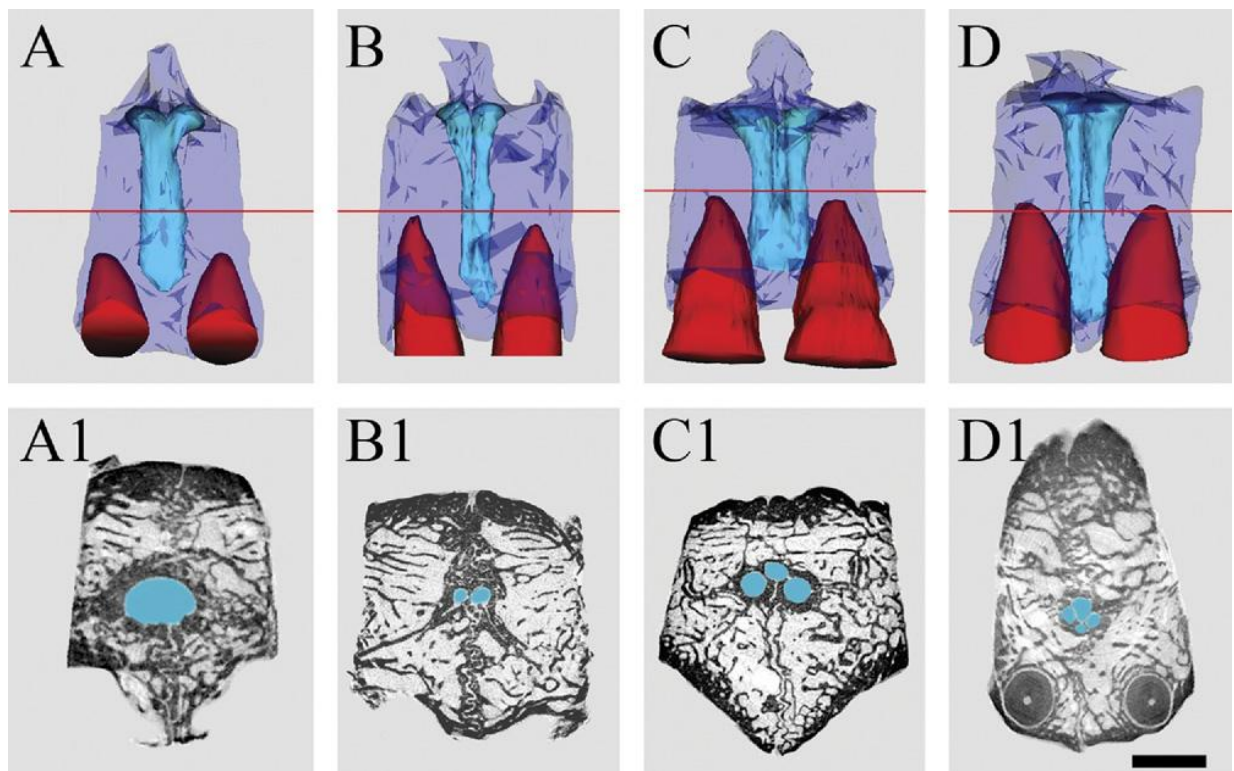


Figure 2.4: Classification of the nasopalatine canal according to the number of channels in the middle portion. **A-D,** Anterior views of the reconstructed incisive canal. **A1-D1,** Cross-sectional images. Single-channel (**A, A1**), 2-channel (**B, B1**), 3-channel (**C, C1**), and 4-channel (**D, D1**) nasopalatine canals are shown. Red lines: Levels of the cross-sectional images. Figure adapted from: Song W. C., Jo D. I., Lee J. Y., Kim J. N., Hur K. S., Kim H. J., Shin C. and Koh K. S (2009). Microanatomy of incisive canal using three dimensional reconstruction of microCT images : An ex vivo study .

2.5. 2. According to its direction and course

In the lateral view, the incisive canal appears in 4 patterns as following: (Ia) vertical-straight, (Ib) vertical-curved, (IIa) slanted-straight, (IIb) slanted curved (the most common type).

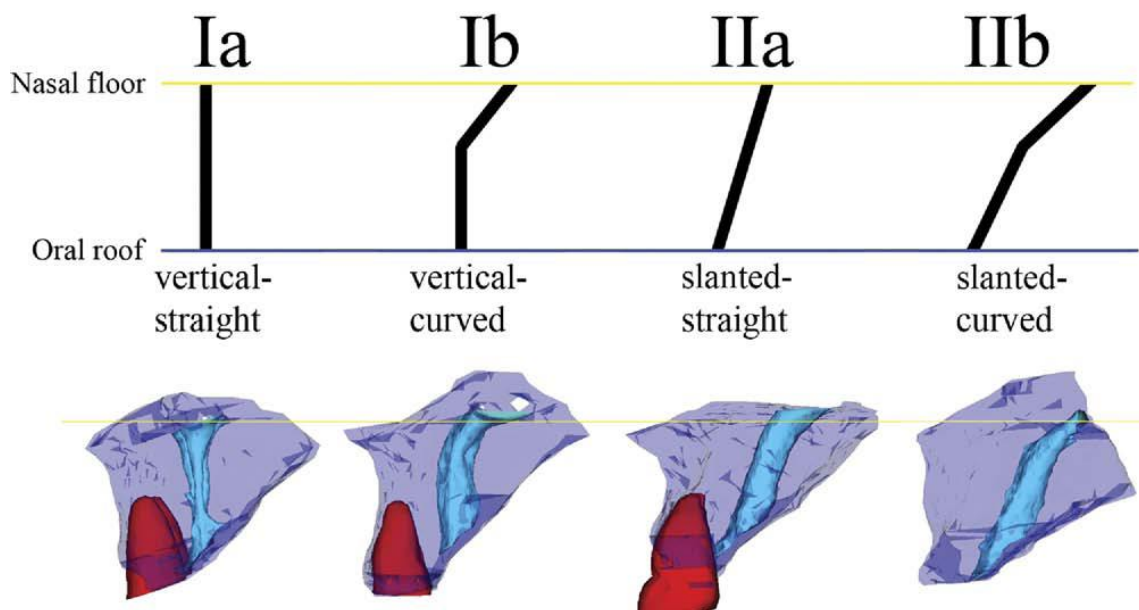


Figure 2.5: Classification and examples of the incisive canal according to its direction and course. Figure adapted from: Song W. C., Jo D. I., Lee J. Y., Kim J. N., Hur K. S., Kim H. J., Shin C. and Koh K. S (2009). Microanatomy of incisive canal using three-dimensional reconstruction of microCT images : An ex vivo study . *Oral Surg Oral Med Oral Pathol Oral RadiolEndod.* 108:583-590.

Another classification for the incisive canal depends on the shape of the canal described by Mardinger *et al.* (2008), and supported by Liang *et al.* in the following year. They described the canal as being conical (funnel-like) shape, cylindrical, hourglass-like shape, and banana-like shape.

The most common shapes are conical and cylindrical shapes. The conical shape is found in small canals with diameter less than 3mm, while in contrast to the cylindrical ones are found in those canals which are in excess of 4mm.

2.6 Changes of the incisive canal related to age, gender and ridge resorption

The incisive canal appears to have great variations in length and width after tooth loss with ageing or due to trauma (Bronstein *et al.*, 2010). The atrophy of disuse may influence the surrounding structures (e.g., the alveolar palatal plate) and the related distant structure, such as the nasal opening and palatal canal wall (Mardinger *et al.*, 2008).

The canal diameter increases with any degree of ridge absorption in all measured sites, mainly in the palatal opening. However the canal length tends to decrease due to ridge absorption. In general, males have wider and longer canals (Iordanishvili, 1991) than females. More bone loss is found to be common in women due to hormonal changes. In postmenopausal women, it is reported that bone loss occurs at a more rapid rate characterized by a change in bone architecture and a reduction in bone density and strength (Roberts *et al.*, 1992 and Baxter *et al.*, 1993).

2.7. Radiographic appearance

2.7. 1. Incisive foramen

It is almost always elliptical in shape and variable in size located between the roots of maxillary central incisors. The foramen is actually in the anterior portion of palate, but superimposition makes it appear as if it is located between the roots of central incisors (Former, 2001 and Gibilisco, 1985).

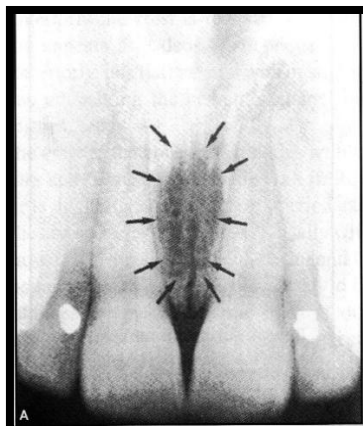


Figure 2.6: Incisive foramen. Figure adapted from: Gibilisco J. A. (1985). Anatomical landmark. Oral Radiographic Diagnosis 5th ed. pp4-5.

2.7. 2. Nasopalatine foramina (Superior foramina of incisive canal)

They are seen as round radiolucent areas situated adjacent to the nasal septum and in the anterior region of the floor of each nasal fossa (Gibilisco, 1985).



Figure 2.7: Nasal foramina. Figure adapted from: Gibilisco J. A. (1985). Anatomical landmark. Oral Radiographic Diagnosis 5th ed. pp4-5.

2.7. 3. Incisive canal (Nasopalatine canal)

It is not always visualized in radiograph and when seen it is evidenced by two radiopaque lines that extend downward (one from the floor of each nasal fossa) that depict the lateral walls of the canal. These lines tend to converge, and they fade out imperceptibly at the lateral border of anterior incisive foramen (Gibilisco, 1985).

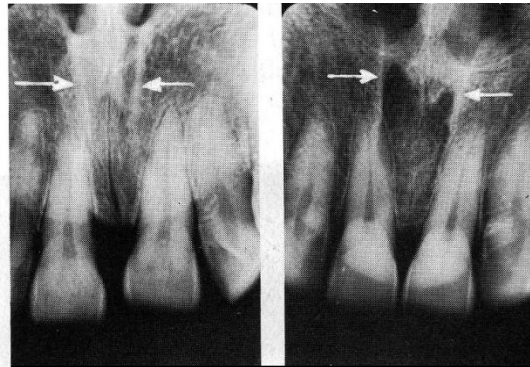


Figure 2.8: Incisive canal. Figure adapted from: Gibilisco J. A. (1985). Anatomical landmark. Oral Radiographic Diagnosis 5th ed. pp4-5.

2.8. Incorrect interpretation of incisive canal

There are many osteolytic lesions that can be mistaken as anatomic structures in the anterior maxillary region, for example:

2.8. 1. Periapical granuloma

Appear as radiolucent lesion, less than 1.5cm in diameter, and well-defined.

2.8. 2. Periapical cyst

Radiolucent lesion, more than 1.5cm in diameter, with a sclerotic border (Karjodkar, 2005).



Figure 2.9: periapical cyst. Figure adapted from: Karjodkar F. R. Normal anatomy on intraoral and extraoral radiographs. Text book of Dental And Maxillofacial Radiology. (2006):264-266.

2.8. 3. Nasopalatine duct cyst

Nasopalatine duct cysts are the most common developmental cysts of epithelial origin of maxilla (Francoli *et al.*, 2008 and Purkait, 2005).They represent about 1% of all maxillary cysts (Ely *et al.*, 2001) and was first described by Meyer in 1914 (as quoted by Vasconcelos *et al.*, 1999). Most cases occurred in the third to the sixth decades (Velasquez-Smith *et al.*, 1999) and their frequency was almost three times more common in males than in females (Elliott *et al.*, 2004). Due to the appearance of nasopalatine duct cyst in incisive canal it will be difficult sometimes to decide whether radiolucency in that area is a cyst or enlarged incisive canal (Allard *et al.*, 1981). Nasopalatine duct cyst may have round or ovoid shape and some may appear heart-shaped, either because they become notched by the nasal septum during their expansion or because the nasal spine is superimposed on the radiolucent area, or if there are bilateral cysts (Coulthard, 2003). Radiographically, the nasopalatine cyst may be confused with incisive fossa and become difficult to differentiate the two. Maximum accepted size of incisive fossa range between 6mm and to 8 mm, a radiolucency which exceeds 8 mm and beyond, is considered to be a cyst (Saraf, 2006).

Normally nasopalatine duct cysts are usually asymptomatic, but in some cases swelling associated with pain may occur due to the pressure on nasopalatine nerve. Occasionally

mucoïd discharge is one of the symptoms. In this case the patient may describe a salty taste, or it may be purulent and the patient complains of a foul taste (Shear *et al.*, 2007; Saraf, 2006 and Cawson *et al.*, 2008).

As the aetiology of the nasopalatine duct cysts are of uncertain origin, it has been suggested that trauma or bacterial infection could stimulate the incisive canal remnants to proliferate (Shear *et al.*, 2007 and Stafne, 1969).

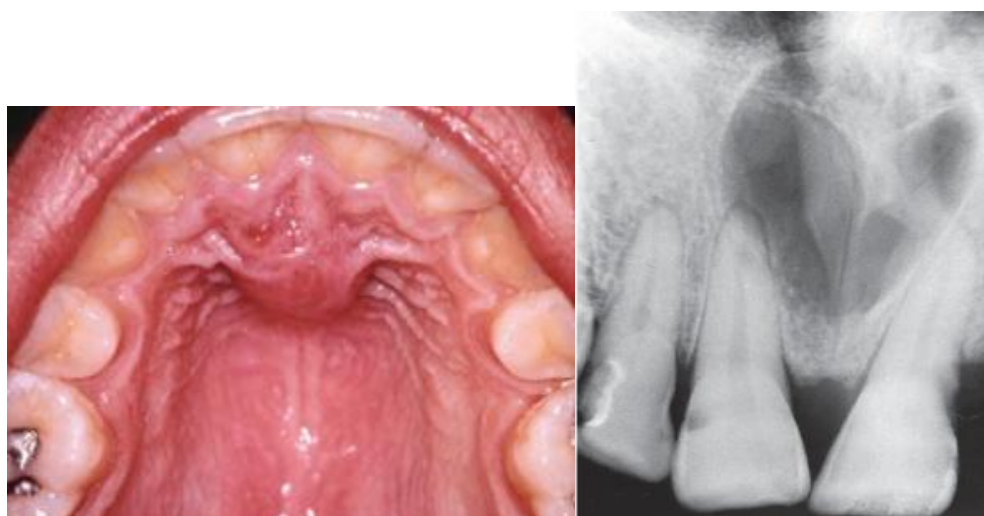


Figure 2.10: clinical and radiographical appearance of nasopalatine duct cyst. Figure adapted from: Shear M., Speight P. (2007). Nasopalatine duct cyst: Cysts of Oral and Maxillofacial Region, 4thedn: p 108-115. Blackwell Munksgaard

Sometimes radiolucent pathoses at root apex can be differentiated from the normal anatomical structures by employing combination of radiographs at different angulations (parallax technique) and also by pulp-testing procedures. Radiolucencies not associated with the root apex will move or be projected away from the apex ascertaining that they are indeed anatomical structures (Cohen, 2006).



Figure 2.11: (A) The incisive foramen superimposed the apex of the right central incisor (B) with change of the angulations the incisive foramen also shift to superimpose the apex of the left central incisor. Figure adapted from: Gibilisco J. A. (1985). Anatomical landmark. Oral Radiographic Diagnosis 5th ed. pp4-5.

2.9 Patent nasopalatine canal

Lebouiq was the first who described the patent nasopalatine duct in 1881 (Rodrigues *et al.*, 2009). This phenomenon is a rare developmental anomaly in humans (Lundner *et al.*, 2006). In humans nasopalatine duct remain patent in fetus only then the duct degenerates, and is obliterated by mucous membrane at their ends before or within the first postnatal year (Rodrigues *et al.*, 2009)



Figure 2.12: Clinical appearance of patent nasopalatine duct. Figure adapted from: Rodrigues M. T. V., Munhoz E. A., Cardoso C. L., Junior O. F. and Damante J. H.(2009). Unilateral patent nasopalatine duct: a case report and review of the literature. American Journal of Otolaryngology-Head and Neck Medicine and Surgery. **30:** 137-140.

Patent nasopalatine duct may occur in adults and may be unilateral, bilateral, or central as a result of failure of embryonic incisive canal to obliterate (Ghom, 2005). Most of the

cases are asymptomatic and when it is symptomatic one or more of the following complaints are present: passage of food or liquids into nasal cavity, discharge from the anterior palate, whistling noises, and collection of debris, local swelling, or pain. Due to the presence of this osseous canal, the simple mucosal excision of the palatal duct orifice(s) is not recommended to avoid reopening of the canal.

Sometimes asymptomatic patent nasopalatine duct may become symptomatic once after rapid maxillary expansion (Catros *et al.*, 2008; Valstar *et al.*, 2008). Failure to recognize it can lead to permanent oroantral fistula and maxillary sinusitis (Skoglund *et al.*, 1983). According to Eppley *et al.* (1988) the canal obliteration is performed successfully using either autogenous or alloplastic bone material.

2.10. Human race – Mongoloids

Human races in the world are classified as Caucasoids, Mongoloids, Negroids and Australoids. In peninsular Malaysia there are three major ethnic groups namely, the Malays, Chinese and Indians. The Chinese and Malays belong to the Mongoloid division. The Indians belong to the sub-group of Caucasoid called Indo-Dravidian (Hashirn *et al.*, 1996). The Mongoloids are characterized by their non-projecting noses, flat faces formed by forward projecting cheekbones, round eye orbits, shovel-shaped incisors, complex cranial sutures, flattened chins, elliptic dental archs and brachycephalic skulls. Mongoloids are also characterized by an absence or thinly distributed facial and body hair, lesser sweat glands and possess wormian bones at a higher frequency. They have straight black hair, dark brown eyes, and the skin colour may vary between very pale white to yellow undertones to brown. The width between the eyes is greater in Mongoloids and they have the least mandible projection (Relethford J., 2003; and Quigley C., 2001). In this study the target population are Malays and Chinese who are Mongoloids. The Indian population are excluded due to

insufficient number of Indian recordings at the Division of Oral and Maxillofacial Radiology.

2.11. Cone Beam Computed Tomography

The proper pre-operative treatment planning during which the appropriate radiographic evaluations of the edentulous ridge and potential implant sites is essential and play an important role in the success of the oral implantation (Garg, 2007). The data collected from the radiograph are used in the assessment of the dimension of the implant to be inserted, the number of implants needed, the location and orientation of implants, and the possible need for bone augmentation (Anil *et al.*, 2007).

Although, the panoramic radiograph provides useful data for the general status of the dentition, the relationship between alveolar bone, basal bone, and main anatomical structures, it is not sufficient for implantation procedures. The intraoral periapical radiograph too is similarly valuable for assessment of the mesiodistal dimension of a possible implant site and to obtain a preliminary estimate of vertical dimensions. However both of them (panoramic and periapical radiographs) provide only two-dimensional images and hence have limitations as diagnostic tools. Some of the limitations include magnification, distortion, superimposition and misrepresentation of structures (Calhoun *et al.*, 1999; Scarfe and Farman, 2008). They do not allow for the accurate measurement of the buccolingual dimension of the bone or assessment of the location of unanticipated undercuts (Anil *et al.*, 2007; and Garg, 2007).

This limitation could be solved with the use of advanced cross-sectional imaging techniques such as computed tomography (CT) (Miracle^a *et al.*, 2009). One of the most recent developments in CT imaging technology is cone beam imaging, which has reduced machine size and cost of CT scanners (Garg, 2007).

CBCT is well suited for imaging the craniofacial area. It provides clear images of highly contrasted structures and is extremely useful for evaluating bone and has the ability to

characterize mandibular and alveolar bone morphology. They are useful to visualize the maxillary sinuses, incisive canal, mandibular canal, and mental foramina. All these structures are particularly important in surgical planning for dental implantation. (Sukovic *et al.*, 2003; Ziegler *et al.*, 2002; Miracle^a *et al.*, 2009 and Angelopoulos *et al.*, 2008). Suomalainen *et al.* (2008) stated that CBCT could provide a considerable reduction in radiation dose (compared to conventional CT) without a major loss in measurement accuracy. Furthermore there is significantly higher resolution than conventional dental radiographic techniques (Roberts *et al.*, 2009), a feature making it more suitable for children seek who orthodontic treatment (SEDENTEXCT project, 2009).

However, one apparent limitation of this CBCT technology is its inability to do soft-tissue imaging unlike conventional CT (Scarfe and Farman, 2008).

2.11. 1. Advantages of cone-beam CT in dentistry

Scarfe and Farman (2008) described the advantage of cone-beam CT as follows:

2.11. 1. 1. X-ray beam limitation

Collimation of the CBCT primary x-ray beam enables limitation of the x-radiation to the area of interest. Therefore, an optimum field of view (FOV) can be selected for each patient based on suspected disease presentation and region of interest.

2.11. 1. 2. Image accuracy

CBCT imaging has the capability of producing with submillimeter isotropic voxel resolution ranging from 0.4mm to as low as 0.076 mm.

This provides images with a level of resolution accurate enough for measurement in maxillofacial applications, where precision in all dimensions is important.

2.11. 1. 3. Rapid scan time

Because CBCT acquires all projection images in a single rotation, scan time for reconstruction however is substantially longer; it varies, depending on field of view

(FOV), number of basis images acquired, resolution, and reconstruction algorithm. The scan time may range from approximately 10 to 70seconds.

2.11. 1. 4. Radiation dose reduction

When comparison of patient dose between conventional CT and CBCT was made it is reported that CBCT provides less than 76.2% - 98.5% of conventional CT.

2.11. 1. 5. Display modes unique to maxillofacial imaging

The most important advantage of CBCT is that it provides unique images demonstrating features in 3D that other dental machines could not provide.

2.12 SimPlant software version 13

In 1993 new generation of windows software are developed namely SimPlant interactive software by Materialise Inc (Belgium) (Reverse modelling Inc website). This SimPlant software allows viewing of axial, cross-sectional, panoramic and 3D visualization of the maxillofacial region on the same screen.

Besides these renderings, the property of the program allows the clinicians to use their own computers to plan an implant case interactively. SimPlant program has also other benefits:

- Measures bone density.
- Measures accurately the distance of vital structures.
- Marks vital structures such as the inferior alveolar nerve and maxillary sinus clearly.
- Measures the volume needed for a sinus graft (Tischler, 2005).

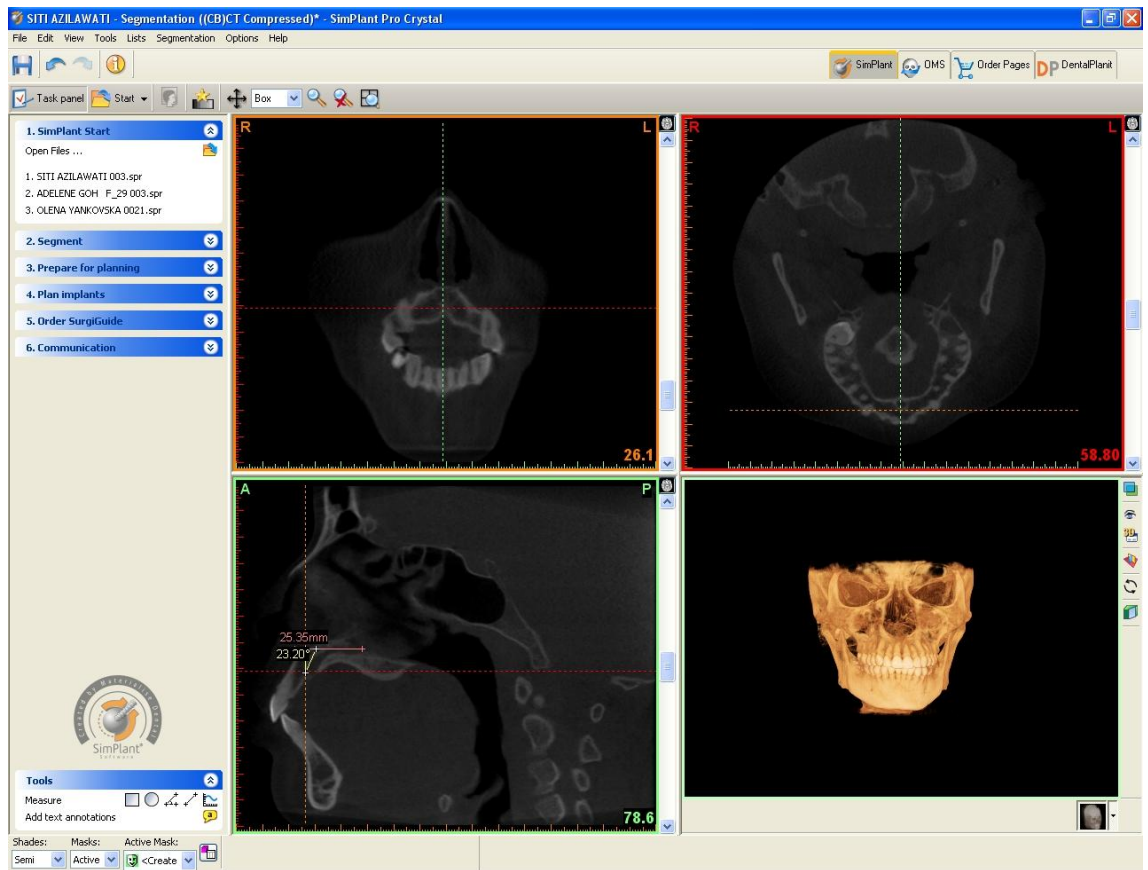


Figure 2.13: SimPlant work station showing coronal, axial, sagittal views and 3-D visualization.