CHAPTER 1

INTRODUCTION

1.1 Aim of the study

The main aim of this study was to determine the path and the course of the mandibular canal of dentate Malaysian patients using the Cone Beam Computed Tomography (CBCT) and SimPlant interactive software. This will then add normative information that might prevent injuries to vessels and nerves during any surgical procedure in this area.

1.2 Statement of problem

Before any surgical procedure concerning the mandible, the primary concern is to locate the course of the mandibular canal.

Evaluating the course of the mandibular canal during the last few decades was made using different imaging modalities, ranging from intraoral and extraoral radiographs to computed tomography (CT). Each imaging modalities has its own associated advantages and disadvantages (Frederiksen, 1995).

Recently, more practitioners are localizing the path of the mandibular canal using the CBCT images. This modality which uses only 3-5% of the radiation dose of the conventional computed tomography might mitigate the injuries to neurovascular bundle and thus avoiding paralysis and hemorrhage in the mental and check regions.

The inferior alveolar nerve (IAN) was located between 4 and 11 mm inferior to the surface of mandibular ridge, but in 5% of cases, the distance were from 1 to 4 mm (Mercier, 1973). Its injury not only gives rise to unpleasant sensations, but may also affect the ability to talk and masticate effectively (Neugebauer et al., 2008). The nerve deficit may give rise to continuous aching in the lower face (hyperalgesia, neuralgia) and social suffering. Some patients complain of strange sensations (allodynia, dysesthesia, paraesthesia) when touching the area in the lower lip. In addition, damage of related blood vessels (e.g., inferior alveolar or lingual artery) may cause excessive bleeding.

Damage to these vital structures often arises from clinicians' surgical mistakes as well as failure to identify these structures (Kim et al., 2006). Hence, it is essential to determine the location and the configuration of the mandibular canal and related anatomical structures to minimize these types of damages (Rueda et al., 2006).

Many surgical procedures in the mandibular segment may lead to inferior alveolar nerve injury as it is in the proximity of the roots of the third molar (Kipp et al., 1980). Furthermore, several retrospective studies reported an 80% to 100% incidence of neurosensory disturbance immediately after Bilateral Sagital Split Osteotomy (BSSO) (Tamas, 1987; Ylikontiola et al., 2000).

Operative injury to the vascular and nerve bundle within the mandibular canal also represents a main risk factor during sagittal split osteotomy of the ramus leading to impairment of the inferior alveolar nerve (Yoshida et al., 1989).

Injection of local anesthetics into the inferior alveolar nerve is considered a potential factor of nerve damage too (Jones and Thrash, 1992).

The repositioning and manipulation of the inferior alveolar nerve during placement of endosseous implants in the posterior mandible is also another risk for nerve injury (Smiler, 1993). Intraosseous implantation was widely used in dentistry for several decades. Although many factors affect the outcome of treatment, precise presurgical evaluation of the bony support in the jaws and precise localization of critical anatomic structures are among the most crucial factors for successful outcomes.

1.3 Objectives of the study

The overall purpose of this research is to localize the path of the mandibular canal in Malaysian population.

Specifically the study will focus on 6 objectives.

(I) Localize path for the mandibular canal in human mandibles using CBCT imaging technique and SimPlant software.

(II) Compare the course of the mandibular canal on right and left side of the mandible.

(III) To determine any racial and gender differences among the Malaysian population.

(IV) Provide normative information that would assist surgeons in avoiding injury to the nerve during any surgical procedure in mandible and that may traumatize neurovascular bundle.

(V) Determine the mandibular canal and the mandibular foramen diameter among the Malaysian population.

(VI) Indicate the frequency of the bifid mandibular canal using CBCT imaging technique and SimPlant software among the Malaysian population.

1.4 Research Questions

Based upon the objectives mentioned previously, this research study aims to answer the following questions:

(I) What is the path for the mandibular canal in human mandibles among the Malaysian population?

(II) Is there any difference between the right and the left mandibular canal metrical measurements?

(III) Is there any difference between the races and gender among the Malaysian population?

(IV) What is the information gained from this research that will help surgeons and practitioners to minimize any injury to the mandibular canal during any surgical intervention in the mandible?

(V) What is the diameter for the mandibular canal and the mandibular foramen among the Malaysian population?

(VI) What is the frequency of bifid mandibular canal among the Malaysian population?

1.5 Significance of the study

This study is the first local study to be carried out on three major races of the Malaysian population. These results may be used as a safety guide during surgical procedures in oral implantology cases and oral and maxillofacial surgery to prevent postoperative complications. This is a landmark study done on life patients with CBCT and 3D simulation which must be very accurate.

Studies on the comparison between right and left mandibular canal measurements were made and this shall provide a guide as to whether future researchers shall include both or one side of the mandible for their research among the Malaysian population.

1.6 Limitations of the study

As many number of measurements were required, the sample size of the CBCT records were limited to sixty patients (bilateral measurements – 120). Even though the results of this study were statistically relevant some may consider the sample size used was not sufficiently large. This study also deals mainly with CBCT record transfer and the application of the SimPlant software programs to produce accurate jaw simulation of relevant structures.

It was therefore necessary to have vast knowledge and expertise in the anatomy of the jaw as well as be competent in images interpretation in order to accurately identify the required structures during 3D simulation.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Anatomical Consideration

The mandibular canal is a canal within the mandible that houses the inferior alveolar nerve (a.k.a. mandibular nerve), the inferior alveolar artery and the inferior alveolar vein (Tammisalo et al., 1992). The canal is seen bilaterally as it enters the mandible at the mandibular foramen on the lingual side of the ramus. It runs obliquely downward and forward in the ramus, and then horizontally forward in the body, where it is placed under the alveloi and communicates with them by small openings (Williams et al., 1989). On arriving at the incisor teeth, it turns back to communicate with the mental foramen, giving off two small canals which run to the cavities containing the incisor teeth (Greenstein and Tarnow, 2006).

The canal appears as a dark ribbon of radiolucency flanked by two radiopaque white lines and is usually seen inferior to the roots of the mandibular teeth on a dental panoramic radiograph (Figure 2.1) (Nortjě et al., 1977b).

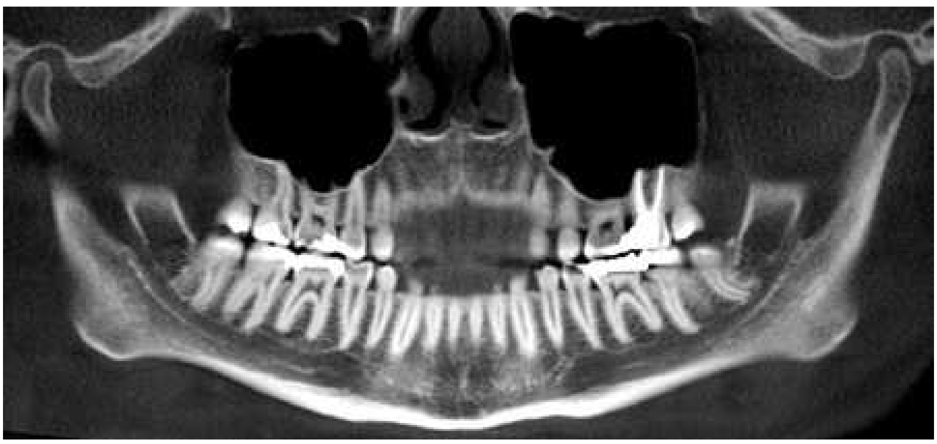

Figure: 2.1: A reconstructed panoramic image displayed in a thin section to show the bilateral course of the mandibular canals (Mardini and Gohel, 2008).

The study of Rajchel et al. (1986) employing panoramic radiograph of 45 Asian adults demonstrated that the mandibular canal, when proximal to the third molar region, is usually a single large structure, 2.0 to 2.4 mm in diameter. While Obradovic et al. (1993) measured 105 cadaveric mandibles and found the average diameter of the mandibular canal in its horizontal part is 2.6 mm. Ikeda et al. (1996) conducted similar cadaver study and reported that the canal is approximately 3.4 mm wide.

2.2 Anatomical Variations

Different anatomical variations in the course of the mandibular canal superior-inferior and bucco-lingual were described in many studies. Bifid canal was noticed in many research studies.

2.2.1 Vertical position

Root apices of mandibular teeth and the inferior border of the mandible were considered as anatomical landmarks to evaluate and determine the vertical position of the mandibular canal in many studies. Thus, Heasman (1988) reported that from a study of 96 plain films of dried mandibles, in 68% of cases the mandibular canal passed along an intermediate course between the mandibular root apices and the inferior border of the mandible. Rajchel et al. (1986) reported that proximal to the third molar a mean distance of 10 mm between the mandibular canal and the inferior mandibular border. It has also been shown the upper border of the mandibular canal was located 3.5 to 5.4 mm below the root apices of the first and second molars (Littner et al., 1986). Denio et al. (1992) conducted their research on 22 cadavers and found the mean distance of the mandibular canal to the apices of mandibular second molar, the first molar and second premolar were 3.7, 6.9, and 4.7 mm respectively.

Sato et al. (2005) defined the presence and course of the mandibular canal using macroscopic cadaveric dissection, CT and panoramic X-ray observation. Panoramic X-ray observation revealed that the vertical position of the mandibular canal was closer to the apices of the first and the second molars than that to the distance of inferior border of mandible. The mandibular canal position was measured within 30% of the ratio from the distance of inferior border of mandible to the apices of the roots (mesial root of the first molar: 20%; distal root of the first molar: 22.6%; mesial root of the second molar: 27.8% and distal root of the second molar: 47%) on panoramic X-ray observation. All classic descriptions of the mandibular canal course mentioned above refer to dentate mandibles.

Greenstein et al. (2008) revealed that the mandibular canal is fairly close to the apices of the second molar in 50% of the radiographs. In 40%, the canal is away from the root apices, and in only 10% of the radiographs the root apices appeared to penetrate the canal.

Based on eight dissected mandibles, Carter and Keen (1971) initially classified the three vertical positions of the course of the alveolar nerve (Figure 2.2). According to Type l, the nerve has a course near the apices of the teeth, where in Type ll, the main trunk is low down in the body, finally type III, the main trunk is low down in the body of the mandible with several smaller branches to the molar teeth.

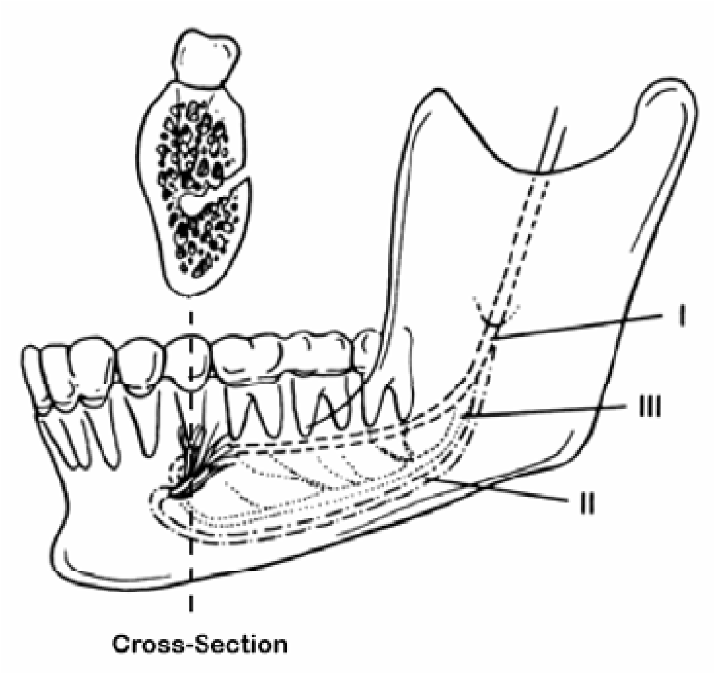

Figure: 2.2: Variations of the vertical position of the inferior alveolar nerve (Carter and Keen, 1971)

In another larger study, the course of the IAN was evaluated from 3612 radiographs (Nortjě et al., 1977b). The radiographs were divided into four categories: 1) high mandibular canals (within 2mm of the apices of the first and second molars), 2) intermediate mandibular canals, 3) low mandibular canals, and 4) other variations - these included duplication or division of the canal, apparent partial or complete absence of the canal or lack of symmetry. Of the 3612 subjects, 47% of the canals were high, 49% were low, and only 3% could not be matched into the high or low canal categories. The conclusion of this study was that the mandibular canals are usually, but not invariably, bilaterally symmetrical, and that the majority of the hemimandibles contain only one major canal.

Anderson et al.(1991) reported that the buccal-lingual and superior-inferior positions of the inferior alveolar nerve were not consistent among mandibles. The inferior alveolar nerve frequently showed as concave curve when descending at the posterior segment and then progressed anteriorly. At the anterior segment the nerve ascended to the mental foramen. He further stated that a bony canal was not always visible and the canal itself frequently lacked definite walls, especially in the vicinity of the mental foramen. Bilateral symmetry was commonly observed, while on the other hand duplications of the canal were rare.

Kieser et al.(2004) also studied vertical positioning and intra-bony branching patterns of the inferior alveolar nerve in 39 edentulous mandibles. This was possible as the researchers undertook micro-dissections. Classification is done according to height of the inferior alveolar nerve within the body of the mandible and the branching pattern of the inferior alveolar nerve. In 30.7% (12/39) of the cases, the IAN was located in the superior part of the body of the mandible, and in 69.3% (27/39) of the cases the IAN was half-way or closer to the inferior border of the mandible.

In another study with 107 edentulous human cadaveric mandibles by Kieser et al.(2005), found that for 73% of males and 70% of females the IAN was located in the lower half of the mandible. The most common branching pattern observed was a single nerve trunk with a series of simple branches directed at the superior border of the mandible (59.6% males, 52% females). The second most common pattern was that of a small nerve plexus in the molar region (21.1% males, 26% females). This study showed that the pattern of distribution does not significantly differ between the sexes, between sides of the jaw, or with age.

Narayana and Vasudha (2004) evaluated the position of the mandibular foramen and the course of the IAN. This study concluded that the canal and consequently the nerve do not maintain a constant position in the mandible and the location of the mandibular foramen varies despite its bilateral symmetry.

Mandibular alveolar bone undergoes resorption in a varying degree when the mandibular teeth are lost (Lavelle, 1985; Polland et al., 2001). The dental ridge becomes lower during mandible atrophy, and this is why Levine et al. (2007) measured the distance from the edentulous alveolar crest to the superior aspect of the MC of 50 patients who had a radiographically identifiable mandibular canal and at least one mandibular first molar. Results showed that the superior aspect of the MC was 17.4 mm inferior from the alveolar crest. Similarly, Watanabe et al. (2009) analyzed CT data of 79 Japanese patients (52 males and 27 females) and found that the distance from the alveolar crest to the mandibular canal ranged from 15.3 to 17.4 mm. It is clear that the distance between the mandibular canal and the atrophic alveolar ridge is a variable dimension and should be assessed in each particular case.

2.2.2 Horizontal position

It was reported that the mandibular canal might have different anatomic configurations in the horizontal plane. Usually the mandibular canal crosses from the lingual to the buccal side of the mandible and in most cases the midway between the buccal and lingual cortical plates of bone is at the first molar (Miller et al., 1990; Obradovic et al., 1995). According to Rajchel et al.(1986), the mandibular canal, when proximal to the third molar region, courses approximately 2.0 mm from the inner lingual cortex, 1.6 to 2.0 mm from the medial aspect of the buccal plate.

Levine et al.(2007) assessed the mandibular canal buccolingual course for 50 patients. The mean buccal aspect of the canal was 4.9 mm from the buccal cortical margin of the mandible. They found that age and race were statistically associated with the mandibular canal position. Older patients and white patients have less distance between the buccal aspect of the canal and the buccal mandibular border.

2.3 Bifid mandibular canal (MC)

Bifid variety of the mandibular canals which are characterized by a single mandibular foramen and two nearly equal canals are indeed unusual (Figure 2.3). In the study employing panoramic radiographs, Nortjě et al. (1977b), reported that duplication or division of the canal was found in 0.90% (33/3612) of the cases. In another study by Grover and Lorton (1983) showed that 0.08% bifurcation of the inferior alveolar nerve canal was found in 5000 US Army soldiers, aged 17 to 26 years. Furthermore, Langlais et al. (1985), evaluated routine panoramic radiographs of 6000 patients, they found 57 (0.95%) cases of bifid inferior mandibular canals, 19 in males and 38 in females. Another study on 2012 panoramic radiographs reported that 0.35% of canals were bifid and all cases were registered in women (Sanchis et al., 2003). Utilizing CBCT technology (Naitoh et al., 2009a) reconstructed 122 2D images of various planes in the mandibular ramus region to the computer program using 3D visualization and measurement software. Bifid mandibular canal in the mandibular ramus region was observed in 65% of patients and 43% of sides. Furthermore, they classified bifid mandibular canal into four types: retromolar, dental, forward, and buccolingual canals.

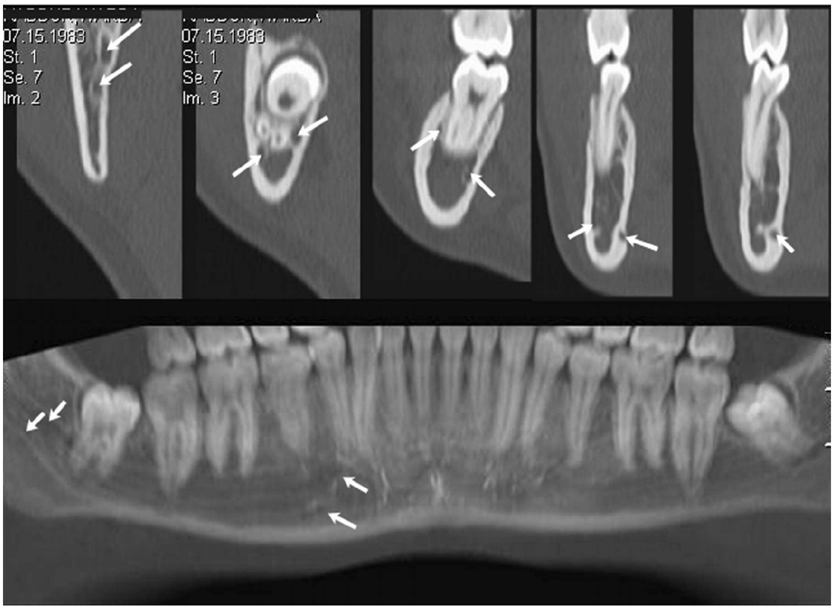

Figure 2.3: Bifid MC (Claeys and Wackens, 2005)

2.4 Inferior alveolar neurovascular bundle

The mandibular nerve is the third and inferior most division of the trigeminal nerve, or the fifth cranial nerve. The trigeminal nerve is predominantly a sensory nerve, innervating most of the face. The upper branch of the trigeminal nerve is called the ophthalmic nerve and innervates the forehead. The middle branch is called the maxillary nerve and innervates the maxilla and the midface. The lower branch is called the mandibular nerve and innervates the teeth and the mandible, the lateral mucosa of the mandible, and the mucosa and skin of the cheek, lower lip and chin (Gosling, 1985).

The mandibular nerve runs from the trigeminal ganglion through the foramen ovale down towards the mandible (Figure 2.4). The nerve enters the mandible through the mandibular foramen on the medial surface of the ascending mandibular ramus. Before it enters the bone, the mandibular nerve gives branches to the tongue and to the soft tissues of the cheek.

After passing through the mandibular foramen, the nerve is called the inferior alveolar nerve (IAN). The IAN contains mainly sensory fibres and only a few motor fibres distributed by the mylohyoid nerve to the mylohyoid and the anterior belly of the digastric muscles. Within the mandibular canal, the IAN runs forwards in company with the inferior alveolar artery, inferior alveolar vein and lymphatic vessels and together they are called the inferior alveolar neurovascular bundle (Figure 2.5) (Tammisalo et al., 1992). The artery lies parallel to the nerve as it traverses anteriorly, but its position varies with respect to being superior to the nerve within the mandibular canal (Ikeda et al., 1996). Anterior to the mental foramen, the mandibular canal is referred to as the incisive canal (Mardinger et al., 2000; De Andrade et al., 2001; Mraiwa et al., 2003; Jacobs et al., 2004).

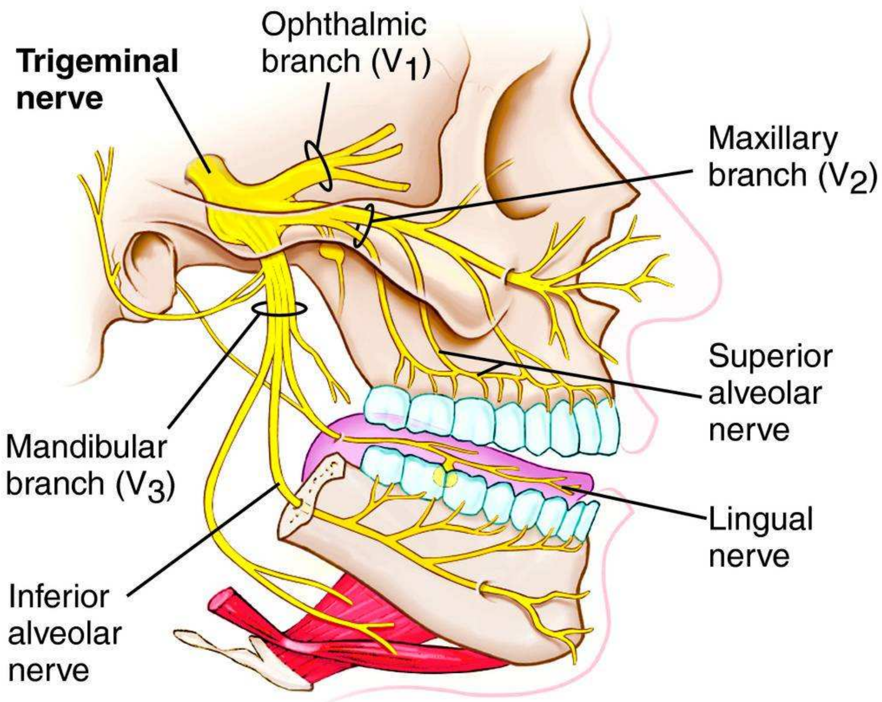

Figure 2.4: Illustrated diagram of the anatomy of trigeminal nerve [Source: The Free Dictionary website <http://medical-dictionary.thefreedictionary.com/trigeminal+nerve> (last accessed on 07 May 2011)

The IAN supplies the lower molar and premolar teeth and adjacent parts of the gingiva. Its larger terminal branch emerges from the mental foramen as the mental nerve to innervate the skin of the chin and the lower lip, while the smaller incisive branch supplies the canine and incisor teeth. Disturbances of the IAN and mental nerve will predominantly give sensitivity symptoms in the soft tissue of the lower lip and chin (Aldskogius et al., 1985).

According to the report of Gowgiel (1992), the neurovascular bundle from the mandibular foramen to the mental foramen is always in contact with, or in close proximity to the lingual mandibular cortex. This researcher further stated that vascular and nerve bundles may be extremely close to the buccal cortex of the mandible in patients with broad and thick mandibular rami.

Figure 2.5: Neurovascular bundle. [Source: Acland's Video Atlas of human anatomy website <http://aclandanatomy.com/abstract/4010594> (last accessed on 22 June 2011)

2.5 Injury of the inferior alveolar nerve

IAN is the most commonly injured nerve in the mandible (64.4%), followed by the lingual nerve (28.8%) (Tay and Zuniga, 2007). The differences between IAN injuries and other peripheral sensory nerve injuries are predominantly iatrogenic and not resolved within the first 2 months after injury (Haskell et al., 1986; Venta et al., 1998). The closed injuries can also occur that often delays diagnosis and treatment (Pogrel and Maghen, 2001).

The number of practitioners performing implant surgery has increased dramatically over the last fifteen years. As confidence is gained they tend to accept increasingly challenging cases and it is to be expected that the incidence of problems and complications will increase (Worthington, 1995). It was a discerning remark, however, it remains a serious complication and many had reported the incidence, varies from 0 to 40% of implant related inferior alveolar nerve (IAN) injuries (Wismeijer et al., 1997; Dao and Mellor, 1998; Bartling et al., 1999). The damage can result from the traumatic local anesthetic injections or during the dental implant site osteotomy or placement (Kraut and Chahal, 2002). This damage is one of the most unpleasant experiences, from mild paresthesia to complete anaesthesia and/or pain (Alhassani and AlGhamdi, 2010), for both the patient and the dentist. As a result, many functions such as speech, eating, kissing, make-up application, shaving and drinking will be affected (Ziccardi and Assael, 2001).

2.5.1 IAN nerve injury due to implant surgery

Damage of inferior alveolar nerve during dental implant placement can be a serious complication. Clinician should recognize and exclude aetiological factors leading to nerve injury. Proper presurgery planning, timely diagnosis and treatment are the key to avoid nerve sensory disturbances management. There are four possible aetiological factors of IAN injury during the implant placement and can be summarized as:

2.5.1.1 Inferior alveolar nerve injury during traumatic local anaesthesia injection

Profound local anaesthesia during the dental implant surgery can drastically reduce patient anxiety during the surgery. Local anaesthetics are designed to prevent sensory impulses being transmitted from intraoral and extraoral areas to the central nervous system with minimal effect on muscular tone (Hillerup and Jensen, 2006). Unfortunately, the injury of an IAN can occur during a traumatic local anaesthesia injection (Malamed, 2010; Jones and Thrash, 1992).

Three main theories were proposed for the inferior alveolar nerve injury during traumatic local anaesthesia injection and these includes direct trauma from the injection needle (Crean and Powis, 1999; Stacy and Hajjar, 1994), hematoma formation (Harn and Durham, 1990; Haas and Lennon, 1995) and neurotoxicity of the local anaesthetic (Pogrel and Kaban, 1993; Nickel, 1990).

2.5.1.2 Inferior alveolar nerve injury by implant drill

The most severe types of injuries are caused by implant drills and implants themselves (Worthington, 2004). Sensory IAN injuries made by implant drills may be caused by direct intraoperative (mechanical and chemical) and indirect postoperative trauma (ischemia and thermal stimuli) (Nazarian et al., 2003). Many implant drills are slightly longer, for drilling efficiency, than their corresponding implants. Implant drill length varies and must be understood by the surgeon because the specified length may not reflect an additional millimetre so called “y” dimension (Alhassani and AlGhamdi, 2010). Lack of knowledge about this may cause complications (Kraut and Chahal, 2002). Damage to the IAN can occur when the twist drill or implant encroaches, transects, or lacerates the nerve (Figures 2.6 A and B).

One of the possible intraoperative complications is direct chemical trauma - alkalinic nerve injuries from irrigation of the implant bed during preparation with sodium hypochlorite. This solution has not been recommended in practice and should be avoided (Khawaja and Renton, 2009).

Some sensory IAN injuries evoked by partial perforation of the mandibular canal during the drilling is caused by indirect postoperative trauma – secondary ischemia of the IAN by haemorrhage into the canal and scaring process, rather than direct mechanical trauma by the drill or implant itself (Figure 2.6 C) (Khawaja and Renton, 2009; Lamas Pelayo et al., 2008).

Thermal stimuli can evoke peri-implant bone necrosis and postoperative secondary IAN damage. Nerve tissue is thought to be more sensitive to thermal insult than bone and it may lead to primary IAN injury (Figures 2.6 D and E) (Fanibunda et al., 1998). The increase in temperature, produced by excessive drill speed produces necrosis, fibrosis, osteolytic degeneration and an increase in osteoclastic activity. The thickness of the necrotic area is directly proportional to the amount of heat generated during the surgery (Tehemar, 1999).

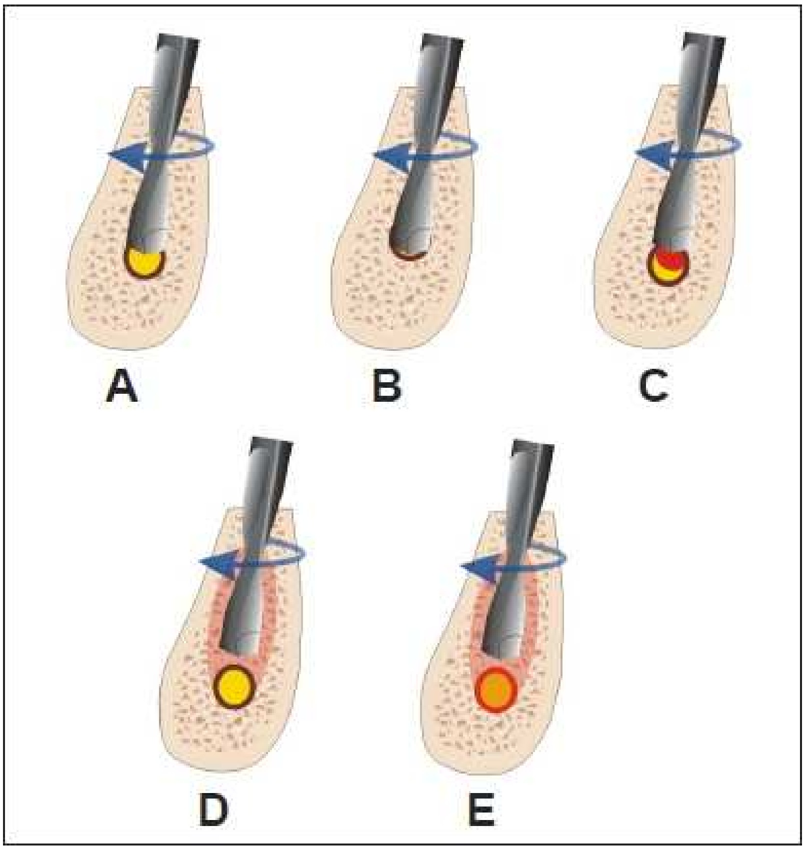

Figure: 2.6 Illustrated diagrams for inferior alveolar nerve injury by implant drill (**Juodzbalys** et al., 2011). A = partial implant drill intrusion into the mandibular canal can cause direct mechanical IAN trauma - encroach, or laceration and primary ischemia. B = full implant drill intrusion into the mandibular canal can cause direct IAN transection and primary ischemia. C = partial implant drill intrusion into the mandibular canal can cause indirect trauma due to hematoma and secondary ischemia. D = thermal stimuli can evoke periimplant bone necrosis and postoperative secondary IAN damage. E = thermal stimuli can evoke primary IAN damage.

2.5.1.3 Inferior alveolar nerve injury by dental implant

Sensory IAN injuries made by dental implant may be caused by direct intraoperative (mechanical) and indirect postoperative trauma (ischemia) or periimplant infection (Nazarian et al., 2003). Direct mechanical injury i.e. encroach, transection, or laceration of the nerve is related to implant intrusion into the MC (Figures 2.7 A and B).

After a direct trauma that is when the implant is placed through the bony canal, the nerve ending may get retrograde degeneration in some of the cases, because the nerve running in the canal is a terminal ending of the nerve and the size is quite small (Beirowski et al., 2005). Whereas partial implant intrusion into MC can evoke IAN injury due to compression and secondary ischemia of corresponding neurovascular bundle (Leckel et al., 2009; Worthington, 2004). This is especially when immediate implantation following tooth extraction can sometimes cause implant intrusion into MC. Furthermore, efforts by the surgeon to achieve primary stability can also lead to unintentional apical extension and subsequent nerve injury. Re-measurement of the amount of available bone after tooth extraction is recommended especially in those cases of nerve proximity since a few millimetres of the crestal bone might be lost during the extraction (Alhassani and AlGhamdi, 2010).

Another cause of injury to the IAN is the displacement of an implant into canal. For example this is possible in the posterior mandible as the cancellous bone is more abundant with larger intratrabecular spaces than the anterior mandible (Theisen et al., 1990; Fanuscu and Chang, 2004).

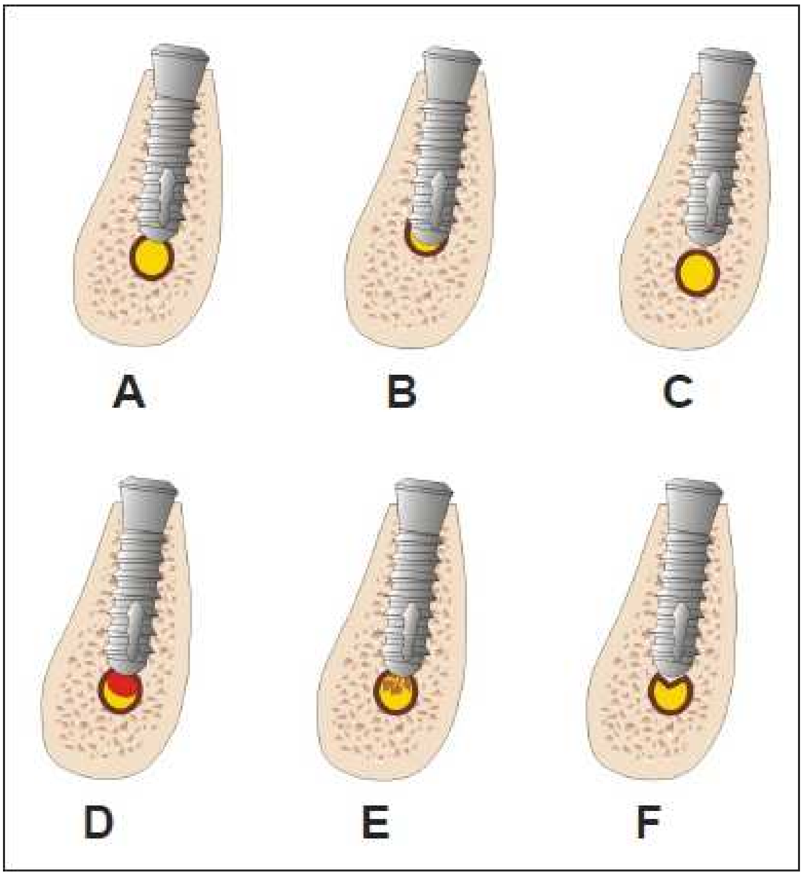

Figure 2.7 Illustrated diagrams for inferior alveolar nerve injury by dental implant (**Juodzbalys** et al., 2011).

A = partial implant intrusion into the mandibular canal can cause direct mechanical IAN trauma - encroach, or laceration and primary ischemia. B = full implant intrusion into the mandibular canal can cause direct IAN transection, and/or compression and primary ischemia. C = dental implant is too close to the mandibular canal, it can cause IAN compression. D = partial implant intrusion into the mandibular canal can cause indirect trauma due to hematoma and secondary ischemia. E = partial implant intrusion into the mandibular canal can cause indirect trauma due to bone debris and secondary ischemia. F = "cracking" of the IAN canal roof by its close proximity to the preparation of the implant bed. It can cause compression and primary ischemia.

2.5.1.4 Inferior alveolar nerve injury – The mental nerve

Injury of the final part of the IAN – the mental nerve can occur in those cases when an extreme degree of the alveolar process resorption exists. In such cases, the mental foramen was found on the surface of alveolar bone and directly under the gums (Ulm et al., 1993; Mraiwa et al., 2003; Gershenson et al., 1986).

2.5.2 IAN nerve injury due to other surgical procedures

Other than implant surgery, sensory disturbance is a serious concern in other mandibular surgical procedure, particularly in BSSO (Karabouta-Voulgaropoulou and Martis, 1984).

The inferior alveolar nerve (IAN) is at significant risk during this operation and the risk is existing in all stages of surgery; including incision, dissection, retraction, bone cuts, mobilization and internal fixation. Nerve damage at surgical operation during BSSO is reported from 1.3% to 18% of the cases (van Merkesteyn et al., 1987).

IAN injury can also follow other surgical procedures in the mandible. The proximity of third molar roots to the mandibular canal endanger the IAN to an injury during extraction of the third molar (Kipp et al., 1980), especially if it is impacted. Lindquist and Obeid (1988) even reported in their study an incidence of IAN injury of about 10% during genioplasty.

The best way to prevent these damages is to have clear three-dimensional vision of the jaw. This can be achieved by combining the practical knowledge of basic mandibular anatomy and the data obtained from clinical and radiological examinations.

2.6 Radiographic methods used to locate the mandibular canal

The location and configuration of the mandibular canal is important in imaging diagnosis for most surgical procedure of the mandible. Therefore special attention should be given to the exact location of the mandibular canal, thereby avoiding the neurovascular bundle.

Periapical radiographs were used for many years to assess the jaws pre- and post-implant placement (van der Stelt, 2005). Similarly panoramic projection were used for diagnostic purposes where the canal is identifiable as a narrow radiolucent ribbon bordered by radioopaque lines (Nortjĕ et al., 1977a), but the buccolingual location of the mandibular canal cannot be obtained on this image.

To obtain the more precise location of the mandibular canal, the clinician may use different tomography modalities. Tomography can be utilized to section or slice an object. This is accomplished by the simultaneous movement of the tube and the film, which is connected so that the movement occurs around a point of a fulcrum. The object closest to the point or fulcrum is seen most sharply, while the object farthest away from the point of rotation is almost completely blurred. Tomographic methods for dental procedures can be broadly classified into three categories: conventional tomography, computed tomography (CT), and Cone Beam Computed Tomography (CBCT).

2.6.1 Periapical radiographs

Periapical radiographs have been used for many years to assess the jaws pre- and post-implant placement (van der Stelt, 2005). The long cone paralleling technique for taking periapical X-ray is the technique of choice for the following reasons: reduction of radiation dose; less magnification; a true relationship between the bone height and adjacent teeth is demonstrated. It should be noted that for the long cone paralleling technique, it should be taken with a film-focal distance of approximately 30 cm (Denio et al., 1992). One of the shortcomings of the present method is the use of film. Since the film is highly flexible, literally and figuratively, its processing can be suboptimal and it often leads poor image. Furthermore, maintaining a darkroom requires space and time as well as the additional environmental expenses (van der Stelt, 2005).

Nevertheless, the biggest concern of periapical radiographs is in 28% of patients that the mandibular canal could not be clearly identified in the second premolar and first molar regions (Denio et al., 1992). In case, when X-ray beam is perpendicular to the canal, but not the film, elongation occurs, and the canal appears further from the alveolar crest than it really is. Conversely, when the X-ray beam is perpendicular to the film, but is not parallel to the canal, foreshortening happens (Greenstein and Tarnow, 2006).

During the last decade, many dental practices replaced the film with digital imaging systems. Common reasons for making this transition included capable of manipulating the images, lower exposure, greater speed of obtaining images, and the perception of being up to date in the eyes of patients (White et al., 2001; Kim et al., 2006).

2.6.2. Panoramic radiography

Even until today panoramic radiography are routinely used in the dental office for various diagnostic purposes of the jaws and considered the standard and simplest diagnostic aid for imaging of maxillofacial structures before any surgery.

Panoramic radiograph can be the method of choice when a specific region that is too large to be seen on a periapical view. The major advantages of panoramic images are the broad coverage of oral structures, low radiation exposure (about 10% of a full-mouth radiographs), and relatively inexpensive of the equipment. The major drawbacks of panoramic imaging are: lower image resolution, high distortion, and presence of phantom images. These can artificially produce apparent changes thus may hide some of important vital structures (White et al., 2001). For example, cervical spine images often overlap on the anterior mandible.

Wadu et al. (1997) employed panoramic radiographs to study the mandibular canal appearance and they found that in number of cases the radio-opaque border was either disrupted or even absent. The superior border was more prone to disruption than the inferior border (Figure 2.8).

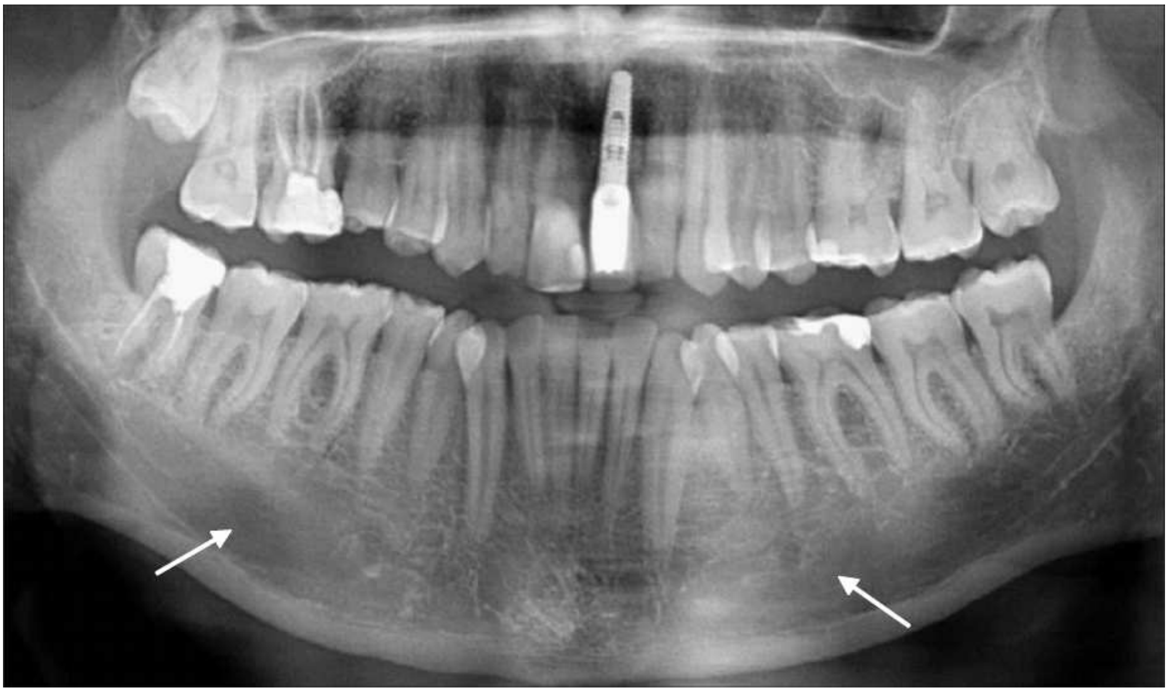

Figure: 2.8 The orthopantomograph shows the disrupted superior border of the mandibular canal (arrows) and cancellous bone which has few and thin trabecullae (Juodzbalys and Wang, 2010).

It was further reported that the contrast enhancement application to the digital images improved significantly the diagnostic image quality (Gijbels et al., 2000), but this did not improve the depiction of the MC (Naitoh et al., 2009b). Furthermore, Naitoh et al. (2009b) concluded that the mandibular canal border depiction on digital panoramic images was related to the bone density in the alveolar region when assessed using the multislice CT images. They found that the mandibular canal visible with superior and inferior wall was only 36.7%. Similarly, Lindh et al. (1995) reported that the mandibular canal of specimen cadavers was clearly visible in 25% of panoramic radiographs (range 12 to 86%). In an earlier research Klinge et al. (1989) reported that the mandibular canal of specimen cadavers was not visible in 36.1% of panoramic radiographs.

According to Vazquez et al.(2008), if a safety margin of at least 2 mm above the mandibular canal is ascertained, panoramic radiography appears to be sufficient to evaluate available bone height prior to insertion of posterior mandibular implants; cross-sectional imaging techniques may not be necessary.

Panoramic radiographs can be predictably used for visualization of the mental foramen and a potential anterior looping but not suitable for locating the mandibular incisive canal. To verify its existence for preoperative planning purposes, cross-sectional imaging modalities such as high resolution computed tomography (HR-CT) or spiral tomography, and CBCT should be preferred. High resolution magnetic resonance imaging (HR-MRI) is not preferred due to the high cost of this machine.

2.6.3 Conventional tomography

Tomography word was derived from the Greek word “tomos” which means "a section", "a slice" or "a cutting". In conventional tomography, different types of motion of the x-ray tube and the film are employed. They are linear, circular, trispiral, elliptical, and hypocycloidal, the simplest of the motions being linear. The more complex the motion is, the sharper the image. There is always some degree of blurring in tomography, the greatest amount of blurring being at the periphery. This modality has now become obsolete.

2.6.4. Computed tomography (CT)

Computerized tomography, unlike the conventional radiological technique, enables the 3D evaluation of the bone without the overlapping of the adjacent structure, as well as a precise measurement of the bone tissue availability.

CT was introduced in imaging the maxillofacial structure in the early 1970's. It was considerably developed after the introduction of dental implantology, when the need increased for advanced radiologic procedures to document the availability or nonavailability of bone and to identify important anatomic structures such as the mandibular canal.

The obtained CT data can be manipulated and reconstructed with a software program such as DentaScan or SimPlant. Interpretation of these processed images is much easier, accurate and may reveal most of the relevant structures such as accessory canals and foramen which are occupied by neurovascular bundles, arterioles and venules.

CT images are produced by x-ray beams that penetrate patients to varying degrees and strike a detector. The generation of the scan is determined by the placement of the x-ray tube relative to the detectors. The entire CT process is divided into three segments: data acquisition, image reconstruction and image display. Raw data include all measurements obtained from the detector array. After the raw data is averaged and each pixel is assigned a CT number (quantified measurement of density), an image can be reconstructed. The data that form this image is then referred as image data (Gultekin et al., 2003).

In a study done by Yang et al.(1999), employed a spiral computed tomography machine to scan on four edentulous cadaver heads with intact mandible. They wanted to find out if there were any statistically significant differences between the 2D computed tomography measurements and the physical measurements or between the 3D computed tomography measurements and the physical measurements. The data were then transferred to third party software - Radredux to generate 2D and 3D images. Linear measurements of the images were made from the superior border of the inferior alveolar canal to the alveolar crest. The specimens were then dissected at corresponding locations, and physical measurements were made. It was concluded that 2D and 3D computed tomography images allowed accurate measurements for localization of the inferior alveolar canal.

CT values (Hounsfield units: HU) and bone mineral densities obtained by medical CT were used to assess the bone density of jaws. Norton and Gamble (2001) measured the bone density in the posterior mandible using SimPlant software (3D Diagnostix, Boston, MA, USA) and concluded that the mean CT value was 669.6 HU. (Misch, 1999).

Another attempt to improve depiction of the mandibular canal was by changing the thickness of double-oblique computed tomography images (Naitoh et al., 2008). A total of 38 sites in the mandibular molar region were examined using multislice helical CT. The thicknesses of the double-oblique images using multislice helical CT scans were reconstructed in 4 conditions: 0.3 mm, 0.9 mm, 1.6 mm, and 4.1 mm. In the alveolar crest and the entire mandibular canal, highest value was obtained with 0.9 mm thick images; however, there was no significant difference between 0.3 mm and 0.9 mm thick images. The researchers then concluded that the description of superior wall of MC cannot be improved by changing the thickness of images.

However, the measurements obtained from computed tomographic images are more consistent with direct measurements than the measurements obtained from panoramic radiographic images or conventional tomographic images (Figure 2.9 A and B). This conclusion was made by Peker et al. (2008) after the comparison of efficiency of panoramic radiographs, conventional tomograms, and computed tomograms for location of the mandibular canal at 12 regions of 6 dry adult human skulls. Furthermore, Rouas et al. (2007) reported that the atypical mandibular canal (such as bifid MC). In most cases can be identified using only three-dimensional imaging techniques. Therefore it is reported that the bifid MC is often left unrecognized (Claeys and Wackens, 2005).

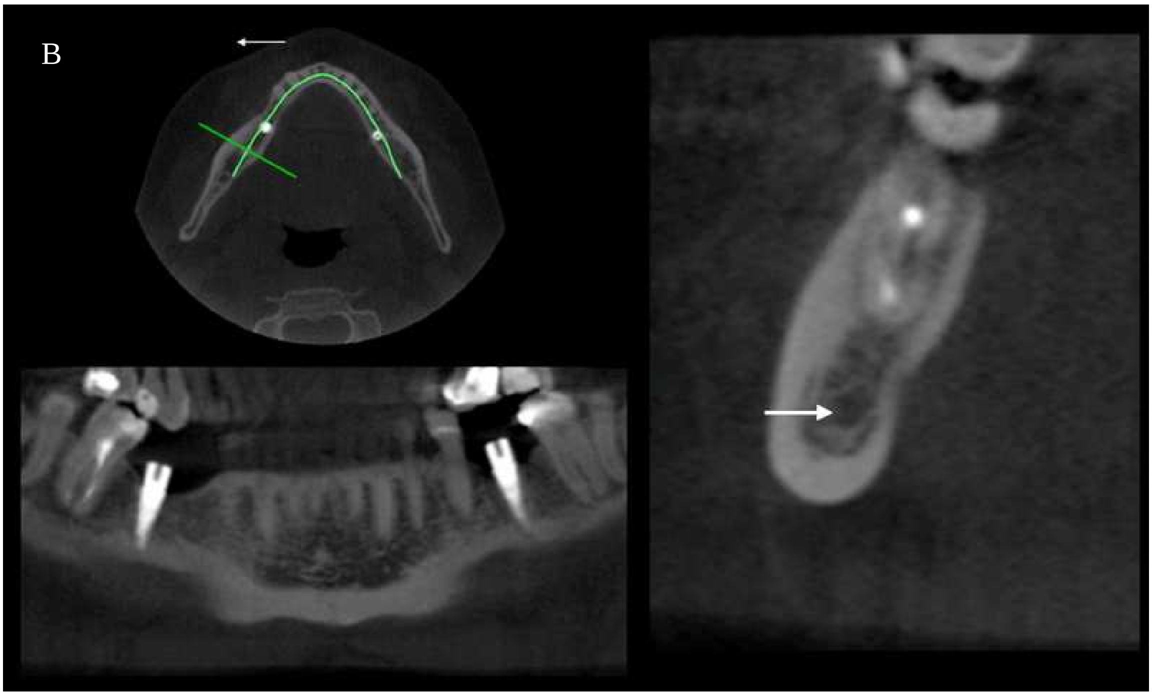

Figure: 2.9 Computed tomographic images A. Mental foramen (arrow) detection (top image). B. Mandibular canal detection (arrow) (lower image) (Juodzbalys and Wang, 2010).

2.7 Studies locating the mandibular canal preoperatively

The earlier study made to determine the vertical location of the mandibular canal was mostly based on cadaver studies (Carter and Keen, 1971; Tamas, 1987; Gowgiel, 1992). There were also radiographic studies (Nortjě et al., 1977b; Heasman, 1988; Fox, 1989) that disclosed the position of the mandibular canal adjacent to the apices of the teeth, but could not determine if the canal is buccal or lingual to the teeth. However, some radiographic methods have been used to locate the mandibular canal buccolingually, mostly before the implant surgery (Rothman et al., 1988; Klinge et al., 1989; Lindh and Petersson, 1989; Jacobs et al., 1999; Yang et al., 1999; Hallikainen et al., 1992).

It has been assumed that in areas where the neurovascular bundle is in contact with either the buccal or lingual cortex, the mandibular canal is well visualized in radiographs (Miller et al., 1990) and it is suggested that cortication of the mandibular canal on the panoramic film may serve as a predictor of the proximity of the mandibular canal to the cortical plates.

The anatomic features of the ascent or descent of the canal, as well as its buccolingual relationships, have been studied by Mercier (1973), Tamas (1987) and Gowgiel (1992). According to the report by Gowgiel on dissections of the IAN, the neurovascular bundle from the mandibular foramen to the mental foramen is always in contact with, or in close proximity to the lingual mandibular cortex. Furthermore, the rnandibular canal ascends slightly toward the mental foramen in the anterior mandible. However, it has been shown, that vascular and nerve bundles may also be extremely close to the buccal cortex of the mandible in broad and thick mandibular rami. The study of Rajchel et al. (1986) on 45 Asian adults demonstrated that the mandibular canal when proximal to the third-molar region is usually a single large structure (2.0 to 2.4 mm in diameter). It courses approximately 2.0 mm from the inner lingual cortex, 1.6 to 2.0 mm from the medial aspect of the buccal plate, and about 10 mm from the inferior border.

A study done by Lindh et al. (1992), employed visualization of the mandibular canal by five different radiographic techniques: periapical radiography, panoramic radiography, hypocycloidal tomography, spiral tomography and computerized tomography. They noticed that direct CT demonstrated the mandibular canal best of the examined techniques, and it also gave a high inter- and intraobserver agreement rate. This was supported by Sonic et al.(1994) on the accuracy of periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. They too found CT to be superior to the other techniques in locating the mandibular canal.

Comparing the tomographic techniques with panoramic radiography, Tal and Moses (1991) reported that CT-scans have again been found to be more precise in measuring the distance between the bony crest and the mandibular canal compared to panoramic radiography. In addition, the tomographic radiographs have an additional advantage in presurgical planning as they reveal the horizontal dimension, shape of the mandible and the topography and buccolingual location of the mandibular canal.

A study was performed by Ylikontiola et al.(2002) to compare three radiographic techniques to locate the mandibular canal in the buccolingual direction before BSSO. Panoramic radiographs, computerized tomography (CT) and conventional spiral tomographic (Scanora, Soredex, Helsinki, Finland) radiographs were compared for their ability to localize the mandibular canal in the buccolingual direction. The subjective neurosesnsory deficit of the lower lip and chin on both sides was registered preoperatively at 4 days, 3 weeks, and 3 months after surgery, and the operative outcome was analyzed in relation to the distance from the mandibular canal to the buccal cortex of the mandible. Computed tomography gave better visualization of the mandibular canal than Scanora imaging. Cortication of the mandibular canal on the panoramic radiograph did not serve as a predictor of the proximity of the mandibular canal to the cortices of the mandible. At 3-month follow-up, there were only eight operated sides with abnormal sensation of the lower lip and chin. In seven of these sides, the distance from the mandibular canal to the buccal cortex was less than 2 mm using CT technique. As a conclusion, The buccolingual location of the mandibular canal is visualized better with CT than with Scanora or panoramic radiographs.

Klinge et al.(1989) radiographically examined four mandibular specimens bilaterally to locate the mandibular canal. The following radiographic techniques were used: periapical and panoramic radiography, hypocycloidal tomography, and computed tomography (CT). The distance from the crest of the alveolar process to the superior border of the mandibular canal was measured in millimeters on all radiographs. The specimens were then sectioned, and the location of the mandibular canal (as measured on contact radiographs of the sections) was compared with measurements made on the other radiographs. The results showed that CT gave the most accurate position of the mandibular canal and is therefore probably the best method for preoperative planning of the implant surgery involving the area close to the mandibular canal.

Lindh et al.(1992) radiographically examined six mandibles bilaterally to visualize the mandibular canal. Five imaging techniques were used: periapical radiography, panoramic radiography, hypocydoidal tomography, spiral tomography and computed tomography

(CT). Panoramic radiographs were obtained with 2 different X-ray machines. The CT-examinations comprised direct images and standard reconstruction based on axial slices. The specimens were subsequently sectioned for contact radiography. The visibility of the mandibular canal was estimated by 3 observers at special reference points on all radiographs and classified as clearly visible, questionable visibility or not visible. The contact radiographs served as the "gold standard". The inter-observer and the intra-observer agreement were assessed by calculating the overall agreement and the x value. Direct coronal computed tomography, as well as spiral and hypocycloidal tomography, gave better visualisation of the mandibular canal than periapical and panoramic radiography.

Wang et al.(2008) examined 30 female cases with 3D CT to ascertain the mandibular canal before an operation. The 3D images were used to measure the distances between upper points of lower teeth to the inferior border of the canal. Then the osteotomy was designed according to the canal position to avoid the inferior alveolar neurovascular bundle injury. The canal protection was observed intraoperatively and postoperatively. The mandibular canal was protected very well in all 30 cases without any injury to the inferior alveolar neurovascular bundle. Results indicated 3D CT could accurately locate the mandibular canal to guide the design of the mandibular angle osteotomy for patients with prominent mandibular angle.

2.8 Cone Beam Computed Tomography (CBCT) in dentistry

CBCT Scanners have been available for craniofacial imaging since 1999 in Europe, 2001 in the United States, and 2005 in Australia. Although the imaging was created using computed tomography (CT) and appear similar to conventional medical multislice CT (MSCT) images, the method of x-ray emission and capture is quite different.

CBCT imaging technique is considered as one of the many new imaging modalities and techniques that have changed the way we approach dental diagnosis and treatment planning, particularly when anatomy of the maxillofacial complex is of paramount importance.

The introduction of Cone Beam Computed Tomography (CBCT) in 1998 has completely revolutionized the imaging modalities in dentistry and has changed the practice of oral and maxillofacial radiology and orthodontics (Ludlow et al., 2006).

CBCT produces 3D images of the bony structure being scanned, which has applied in various areas of dentistry such as assessment of tooth impaction, paranasal sinus evaluation, trauma evaluation, temporomandibular joint visualization; surgical guide fabrication, implantology, endodontics and craniofacial surgery assessments and visualization of the anatomy of the mandibular canal.

Whether we are looking at the position of the canal with respect to third molar, or treatment planning for implants, viewing the mandible in all three dimensions helps us extract the maximum information needed for diagnosis and treatment.

CBCT is capable of providing sub-millimeter resolution in images of high diagnostic quality, with short scanning time about 10-70 seconds and radiation dosages reportedly up to 15 times lower than those of conventional CT scan (Scarfe et al., 2006a)

According to Sukovic (2003), CBCT can be combined with application-specific software tools can provide dentomaxillofacial practitioners with a complete solution for performing specific diagnostic and surgical tasks, such as dental implant planning, temporomandibular joint imaging, detection of facial fractures, lesions and diseases of soft tissue in the head and neck as well as in reconstructive facial surgery.

For most dental practitioners, the use of advanced imaging has been limited because of cost, availability and radiation dose considerations. However, the introduction of CBCT for maxillofacial region provides an opportunity for surgeons to request for multiplanar imaging.

CBCT allows the creation in "real time" of the images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal, oblique or curved image planes a process known as Multiplanar reformation (MPR). In addition, CBCT data are amenable to the reformation in a volume, rather than slice, providing three dimensional (3D) information (Scarfe et al., 2006a).

Figure 2.10: Cone beam computed tomography system showing the x-ray source (to the left of the model) and the receptor (Lam, 2007).

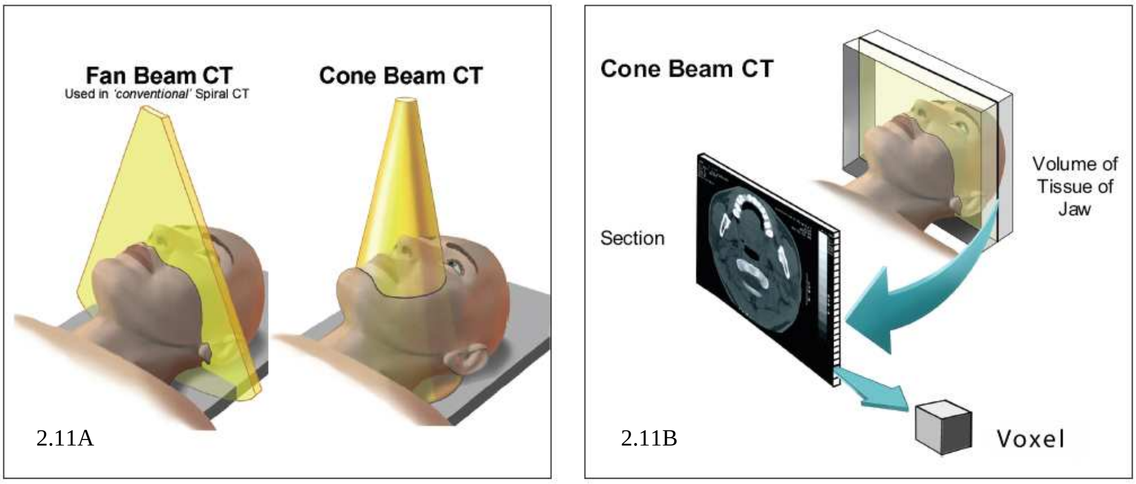

Figure 2.11: Illustrated diagrams for x-ray cone beam emission and detection. 2.11A show the fan beam on which spiral computed tomography (left) is based interrogates only a slice of tissue, whereas the cone-beam of cone-beam computed tomography (right) interrogates a 3-dimensional region within a 360° rotation. 2.11B diagram show Cone-beam computed tomography reconstructs the 3-dimensional images by generating voxel directly, each with its own attenuation coefficient (MacDonald-Jankowski and Orpe, 2007).

CBCT imaging machine scanners are based on volumetric tomography, using a 2D extended digital array which provides an area detector. This is combined with a 3D x-ray beam. The cone beam technique involves a single 360 scan in which the x-ray source and a reciprocating area detector synchronously move around the patient’s head which is stabilized with a head holder. At a certain degree intervals, single projection images, known as "basis" images, are acquired. These are similar to lateral cephalometric radiographic images, each slightly offset from one another. This series of basis projection images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back- filtered projection are applied to these image data to generate a 3D volumetric data set which can be used to provide primary reconstruction images in three orthogonal planes (axial, sagittal and coronal) (White and Pharoah, 2009)

Although the CBCT principle has been in use for almost two decades, only recently the systems become commercially available with the development of inexpensive x-ray tubes, high quality detector systems and powerful personal computers (Figure 2.10). Some of the types of CBCT systems available now are NewTon QR DVT 9000 (Quantitative Radiology, Verona, Italy), CB MercuRay (Hitachi Medical Corp., Japan), 3D Accuitomo-XYZ Slice view Tomography (J.Morita, Kyoto, Japan) and I-CAT (Xoran Technologies and Imaging sciences International). According to Baba et al.(2004), these units can be categorized according to their x-ray detection system. Most CBCT units for maxillofacial applications use an image intensifier tube (IIT)-charge-coupled device. A system employing a flat panel imager (FPI) was released by I-CAT. The FPI consists of a cesium iodide scintillator applied to a thin film transistor made of amorphous silicon. Images produced with an IIT generally result in more noise than images from an FPI; also need to be processed to reduce geometric distortions inherent in the detector configuration.

The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT. Most CBCT units can be adjusted to scan small regions for specific diagnostic tasks. By reducing the size of the irradiated area by collimation of the primary x-ray beam to the area of interest, the radiation dose could be minimized.

Cone Beam CT scanners use a pulsed cone-shaped x-ray beam, which is captured on a square 2 dimensional array of detectors. Instead of data taking the form of a set of consecutive slices as with the conventional medical CT scanners, the Cone Beam CT scanner provides a volume of data. The voxels created are isotropic (i.e. of equal height, breadth and depth dimensions) (Figure 2.11).

The uniform nature of the voxels means; there is superior dimensional accuracy in the reconstruction process of the raw data captured by the scan, the data are easily uploaded into 3rd party software like SimPlant imaging software which is DICOM compatible, and accuracy is not lost if the image data undergoes repositioning or reorientation. Although CT voxels surfaces can be as small as 0.625mm square, their depth is usually in the order of 1-2mm. However, all CBCT units provide voxel resolution ranging from 0.4mm to as low as 0.076 mm (Kodak 9000C 3D) which often exceeding the highest grade multi-slice CT.

CBCT acquires all basic images in a single rotation. As such the scan time is rapid, 10-70 seconds only. Although faster scanning time usually means fewer basis images from which to reconstruct the volumetric data set, the motion artifacts due to subject movement are reduced. The published reports by Schulze et al.(2004), Mah et al.(2003), Ludlow et al.(2006) and Cohnen et al. (2002) indicated that the average range of effective dose of radiation for CBCT is 36.9 - 50.3 microsievert (uSv) which is significantly reduced by up to 98% compared with conventional fan-beam CT systems (average range for mandible is 1.320-3324 uSv and maxilla is 1031-1420 uSv) (Scaf et al., 1997; Dula et al., 1996). This reduces the effective patient dose to approximately that of a film-based periapical survey of the dentition (13-100 uSv) (Gibbs, 2000; Komaki et al., 1992) or 4-15 times that of a single panoramic radiograph (2.9 - 11 uSv) (Ngan et al., 2003; Ludlow et al., 2003).

One of the characteristic of CBCT is the display mode which is unique to maxillofacial imaging. Reconstruction of CBCT data is performed natively by a personal computer and the software can be made available to the user. This provides the clinician with the opportunity to use the chair-side image display, real time analysis and MPR modes that are task specific. Because the CBCT volumetric data set is isotropic, the entire volume can be reoriented so that the patient’s anatomic features are realigned. In addition, cursor-driven measurement algorithms allow the clinician to do real-time dimensional assessment.

Cohnen et al.(2002) has shown that CBCT images can result in a low level of metal artifact, particularly in secondary reconstructions designed for viewing the teeth and jaws.

When the periapical radiography, panoramic radiography, tomography, or CT were compared for their efficiency in the identification of the MC, the CBCT seems to have the most potential while reduces radiation exposure considerably. Angelopoulos et al. (2008) compared CBCT reformatted panoramic images with direct (charge-coupled device-based) panoramic radiographs and digital panoramic radiographs based on a storage phosphor system. They concluded that the CBCT reformatted panoramic images outperformed the digital panoramic images in the identification of the mandibular canal. Due to the fact that the CBCT images were reformatted slices of the mandible, they were free of magnification, superimposition of neighbouring structures, and other problems inherent to the panoramic radiology. It has also been shown that the CBCT had more accuracy and reproducibility of measurements of MC when compared to direct digital calliper measurements (Kamburoglu et al., 2009). Basically, the intraclass correlation coefficients for CBCT and the direct digital calliper ranged from 0.61 to 0.93 for the first observer and from 0.40 to 0.95 for the second observer.

2.8.1 Accuracy of using CBCT

A study done by Kamburoglu et al.(2009), where fix formalin-fixed hemimandible specimens were examined using cone-beam CT systern and sectioned at 7 locations using a Lindemann burr. A digital caliper was used to measure the following distances on both the anterior and posterior sides of each section: mandibular width (W); mandibular length (L); upper distance (UD); lower distance (LD); buccal distance (BD); and lingual distance (LID). The same distances were measured on the correspondence cross-sectional cone-beam CT images using third party software. All caliper and cone-beam CT measurements were made by 2 independent trained observers and were repeated after an interval of 1 week. The Bland/Altman statistical method was used to calculate intra- and inter-rater reliability. Intra-class correlation coefficients (ICCs) from 2-way random effects model were calculated. Agreements between cone-beam CT and direct digital caliper were calculated by ICC for 6 distances and 2 observers.

Intraobserver and interobserver measurements for all distance showed high agreement. ICCs for intraobserver agreement ranged from 0.86 to 0.97 for cone-beam CT measurements and from 0.98 to 0.99 for digital caliper measurements. ICCs between observers ranged from 0.84 to 0.97 for the cone-beam CT measurements and from 0.78 to 0.97 for the digital caliper measurements. ICCs for cone-beam CT and direct digital caliper ranged from 0.61 to 0.93 for the first observer and from 0.40 to 0.95 for the second observer.

As a conclusion, accuracy of cone-beam CT measurements of various distances surrounding the mandibular canal was comparable to that of direct digital caliper measurements.

Another study by Angelopoulos et al.(2008), where panoramic images, generated by 3 different imaging modalities used for general rnaxillofacial diagnosis and preimplant assessment, were compared: (a) CBCT reformatted panoramic images (I-CAT; Imaging Sciences, Hatfield, PA), (b) Direct (charge-coupled device-based) panoramic radiographs (DIMAX; Planmeca, Helsinki, Finland), and (c) digital panoramic radiographs based on a storage phosphor system (DENOPTIX; Gendex, Chicago, IL). Three independent groups of images were used (40 in each group) from patients examined by one of the above imaging modalities over a period of 6 months. In total, 68 randomly selected mandibular canals (out of a possible 80) per imaging modality were evaluated. Four experienced raters evaluated the images of each modality in 3 sessions under standardized conditions for clarity in the visualization of the mandibular canal in 3 locations, using a 4-point scale. As as result CBCT reformatted panoramic images outperformed the digital panoramic images in the identification of the mandibular canal.

Another study was made by (Tantanapornkul et al., 2007) to compare the diagnostic accuracy of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. One hundred and forty two impacted mandibular third molars were evaluated to assess tooth relationship to the mandibular canal. The sensitivity and specificity of the 2 modalities in predicting neurovascular bundle exposure at extraction were calculated and compared. The sensitivity and specificity were 93% and 77% for cone-beam CT, and 70% and 63% for panoramic images, respectively. As a result cone-beam CT was significantly superior to panoramic images in predicting neurovascular bundle exposure during extraction of impacted mandibular third molar teeth.

2.8.2 Image quality of CBCT

Brooks et al.(2004) conducted research on five unembalmed cadaver heads and three living humans head employing cone-beam CT scanner (I-CAT) using default parameters to evaluate identification of the mandibular canal. The latter can be seen easily in living human scan but was not readily visible on scans of cadavers. This suggests that factors such as the age of the specimens and the effect of the thawing process must be taken in consideration when evaluating image quality.

Neugebauer et al. (2008) reported that panoramic radiograph and symmetrical panoramic cephalometric radiograph (PAN&PA) was compared with that of a cone-beam volumetric imaging (CBCT) device. Thirteen cases were evaluated by PAN&PA and the same thirteen cases evaluated via CBCT for the position of root tips of third molar. Cone Beam technology actually improved the localization of third molar for presurgical planning.

Kobayashi et al.(2004) examined five cadaver mandibles by spiral computerized tomography (SCT) and cone-beam computed tomography to evaluate the accuracy of measurement of distance on the images produced by computerized tomography. The vertical distance from a reference point to the alveolar ridge was measured by caliper on the sliced mandible, and measurement error on the CT images was calculated in percentages based on the actual values and the measurement values obtained from the CT images. Measurement error was determined to range from 0 to 1.11 mm (0% to 6.9%) on SCT and from 0.01 to 0.65 mm (0.1% to 5.2%) on CBCT, with measurement errors of 2.2% and 1.4%, respectively ($P < .0001$). There is significance in the difference observed with the two modalities.

This research showed that using CBCT is a useful tool for preoperative evaluation in comparison with SCT as it is able to collimate the field size and thereby reducing the exposure to ionizing X-ray radiation.

2.9 SimPlant interactive software

SimPlant (Materialise Dental, Belgium) uses the actual CT scans and reformatted CT images combined with computer graphics to give an impressive preoperative planning tool for placement of implants. The program (Figure 2.12) permits the planner to vary in display of the reformatted CT images to locate important internal structures and to inspect the anatomy of the alveolar ridge. Abnormal radiolucent areas can easily be identified, and once a decision is made in favor of the implant placement, the quality and quantity of bone at the proposed sites can be assessed- Vertical bone height and horizontal bone width can be measured easily from point to point with this data in hand, it is possible to select the proper length and diameter of the implants as well as the appropriate abutments. The proposed implant can be manipulated, modified and rotated into their optimal position and orientation relative to the proposed teeth. The gray level shading can be manipulated to help to identify the inferior alveolar canal. Overall, this interactive image display software is useful in routine and complicated implant treatment planning.

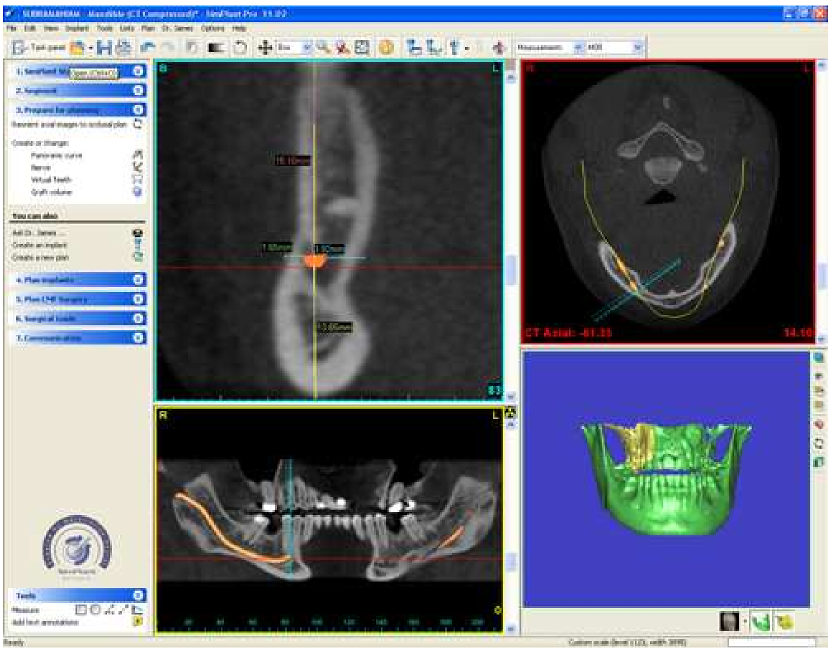

Figure 2.12 SimPlant Workstation

CHAPTER 3

RESEARCH MEHODOLOGY

3.1 Introduction

The present research study was designed to analyze metrically the course of the mandibular canal for dentate patients among Malaysian population in posterior part of the mandible using Cone Beam Computed Tomography (CBCT) and SimPlant interactive software.

3.2 The materials of the study

Cone Beam Computed Tomography images taken using I-CAT CBCT system at the Division of Oral Radiology, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia were used. The relevant data was downloaded and saved in an external hard disc for the purpose of this study.

Latest CBCT records taken shall be the priority of selection; starting from records in the month of January 2010 and moving backwards in time until adequate number of patients were selected. Out of more than one hundred records retrieved from February 2007 to January 2010 and 60 suitable cases were used for this study.

3.3 The subjects of the study

3.3.1 Sample of the study

The demographic characteristics of patients (n=60) summarized in Table 3.1. The sample for this study included imaging of 60 patients (30 males and 30 females) comprising of Malays, Chinese and Indian from the Division of Oral Radiology, with ages ranging from 20 to 60 years (mean age, 47 years). For each specimen the right and left side were considered, so the total sample size was 120. Table 3.2 summarizes the age group distribution for the sample size.

Table 3.1 Selection of cases based on the gender and ethnicity (race)

Ethnicity (race)	Gender	No. of patients	No. of sample specimens (right and left)
Malay	Male	10	20
	Female	10	20
Chinese	Male	10	20
	Female	10	20
Indian	Male	10	20
	Female	10	20
	Total	60	120

Table 3.2 Age group distribution of sample size (n=120)

	Frequency	Percent	Valid Percent	Cumulative percent
21-30	12	10.0	10.0	10.0
31-40	22	18.3	18.3	28.3
41-50	38	31.7	31.7	60.0
51-60	48	40.0	40.0	100.0
Total	120	100	100	

3.3.2 The variables of the study

The outcome variables used for the purpose of this study shall be gender (male and female), race (Malays, Chinese, and Indians) and age.

3.3.3 Selection criteria of the samples

The sample were chosen and carefully selected according to inclusion and exclusion criteria as follows.

Inclusion criteria:

i. Males or females from racial groups, Malays, Chinese and Indians.

ii. Patients aged between twenty (20) and eighty (60) with permanent dentition.

iii. Patients with systemic health problems or are medically compromised.

iv. Patients who had not undergone any radiotherapy.

Exclusion criteria:

i. individuals with mixed racial origin.

ii. patients with history of severe trauma or fracture of the mandible.

iii. patients with existing pathological disorder at mandible such as cyst, tumor, osteomyelitis, fibrous dysplacia etc.

iv. Patients with genetic disorder or congenital abnormalities.

v. Post-surgical cases such as orthognathic surgery, sagital split osteotomy, apicectomy and placement of endosseous oral implants.

vi. Any other cases which we feel shall not be suitable, such as syndromic conditions.

vii. The reformatted CBCT images which appear distorted or blurred with artifacts due to (1) presence of metal within the jaw or teeth, (2) those resulting from patient motion, and (3) due to improperly angled CBCT scan.

viii. Very osteoporotic demineralized mandible which makes it difficult to distinguish the canal and the medullary bone.

ix. Severely atrophied mandible.

3.4 Methodology

3.4.1 Methods

The selected samples from the CBCT data were stored in an external hard disk. They were then transferred to a workstation for further processing. The images were reformatted using SimPlant software version 13 from Materialise lnc. The SimPlant software allows viewing of axial, cross-sectional, Panoramic and 3D visualization of the jaw on the same screen.

The SimPlant workstation is most outstanding for the three dimensional renderings. This workstation is capable of displaying an entire volume of data from a large number of angles. It therefore allows the operator to define the picture elements that make up the osseous structures. In the 3D visualization, the jaw can be turned in space, rotated or spun 360 degrees and viewed from any angle.

The vital structures such as inferior alveolar nerve can be colored and displayed through the bone as if the bone were transparent (Figure 3.1).

For this research, the anatomy of the whole mandible was assessed first in the axial, coronal and panoramic views. Then the mandibular canal was examined and verified in all three planes.

The SimPlant software tool allow the marking to be done in any of the axial, cross sectional, Panoramic or 3D views and it will be simultaneously displayed in all four views on the screen. As such, this fully integrated planning tool allows identification of the canals with unparallel precision and at the same time provides 3D digital visualization of the jaw and canals.

3.4.2 Measurements

The measurements of the mandibular canal length were done in coronal view of the jaw at every 1cm interval from the mental foramen backwards; the position of the mandibular canal was measured at five different locations (Table 3.3) (Figure 3.2).

The outcome variables for this study were the direct linear distance between:

1- a)The buccal aspect of the IAN canal and the outer buccal cortical margin of the mandible, and the b) lingual aspect of IAN canal and the lingual cortical margin of the mandible.

2- c) The superior aspect of the IAN canal and the virtual horizontal line (CL) touching the highest buccal point of alveolar crest .d) The inferior aspect of IAN canal perpendicularly to the inferior point of the lower border of the mandible.

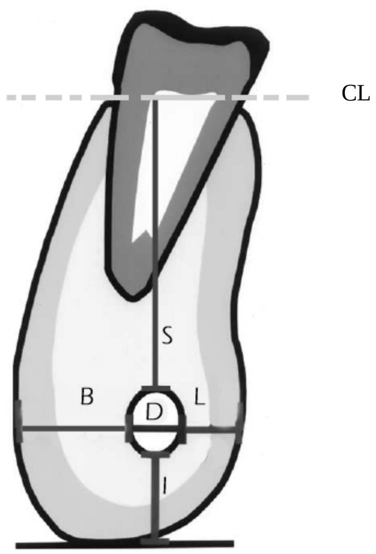

Figure 3.1 Illustrated diagram for the measurements at the coronal view of the jaw

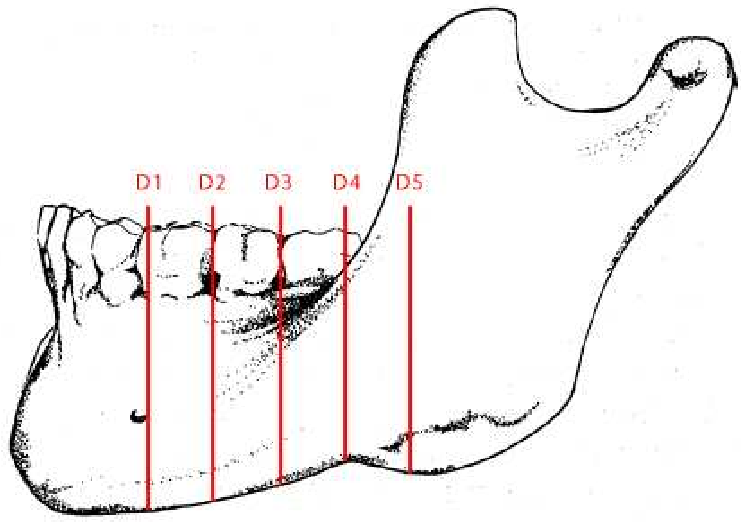

Figure 3.2 Illustrating locations of the measurements at every 10 mm interval starting from the distal aspect of mental foramen backwards (D1-D5).

The mandibular canal and the mandibular foramen diameter for each location mentioned earlier were also measured (Figure 3.2). Number of bifid mandibular canal cases was recorded for each side.

Table 3.3 Landmarks and the base lines record

D1	The location of the mandibular canal at the distal aspect of mental foramen.
D2	The location of the mandibular canal at 10 mm away from D1 distally.
D3	The location of the mandibular canal at 10 mm away from D2 distally.
D4	The location of the mandibular canal at 10 mm away from D3 distally.
D5	The location of the mandibular canal at 10 mm away from D4 distally.
B	The distance from the buccal aspect of the mandibular canal and the outer buccal cortical margin of the mandible.
L	The distance from the lingual aspect of IAN canal to the lingual cortical margin of the mandible.
I	The distance from the inferior aspect of IAN canal perpendicularly to the inferior point of the lower border of the mandible.
S	The distance from the superior aspect of the IAN canal to the horizontal line (L) touching the highest buccal point of alveolar crest.
MCd	The diameter of the mandibular canal length measurement.
ManFd	The diameter of the mandibular foramen length measurement.
CL	Virtual horizontal line touching the highest buccal point of the alveolar crest.

3.4.3 Reliability of the measurement

Since the research consist of huge number of details of quantitative data, the intraexaminer reliability and reproducibility of the measurements obtained were evaluated. A total number of twelve patients' records which is actually 20% of the sample size were randomly selected (two patients from each race and gender group) and all the data were measured again after three weeks using same methods described previously.

The consistency of data was analyzed and the Cronbach alpha coefficient was calculated for all the measured data.

3.5 Data analysis

All calculations and measurements were processed using SPSS statistical software version 12. The measured values for right and left mandible, gender, race and age were computed using appropriate statistical analysis. Figure 3.3 summarizes the methodology of this study.

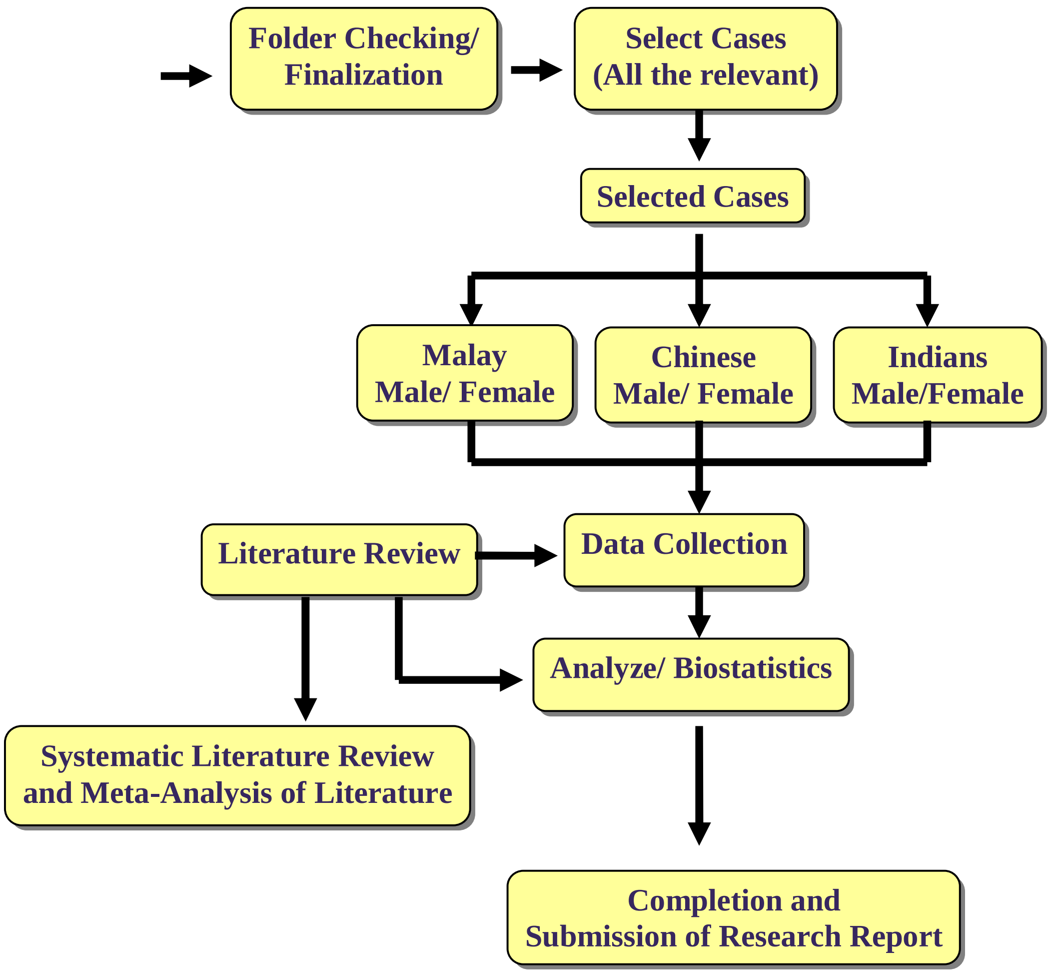

Figure 3.3 Flow Chart showing the methodology of the study

CHAPTER 4
RESULTS AND DATA ANALYSIS

4.1 Introduction

This study analyzes the path and course of the mandibular canal of dentate patient at 5 locations starting from mental foramen backward at 10 mm interval. It also measures the mandibular canal and mandibular foremen diameter, and indicates the frequency of bifid mandibular canal among Malaysian population.

This chapter discusses the results of the study. The analysis and its interpretation for MC course were organized from D1-D5 (Figure 4.1). For each D location there were 4 aspects considered which are the measurements observed buccally, lingually, inferiorly and superiorly respectively (with exception of the measurements at D5S location). Subsequently the following comparisons were made:

1) Exploration of the mandibular canal course

1.1 Comparison of the right and left sides.

1.2 Comparison between ethnicity (race)

1.3 Comparison between gender.

1.4 Comparison by age groups.

1.5 Comparison by ethnicity and gender

2) Determination of the mandibular canal diameter

2.1 Comparison between ethnicity (race)

2.2 Comparison between gender.

2.3 Comparison by age groups.

2.4 Comparison by ethnicity and gender

3) Determination of the mandibular foramen diameter

3.1 Comparison between ethnicity (race)

3.2 Comparison between gender.

3.3 Comparison by age groups.

3.4 Comparison by ethnicity and gender

4) Determination of the bifid mandibular canal

4.1 Comparison between ethnicity (race)

4.2 Comparison between gender.

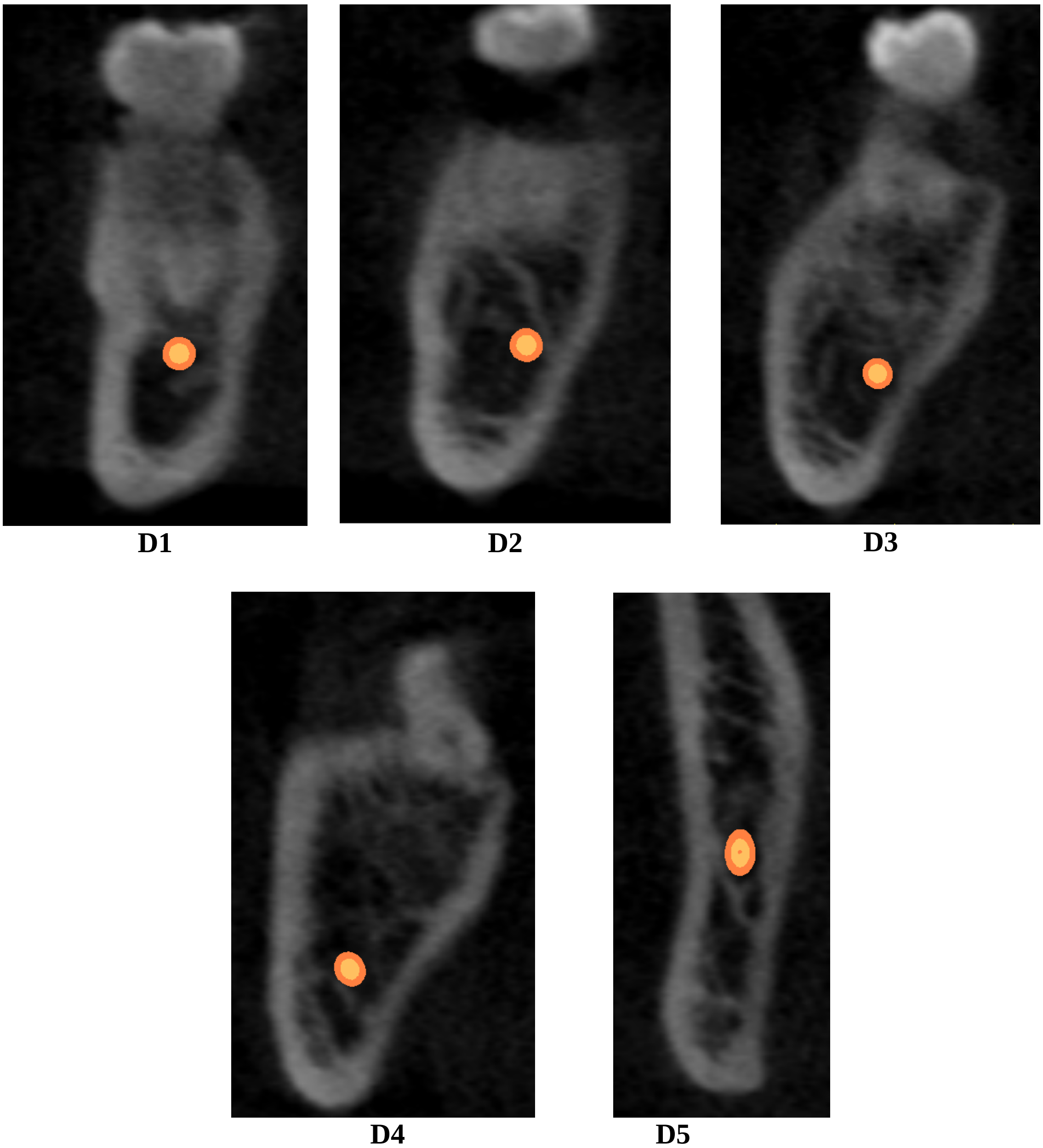

Figure 4.1: Mandibular canal position at each location considered in this study (D1-D5) - coronal view of CBCT image improved with SimPlant software.

4.2 Comparison of D locations on the right and left sides

In this study there were 60 patients' records. The right and left were measured and analyzed for each location from D1 till D5. The measurement unit used was millimeters in all length values of this study. The interest was in determining a significant mean difference between the right and left side of the jaw for each aspect considered in this study along the path of the mandibular canal.

Table 4.1 summarizes the descriptive statistics for the right and left side of all locations (D1-D5) which involved mean, SD, Mean of score different, t-statistics, df value and P value. Four aspects of each location is considered in the statistical test (except D5S) and their P-values was more than 0.05 so there is no significant difference in the location of the mandibular canal for the right and left side for the total sample (n=120).

Paired sample t-test was used to compare two population means in the case of the two samples that are correlated like in 'before-after' studies, or when the samples are the matched pairs or the case is a control study. All the data was assessed to check if it was normally distributed or not (using the histogram).

Table 4.1 Comparison of length measurements for all Ds locations on the right and left sides

D1	Length measurements (mm)		Mean of score different(95% CI)	t-statistics(df)	P value
	Right mean (SD)	Left mean (SD)			
D1B	3.88(1.08)	3.90(0.93)	-0.01(-0.25,0.22)	1.150(59)	0.255
D1L	4.42(1.33)	4.24(1.17)	0.17(-0.13,0.48)	-0.120(59)	0.905
D1I	9.44(1.82)	9.29(1.56)	0.14(-0.16,0.46)	0.931(59)	0.356
D1S	14.86(3.48)	14.85(3.83)	0.01(-0.53,0.55)	0.037(59)	0.971
D2					
D2B	5.58(1.31)	5.60(1.08)	-0.27(-0.28,0.23)	-0.206(59)	0.837
D2L	3.42(1.32)	3.26(1.07)	0.16(-0.13,0.46)	1.08(59)	0.283
D2I	8.39(1.68)	8.08(1.69)	0.309(-0.01,0.62)	1.931(59)	0.058
D2S	13.69(3.75)	14.18(3.95)	-0.48(-1.16,0.18)	-1.446(59)	0.154
D3					
D3B	6.74(1.35)	6.67(1.33)	0.069(-0.22,0.36)	0.468(59)	0.642
D3L	3.38(1.39)	3.12(1.26)	0.257(-0.09,0.60)	1.480(59)	0.144
D3I	8.21(2.02)	7.74(1.86)	0.469(0.06,0.87)	2.335(59)	0.052
D3S	12.82(4.14)	13.16(4.04)	-0.33(-1.29,0.62)	-0.705(59)	0.484
D4					
D4B	5.64(1.69)	5.73(1.57)	-0.089(-0.41,0.23)	-0.554	0.581
D4L	3.09(1.488)	3.07(1.45)	0.016(-0.36,0.39)	0.86	0.932
D4I	9.90(2.53)	9.40(2.54)	0.500(-0.08,1.08)	1.710	0.092
D4S	14.17(4.13)	14.28(3.93)	-0.108(-1.14,0.93)	0.210	0.835
D5					
D5B	4.19(1.67)	4.29(1.53)	-0.09(-0.46,0.26)	-0.535	0.594
D5L	2.18(1.47)	2.06(1.33)	0.120(-0.20,0.44)	0.733	0.466
D5I	15.35(4.25)	15.08(4.13)	0.27(-0.75,1.2)	0.530	0.911

4.3 Descriptive summary of D1

Table 4.2 Descriptive statistics of D1 length measurements

	Mean (mm)	SD	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D1B	3.89	1.00	120	3.83	1.69	7.60	0.50	0.76	0.712
D1L	4.33	1.25	120	4.28	1.75	7.96	0.244	-0.011	0.986
D1I	9.37	1.69	120	9.16	4.23	14.34	0.180	0.23	0.569
D1S	14.85	3.64	120	15.32	2.11	23.79	-0.794	1.529	0.095

Table 4.2 summarizes the D1 length value for four aspects considered in this study, which are the buccal, lingual, inferior, and superior measurements respectively. The values included in the table was number, minimum, maximum, mean, SD, Median, skewness, kurtosis and K-S test value. There were 480 measurements to be made for D1, as there were four aspects at this position and both sides of the jaw were measured (120 hemimandibles) in this study.

Skewness describes asymmetry from the normal distribution in a set of statistical data and it can come in the form of "negative skewness" or "positive skewness", depending on whether data points are skewed to the left (negative skew) or to the right (positive skew) of the average data.

Based on the skewness and kurtosis values the data is fairly symmetrical. The Kolmogorov-Smirnov tests of normality for each aspect showed above in Table (4.2) and all values were more than 0.05, so the four aspects value can be considered approximately normally distributed.

4.3.1 Comparison of D1 length between ethnicity (Race)

Table 4.3 Comparison of D1 mean measurements by ethnicity (race)

D1	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value*
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D1B	4.15(1.01)	4.09(0.96)	3.43(0.88)	3.89(1.00)	7.14(2)	0.001
D1L	4.38 (1.29)	4.39 (1.10)	4.20 (1.38)	4.33 (1.25)	0.29(2)	0.749
D1I	9.12(1.84)	9.82(1.34)	9.15(1.79)	9.37(1.69)	2.21(2)	0.114
D1S	14.86(3.92)	14.56(3.51)	15.14(3.56)	14.85(3.64)	0.25(2)	0.779

* One-way ANOVA

Table 4.3 summarizes the D1 measurements means for the three races Malays, Chinese and Indians. Four aspects were considered which are the buccal, lingual, inferior and superior measurements.

In its simplest form ANOVA gives a statistical test of whether the means of the races are all equal. Therefore One-way ANOVA was conducted to indicate that there was a difference in the location of D1B between the races (p=0.001). Post-hoc Bonferroni's procedure was performed and the findings indicated that there was a difference in the location of D1B between Malays and Indians races (P=0.003) and between Chinese and Indians (P=0.007).

4.3.2 Descriptive summary of D1 location by gender

Table 4.4 Comparison of D1 mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	4.05(1.01)	3.73(0.97)	0.32(-0.40,0.68)	1.75(118)	0.081
D1L	4.42(1.40)	4.23(1.10)	0.19(-0.26,0.64)	0.83(118)	0.405
D1I	10.09(1.65)	8.64(1.40)	1.45(0.89,2.00)	5.17(118)	0.00
D1S	16.48(2.75)	13.23(3.72)	3.25(2.06,4.43)	5.43(118)	0.00

Table 4.4 summarizes the D1 measurements for the 4 aspects among gender. Generally the mean for the males is significantly greater than the mean for the females. In D1B the mean for the male is 0.32 mm larger compared to the mean for the females. In D1L the mean for the male is 0.19 mm larger compared to the mean for the females. While in D1I the mean for the male is 1.45 mm larger compared to the mean for the females. In D1S the mean for the male is 3.25 mm larger compared to the mean for the females.

A two tailed independent samples t-test ($\alpha = 0.05$) was used to compare the means among gender and it was found that there was a strong difference in length measurements between the two gender ($p=0.00$) at D1I and D1S while no significant difference were found between D1B and D1L ($p>0.05$).

4.3.3 Comparison of D1 value by ethnicity and gender
4.3.3.1 Descriptive summary of D1 by gender among Malays

Table 4.5 Comparison of D1 mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	4.16(0.99)	4.15(1.06)	0.01(-0.64,0.67)	0.048(38)	0.962
D1L	4.79(1.28)	3.98(1.19)	0.80(0.01,1.60)	2.05(38)	0.047
D1I	10.30(1.35)	7.95(1.49)	2.34(1.42,3.26)	5.18(38)	0.000
D1S	17.33(2.37)	12.38(3.60)	4.95(2.99,6.90)	5.12(38)	0.000

Table 4.5 summarizes the D1 length means measurements for Malay males and Malay females. According to the histogram the data are normally distributed so a two tailed independent samples t-test (α=0.05) was used to compare the means between male and female among Malays. According to SPSS output, the result showed there was no significant difference in the location of D1B between gender among Malays (p=0.962), whereas there were differences in the location of D1L, D1I, and D1S between gender among Malays with P values 0.047, 0.00, and 0.00 respectively.

The mean for the Malay males was greater than the mean for Malay females in all aspects as shown in the 2nd and 3rd column in the above table.

4.3.3.2 Descriptive summary of D1 by gender among Chinese

Table 4.6 Comparison of D1 mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	4.34(1.10)	3.84(0.74)	0.50(-0.10,1.10)	1.68(38)	0.100
D1L	4.38(1.21)	4.41(1.02)	-0.022(-0.74,0.69)	0.06(38)	0.951
D1I	10.18(1.55)	9.47(1.02)	0.71(-0.13,1.55)	1.70(38)	0.096
D1S	15.76(2.84)	13.36(3.77)	2.40(0.26,4.54)	2.27(38)	0.029

Table 4.6 summarizes the D1 length mean for Chinese males and Chinese females. Independent T-test results indicated that there was no difference in the locations of D1B, D1L and D1I between gender among Chinese - p=0.100, p=0.951 and p=0.096 respectively, whereas there were differences in the location of D1S between gender among Chinese (p=0.029).

The mean for the Chinese males is greater than the mean for Chinese females in all aspects as shown in the 2nd $_{and}$ 3rd column in the above table.

4.3.3.3 Descriptive summary of D1 by gender among Indians

Table 4.7 Comparison of D1 mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	3.65(0.85)	3.20(0.87)	0.44(-0.11,0.99)	1.60(38)	0.117
D1L	4.10(1.64)	4.31(1.08)	-0.20(-1.10,0.68)	-0.466(38)	0.644
D1I	9.80(2.02)	8.51(1.26)	1.29(0.21,2.37)	2.43(38)	0.020
D1S	16.34(2.90)	13.94(3.81)	2.40(0.22,4.57	2.23(38)	0.031

Table 4.7 summarizes the D1 length mean for Indian males and Indian females. Independent samples t-test (α =0.05) results indicated that there was no difference in the locations of D1B and D1L between gender among Indians - p=0.117 and p=0644 respectively, whereas there was a difference in the location of D1I and D1S, p=0.020 and P=0.03 respectively.

The mean for the Indian males is greater than the mean for Indian females in all aspects except for D1L where the mean of Indians male is 0.20 mm less than the mean for Indian females.

4.3.4 Comparison of D1 value with age groups

Table 4.8 Comparison of D1 mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 years (n=12)	31-40 years (n=22)	41-50 years (n=38)	51-60 years (n=48)		
D1B	4.08(0.68)	4.19(0.89)	3.90(0.88)	3.70(1.17)	1.37(3)	0.254
D1L	3.71(2.02)	4.13(1.05)	4.24(1.15)	4.64(1.13)	2.23(3)	0.088
D1I	10.08(2.24)	9.61(1.61)	8.95(1.50)	9.41(1.68)	1.68(3)	0.174
D1S	17.09(2.21)	17.16(2.30)	14.12(3.85)	13.82(3.63)	7.17(3)	0.000

The comparison of D1 length mean between age groups is summarized in Table 4.8, where mean, SD, number, F-statistics and P value were included.

To test the difference between these 4 age groups, One-way ANOVA was used as the inferential statistical method. These inferential statistical techniques require some assumption that needs to be met before conducting such techniques to test the difference between different age groups of participants. This assumption is the normality of D1 aspects data. Exploring data can help to determine whether the statistical techniques that the researcher is considering for data analysis are appropriate or not. SPSS statistical software provides a variety of visual and numerical summaries of the data, either for all cases or separately for groups of cases. The exploration may indicate to use nonparametric tests. In this study, graphical and numerical methods were used to check the assumptions of normality of the data.

According to SPSS results, there were statistical difference in the location of D1S among age groups (p=0.000). Further post-hoc Bonferroni's procedure indicates that there was a difference in the location of D1S between age group 21-30 years and age group 51-60 years at p= 0.021 and between age group 31-40 years and 41-50 years at p = 0.007 and between age group 31-40 years and age group 51-60 years at p = 0.001. While no significant differences were statistically found with other measurements.

4.4 Descriptive summary of D2

Table 4.9 Descriptive statistics of D2 length measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D2B	5.59	1.20	120	5.46	2.45	8.83	0.362	0.218	0.712
D2L	3.35	1.20	120	3.20	0.62	6.15	0.051	-0.578	0.986
D2I	8.24	1.69	120	8.23	5.05	12.98	0.148	-0.452	0.569
D2S	13.94	3.85	120	14.25	1.92	22.47	-0.596	0.844	0.095

Table 4.9 summarizes the D2 length value for 4 aspects considered in this study, which are the buccal, lingual, inferior, and superior measurements respectively. There were 480 measurements to be made for D2, as there were four aspects at this position and both sides of the jaw were measured (120 hemimandibles) in this study.

Based on the skewness and kurtosis values the data is fairly symmetrical. The Kolmogorov-Smirnov tests of normality for each aspect showed values were more than 0.05 and therefore can be considered approximately normally distributed.

4.4.1 Comparison of D2 length between ethnicity (Race)

Table 4.10 Comparison of D2 mean measurements by ethnicity (race)

D2	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D2B	5.62(1.08)	6.01(1.13)	5.14(1.24)	5.59(1.20)	5.56(2)	0.005
D2L	3.34(1.13)	3.63(1.17)	3.06(1.25)	3.35(1.20)	2.28(2)	0.106
D2I	8.11(1.73)	8.90(1.51)	7.71(1.63)	8.24(1.69)	5.46(2)	0.005
D2S	13.75(4.36)	13.54(3.98)	14.52(3.12)	13.94(3.85)	0.704(2)	0.497

Table 4.10 summarizes the D2 measurements means for the three races - Malays, Chinese and Indians. Four aspects were considered which are the buccal, lingual, inferior and superior measurements.

One-Way ANOVA test indicated that there was a significant difference in the location of D2B and D2I between the races - p=0.005 and p=0.005 respectively. Post-hoc Bonferroni's procedure indicated that there was a difference in the measurements of D2B between Chinese and Indians races (p=0.003) and there was a difference in the location of D2I between Chinese and Indian races (p=0.005).

4.4.2 Descriptive summary of D2 location by gender

Table 4.11 Comparison of D2 mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D2B	5.67(1.21)	5.51(1.19)	0.157(-0.27,0.59)	0.718(118)	0.474
D2L	3.38(1.30)	3.31(1.10)	0.06(-0.37,0.50)	0.28(118)	0.774
D2I	8.96(1.63)	7.52(1.43)	1.43(0.88,1.99)	5.13(118)	0.00
D2S	15.64(3.01)	12.23(3.86)	3.41(2.16,4.66)	5.39(118)	0.00

Table 4.11 summarizes the D2 measurements for the four aspects among the gender. The mean for the male in D2B is 0.15 mm larger compared to the mean for the females. In D2L the mean for the male is 0.06 mm larger compared to the mean for the females. While in D2I the mean for the male is 1.43 mm larger compared to the mean for the females and lastly in D2S the mean for the male is 3.41 mm larger compared to the mean for the females.

The independent T-test indicated that there were a strong differences in the length measurements of D2I and D2S between the two gender p=0.00 and p=0.00 respectively. While no significant difference were found in the length measurements of D2B and D2L between the two gender, P=0.474 and P= 0.774 respectively.

4.4.3 Comparison of D2 value by ethnicity and gender

4.4.3.1 Descriptive summary of D2 by gender among Malays

Table 4.12 Comparison of D2 mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D2B	5.64(1.07)	5.60(1.13)	0.037 (-0.66,0.74)	0.107(38)	0.915
D2L	3.56(1.25)	3.13(0.99)	0.425 (-0.298,1.149)	1.190(38)	0.241
D2I	9.31(1.36)	6.91(1.13)	2.40(1.59,3.20)	6.048(38)	0.000
D2S	16.39(2.73)	11.12(4.12)	5.27(3.03,7.51)	4.77(38)	0.000

Table 4.12 summarizes the D2 length mean for Malay males and Malay females. Independent T-test results indicated that there was no significant difference in the locations of D2B and D2L between the gender among Malays, P=0.915 and P=0.24 respectively, whereas there were a strong significant differences in the measurements of D2I, and D2S with P values 0.00 and 0.00 respectively.

The mean for the Malay males is greater than the mean for Malay females in all aspects as shown in the 2nd and 3rd column in the above table.

4.4.3.2 Descriptive summary of D2 by gender among Chinese

Table 4.13 Comparison of D2 mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D2B	6.06(1.12)	5.95(1.17)	0.109(-0.62,0.84)	0.302(38)	0.765
D2L	3.87(1.22)	3.39(1.10)	0.486(-0.261,1.234)	1.371(38)	0.196
D2I	9.40(1.54)	8.40(1.34)	1.00(0.076,1.93)	2.19(38)	0.035
D2S	14.89(3.81)	12.20(3.77)	2.69(0.266,5.12)	2.24(38)	0.031

Table 4.13 summarizes the D2 length mean for Chinese males and Chinese females. Independent T-test results indicated that there was no difference in the locations of D2B and D1L between gender among Chinese, p=0.765 and p=0.196 respectively, whereas there were significant differences in the location of D2I and D2S between gender among Chinese p=0.035 and p=0.031 respectively.

The mean for the Chinese males is greater than the mean for the Chinese females in all aspects as shown in the 2nd and 3rd column in the above table.

4.4.3.3 Descriptive summary of D2 by gender among Indians

Table 4.14 Comparison of D2 mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D2B	5.31(1.36)	4.98(1.11)	0.828(0.47,1.12)	0.828(38)	0.413
D2L	2.70(1.19)	3.42(1.23)	-0.721(-1.49,0.056)	-1.87(38)	0.068
D2I	8.17(1.75)	7.25(1.40)	0.91(-0.10,1.93)	-1.81(38)	0.077
D2S	15.65(2.21)	13.38(3.52)	2.26(0.381,4.148)	2.434(38)	0.020

Table 4.14 summarizes the D2 length mean for Indian males and Indian females. Independent T-test results indicated that there was a difference in the measurements of D2S between gender among Indians (p=0.020), whereas there were no differences in the measurements of D2B, D2L and D2I between gender among Indians P=0.413, P=0.068 and P=0.077 respectively.

The mean for the Indian males is greater than the mean for Indian females in all aspects except for D2L where was the mean of Indians male is 0.72 mm lesser than the mean for Indian females.

4.4.3 Comparison of D2 value with age groups

Table 4.15 Comparison of D2 mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 years (n=12)	31-40 years (n=22)	41-50 years (n=38)	51-60 years (n=48)		
D2B	6.19(1.32)	5.59(1.13)	5.48(1.09)	5.53(1.27)	1.16(3)	0.328
D2L	2.36(1.22)	3.59(1.30)	3.33(1.18)	3.49(1.07)	3.42(3)	0.020
D2I	7.38(1.76)	8.99(1.80)	7.94(1.38)	8.35(1.73)	3.06(3)	0.031
D2S	16.18(1.44)	15.42(2.59)	12.98(4.50)	13.46(3.84)	3.70(3)	0.014

The comparison of D2 length mean between age groups is summarized in Table 4.15. One-Way ANOVA statistical test was conducted for each aspect and P value was listed in the last column above.

According to SPSS output, the result showed there was no statistical difference in the locations of D2B among age groups (p=0.328), whereas there were statistical differences among age groups in D2L, D2I, and D2S with P-values 0.02, 0.031 and 0.014 respectively.

Further Post-hoc Bonferroni's procedure indicates that there were differences in the measurements of D2L between age group 21-30 years and age group 31-40 years at p = 0.024; between age group 21-30 years and age group 51-60 years at p = 0.020 and there was a difference in the measurements of D2I between age group 21-30 years and age group 31-40 years at p = 0.046.

The test of homogeneity for D2S indicated that post-hoc Dunnett test should be conducted to examine the difference between the age groups and it showed that there was a difference in the location of D2S between age group 21-30 years and between age group 31-40 years at p = 0.002. And also there was a difference in the location D2S between age group 21-30 years and between age group 41-50 years at p = 0.002.

4.5 Descriptive summary of D3

Table 4.16 Descriptive statistics of D3 length measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D3B	6.71	1.34	120	6.55	2.58	10.01	0.22	0.12	0.316
D3L	3.25	1.32	120	3.18	0.77	6.81	0.29	-0.40	0.762
D3I	7.96	1.93	120	7.80	2.91	12.48	-0.01	-0.08	0.937
D3S	12.99	4.08	120	13.46	1.35	22.37	-0.34	-0.27	0.343

Table 4.16 summarizes the D3 length value for the 4 aspects considered in this study, which are the buccal, lingual, inferior, and superior measurements respectively. There were 480 measurements to be made for D3, as there were four aspects at this position and both sides of the jaw were measured (120 hemimandibles). Number, minimum, maximum, mean, SD, median, skewness, kurtosis and K-S test value were included for each aspect.

Based on the skewness and kurtosis values the data is fairly symmetrical, the Kolmogorov-Smirnov tests of normality for each aspects is shown in Table 4.16 and the values are more than 0.05. Therefore the four aspects measurements can be considered as normally distributed.

4.5.1 Comparison of D3 length between ethnicity (Race)

Table 4.17 Comparison of D3 mean measurements by ethnicity (race)

D3	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D3B	6.84(1.22)	7.07(1.38)	6.22(1.28)	6.71(1.34)	4.57(2)	0.012
D3L	3.39 (1.26)	3.57 (1.23)	2.78 (1.38)	3.25 (1.32)	4.06(2)	0.020
D3I	7.70(1.83)	8.81(1.55)	7.35(2.03)	7.96(1.93)	6.81(2)	0.002
D3S	12.34(4.41)	12.92(4.18)	13.7(3.59)	12.99(4.08)	1.140(2)	0.323

Table 4.17 summarizes the number, mean, SD, Total Mean, F-statistics, df value and P value for D3 among the three races - Malays, Chinese and Indians. Four aspects were considered which are the buccal, lingual, inferior and superior measurements.

One-Way ANOVA test indicated that there were significant differences in the location of D3B, D3L, and D3I with P values 0.012, 0.020, and 0.002 respectively.

Post-hoc Bonferroni's procedure indicated that there was a difference in the measurements of D3B between the Chinese and Indian races (p=0.013). At D3L there was also a difference between the Chinese and Indian races (p=0.023). At D3I there was a difference in the length measurements between the Chinese and Indians (p=0.002) and between Malays and Chinese (p = 0.024).

4.5.2 Descriptive summary of D3 location by gender

Table 4.18 Comparison of D3 mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	6.88(1.44)	6.53(1.21)	0.35(-0.12,0.83)	1.46(118)	0.146
D3L	3.36(1.50)	3.14(1.12)	0.22(-0.25,0.70)	0.92(118)	0.356
D3I	8.46(1.93)	7.45(1.81)	1.00(0.32,1.68)	2.94(118)	0.004
D3S	14.11(3.89)	11.88(3.98)	2.23(0.81,3.65)	3.10(118)	0.002

Table 4.18 summarizes the D3 measurements for the 4 aspects among gender. Mean, SD, Mean difference, t-statistics, df value and P value were included of each aspect. The mean for the male in D3B is 0.35 mm larger compared to the mean for the females. In D3L the mean for the male is 0.22 mm larger compared to the mean for the females. In D3I the mean for the male is 1.00 mm larger compared to the mean for the females and lastly in D3S the mean for the male is 2.23 mm larger compared to the mean for the females.

The independent T-test indicated that there was a strong difference in the length measurements of D3I and D3S between the two gender, P=0.004 and P=0.002 respectively.

4.5.3 Comparison of D3 value by ethnicity and gender
4.5.4.1 Descriptive summary of D3 by gender among Malays

Table 4.19 Comparison of D3 mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D3B	7.24(0.91)	6.44(1.38)	0.79(0.04,1.55)	2.14(38)	0.038
D3L	3.60(1.42)	3.19(1.08)	0.41(-0.39,1.22)	1.03(38)	0.310
D3I	8.98(1.24)	6.42(1.37)	2.55(1.71,3.39)	6.15(38)	0.000
D3S	14.09(3.57)	10.59(4.54)	3.49(0.87,6.11)	2.70(38)	0.010

Table 4.19 summarizes the D3 length mean for Malay males and Malay females. Independent T-test results were utilized to compare between the gender among Malays. According to SPSS output, the result showed there were difference in the locations of D3B, D3I and D3S between gender among Malays with P values 0.038, 0.000 and 0.01 respectively. However there was no difference in the measurements of D3L between gender among Malays (p=0.310).

The mean for the Malay males is greater than the mean for Malay females in all aspects as shown in the 2^{nd} $_{and}$ 3^{rd} column in the above table.

4.5.3.2 Descriptive summary of D3 by gender among Chinese

Table 4.20 Comparison of D3 mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D3B	7.08(1.53)	7.05(1.25)	0.02(-0.86,0.92)	0.06(38)	0.947
D3L	3.90(1.42)	3.24(0.92)	0.65(-0.11,1.42)	1.73(38)	0.091
D3I	9.07(1.66)	8.56(1.63)	0.51(-0.54,1.57)	0.98(38)	0.331
D3S	13.46(4.52)	12.38(3.84)	1.07(-1.61,3.76)	0.81(38)	0.423

Table 4.20 summarizes the D3 length mean for Chinese males and Chinese females.

It was necessary to determine if there is a significant difference in the means between the gender in the Chinese. Independent samples t-test (α=0.05) was used to compare the means. According to SPSS output, the result showed there were no differences in all the aspects of the measurements between gender among Chinese as shown in the last column.

The mean for the Chinese males is greater than the mean for Chinese females in all aspects as shown in the 2nd and 3rd column in the above table.

4.5.3.3 Descriptive summary of D3 by gender among Indians

Table 4.21 Comparison of D3 mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D3B	6.34(1.67)	6.10(0.75)	0.24(-0.59,1.07)	0.58(38)	0.562
D3L	2.58(1.41)	2.98(1.36)	-0.39(-1.28,0.49)	-0.90(38)	0.374
D3I	7.33(2.28)	7.38(1.80)	-0.04(-1.36,1.27)	-0.07(38)	0.944
D3S	14.78(3.58)	12.65(3.35)	2.13(-0.09,4.35)	1.94(38)	0.060

Table 4.21 summarizes the D3 length mean for Indian males and Indian females. It was necessary to determine if there was significant mean difference between gender among Indians. Independent samples t-test (α=0.05) was used to compare the means and the result showed there was no difference in the location of all aspects between gender among Indians as shown in the last column.

The mean for the Indians males is greater than the mean for Indian females in all aspects, except for D3L and D3I where the mean of Indian male is 0.39 and 0.04 lesser than the mean for Indian females.

4.5.3 Comparison of D3 value with age groups

Table 4.22 Comparison of D3 mean measurements between age groups

	Length measurements Mean (SD)				F-Statistics	P value
	21-30 years (n=12)	31-40 years (n=22)	41-50 years (n=38)	51-60 years (n=48)		
D3B	7.29(1.39)	7.16(1.08)	6.34(1.37)	6.64(1.33)	2.67(3)	0.050
D3L	1.94(0.99)	3.73(1.71)	3.32(1.16)	3.30(1.14)	5.47(3)	0.001
D3I	5.85 (1.41)	8.60(1.72)	7.93(1.91)	8.21(1.84)	6.66(3)	0.000
D3S	15.15(1.97)	12.98(3.43)	12.33(4.82)	12.98(4.01)	1.46(3)	0.227

The comparison of D3 length mean between age groups is summarized in Table 4.22 where number, mean, SD, Total Mean, F-statistics, df value and P value were included. One-Way ANOVA statistical test is conducted for each aspect and P value is listed in the last column.

There was a statistical difference in the locations of D3L and D3I among age groups, P=0.001 and P=0.000 respectively. Post-hoc Bonferroni's procedure indicates that there is a difference in the location of D3L between age group 21-30 years and age group 31-40 years, 41-50 years, and 51-60 years at P= 0.001, P= 0.007 and P=0.007 respectively.

Post-hoc Bonferroni's procedure for D3I indicated that there were differences in the location of D3I between age group 21-30 years and age group 31-40 years, 41-50 years, and 51-60 years at p= 0.000, 0.004 and 0.001 respectively.

4.6 Descriptive summary of D4

Table 4.23 Descriptive statistics of D4 length measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	Ks Value
D4B	5.68	1.63	120	5.69	2.42	9.15	0.146	-0.510	0.832
D4L	3.08	1.46	120	2.98	.48	7.03	0.423	-0.464	0.329
D4I	9.65	2.54	120	9.76	2.09	15.60	-0.203	0.377	0.625
D4S	14.22	4.02	120	14.32	3.78	24.90	-0.020	0.105	0.890

Table 4.23 summarizes the D4 length value for 4 aspects considered in this study, which are the buccal, lingual, inferior, and superior measurements respectively. There were 480 measurements to be made for D4, as there were four aspects at this position and both sides of the jaw were measured (120 hemimandibles). Number, minimum, maximum, mean, SD, median, skewness, kurtosis and K-S test value for all aspects were included as shown in the above table.

Based on the skewness and kurtosis values the data is fairly symmetrical, the Kolmogorov-Smirnov tests of normality for each aspect showed in Table 4.23 and all values were more than 0.05, so the four aspect values can be considered approximately normally distributed.

4.6.1 Comparison of D4 length between ethnicity (Race)

Table 4.24 Comparison of D4 mean measurements by ethnicity (race)

D4	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D4B	5.92(1.60)	6.30(1.56)	4.83(1.38)	5.68(1.63)	9.98(2)	0.000
D4L	3.18 (1.64)	3.38 (1.32)	2.67(1.34)	3.08 (1.46)	2.57(2)	0.081
D4I	9.24(2.77)	10.59(2.04)	9.13(2.54)	9.65(2.54)	4.31(2)	0.016
D4S	13.49(4.34)	15.04(3.91)	14.13(3.73)	14.22(4.02)	1.52(2)	0.223

Table 4.24 summarizes the D4 measurements means for the three races Malays, Chinese and Indians. Four aspects were considered which are the buccal, lingual, inferior and superior measurements.

One-Way ANOVA test indicated that there was a difference in the location of D4B between the races (p=0.000). Post-hoc Bonferroni's procedure indicated that there was a difference in the location of D4B between Malays and Indians (p=0.005) and between Chinese and Indians (p=0.000).

Post-hoc Bonferroni's procedure was conducted for D4I and it indicated that there was a difference in the location of D4I between Malays and Chinese races (p=0.049) and between Chinese and Indians (p=0.028).

4.6.2 Descriptive summary of D4 location by gender

Table 4.25 Comparison of D4 mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D4B	6.09(1.69)	5.28(1.47)	0.80(0.23,1.38)	2.78(118)	0.006
D4L	3.26(1.65)	2.90(1.23)	0.36(-0.16,0.89)	1.36(118)	0.174
D4I	9.86(2.46)	9.45(2.62)	0.40(-0.51,1.32)	0.86(118)	0.388
D4S	14.61(4.18)	13.84(3.84)	0.76(-0.68,2.22)	1.04(118)	0.297

Table 4.25 summarizes the D4 measurements for the 4 aspects among gender. The mean for the male in D4B is 0.80 mm larger compared to the mean for the females. In D4L the mean for the male is 0.36 mm larger compared to the mean for the females. While in D4I the mean for the male is 1.40 mm larger compared to the mean for the females. In D4S the mean for the male is 0.76 mm larger compared to the mean for the females.

The interest was in determining if there was any significant mean difference between the two gender at D4. A two tailed independent samples t-test was conducted to compare the means. Results showed that there was a significant difference among gender in the length measurements of D4B only (p=0.006).

4.6.3 Comparison of D4 value by ethnicity and gender

4.6.3.1 Descriptive summary of D4 by gender among Malays

Table 4.26 Comparison of D4 mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D4B	6.64(1.20)	5.20(1.65)	1.44(0.52,2.37)	3.161(38)	0.003
D4L	3.40(2.00)	2.96(1.20)	0.44(-0.61,1.50)	0.845(38)	0.403
D4I	10.45(2.01)	8.03(2.94)	2.42(0.81,4.03)	3.041(38)	0.004
D4S	13.93(4.02)	13.05(4.69)	0.88(-1.91,3.68)	0.637(38)	0.528

Table 4.26 summarizes the D4 length mean for Malay males and Malay females. Independent T-test results indicated that there was a significant difference in the measurements of D4B and D4I between the gender among Malays, p=0.003 and p=0.004 respectively.

The mean for the Malay males is greater than the mean for the Malay females in all aspects as shown in the 2nd and 3rd column in the above table.

4.6.3.2 Descriptive summary of D4 by gender among Chinese

Table 4.27 Comparison of D4 mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D4B	6.37(1.89)	6.23(1.20)	0.13(-0.88,1.15)	0.271(38)	0.788
D4L	3.59(1.46)	3.18(1.16)	0.41(-0.43,1.25)	0.979(38)	0.334
D4I	10.49(1.93)	10.69(2.20)	-0.19 (-1.52,1.13)	-0.295(38)	0.769
D4S	14.84(4.07)	15.24(3.83)	-0.39(-2.93,2.14)	-0.316(38)	0.754

Table 4.27 summarizes the D4 length mean for Chinese males and Chinese females. It was necessary to determine if there was a significant mean difference between the two gender among Chinese. Independent samples t-test (α=0.05) was utilized and the results indicated that there was no difference in the measurements of D4 with all aspects.

The mean for the Chinese male is greater than the mean for the Chinese females in D4B and D4L, whereas the mean for the Chinese female is greater than the mean for the Chinese males in D4I and D4S as shown in the 2nd and 3rd column in the above table.

4.6.3.3 Descriptive summary of D4 by gender among Indians

Table 4.28 Comparison of D4 mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D4B	5.25(1.65)	4.41 (0.89)	0.83(-0.01,1.69)	1.989(38)	0.054
D4L	2.79(1.40)	2.55(1.31)	0.24(-0.62,1.11)	0.562(38)	0.577
D4I	8.62(2.94)	9.64(2.02)	-1.02(-2.64,0.59)	-1.280(38)	0.208
D4S	15.05(4.57)	13.22(2.43)	1.82(-0.52,4.16)	1.574(38)	0.124

Table 4.28 summarizes the D4 length mean measurements for Indian males and Indian females. Independent samples t-test (α=0.05) was used to compare the means and the SPSS

results indicated that there was no difference in the location of D4 for all aspects between the gender among Indians.

The mean for the Indians males is greater than the mean for Indian females in all aspects except for D4I where the mean of Indian males is 1.28 mm lesser than the mean for Indian females.

4.6.4 Comparison of D4 value with age groups

Table 4.29 Comparison of D4 mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics (df)	P value
	21-30 years (n=12)	31-40 years (n=22)	41-50 years (n=38)	51-60 years (n=48)		
D4B	5.78 (1.53)	6.71(1.14)	5.63(1.51)	5.23(1.75)	4.549(3)	0.005
D4L	2.72 (1.29)	3.56(1.79)	2.93(1.36)	3.07(1.40)	1.158(3)	0.329
D4I	7.18(1.53)	9.58(2.24)	9.82(2.93)	10.17(2.21)	4.973(3)	0.003
D4S	14.66(2.60)	12.94(3.60)	13.23(4.28)	15.48(3.98)	3.319(3)	0.022

The comparison of D4 length mean measurements between age groups is summarized in Table 4.29. One-Way ANOVA statistical test was conducted for each aspect and P value is listed in the last column.

There was no statistical difference in the measurements of D4L among age groups (p=0.329) whereas statistical difference exist in the rest three aspects (D4B, D4I and D4S) with P values 0.005, 0.003 and 0.022 respectively. Further Post-hoc Bonferroni's procedure indicates that there was a difference in the measurements of D4B between age group 31-40 years and age group 51-60 years at the level of 0.05 (p=0.002).

Post-hoc Bonferroni's procedure indicated that there were differences in the location of D4I between age group 21-30 years and age group 31-40 years at p= 0.040 and between age group 21-30 years and age group 41-50 years at P=0.008 , and lastly between age group 21-30 years and age group 51-60 years at P= 0.001. Further Post-hoc Turkey HSD procedure indicated that there was a difference in the measurements of D4S between age group 41-50 years and age group 51-60 years at p= 0.045.

4.7 Descriptive summary of D5

Table 4.30 Descriptive statistics of D5 length measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	Ks Value
D5B	4.24	1.59	120	4.02	1.09	8.83	0.381	-0.064	0.600
D5L	2.12	1.40	120	1.74	0.00	6.54	1.011	0.820	**0.021**
D5I	15.21	4.18	120	14.99	3.49	25.99	0.157	0.291	0.479

Table 4.30 summarizes the D5 length values for three aspects considered in this study, which are the buccal, lingual, and inferior measurements respectively. There were 360 measurements to be made for D5, as there were three aspects at this position and both sides of the jaw were measured (120 hemimandibles). Based on the skewness and kurtosis values for D5B and D5I they showed that the mean value for them was fairly symmetrical, and the data can be considered as normally distributed. The Kolmogorov-Smirnov tests of normality for each aspect shown above in Table 4.30 and all the values were more than 0.05 except for D5L. However, abnormality in distribution was confirmed by Kolmogorov-Smirnov statistical test for D5L which led us to use non-parametric to compare means among different groups.

4.7.1 Comparison of D5 length between ethnicity (Race)

Table 4.31 Comparison of D5 mean measurements by ethnicity (race)

D5	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D5B	4.12(0.94)	5.14(1.71)	3.47(1.58)	4.24(1.59)	13.379(2)	0.000
D5L	2.23 (1.52)	2.03 (1.17)	2.10(1.49)	2.12 (1.40)	0.205(2)	0.990*
D5I	14.49(4.11)	16.05(3.56)	15.10(4.73)	15.21(4.18)	1.427(2)	0.244

* Non parametric test

Table 4.31 summarizes the D4 measurements means for the three races Malays, Chinese and Indians. Three aspects were considered which are the buccal, lingual, and inferior measurements.

One-Way ANOVA test indicated that there was a difference in the location of D5B between the races (p=0.000). Further Post-hoc Bonferroni's procedure indicated that there was a difference in the measurements of D5B between Malays and Chinese (p=0.006), and there was a difference in the measurements of D5B between Chinese and Indians (p=0.000).

4.7.2 Descriptive summary of D5 location by gender

Table 4.32 Comparison of D5 mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D5B	4.07(1.48)	4.41(1.69)	-0.33(-0.91,0.23)	-1.160(118)	0.248
D5L	2.34(1.60)	1.91(1.13)	0.42(-0.07,0.93)	1.691(118)	0.324*
D5I	15.03(4.25)	15.40(4.12)	-0.37(-1.89,1.14)	-0.488(118)	0.626

* Non Parametric test

Table 4.32 summarizes the D5 measurements for the 3 aspects among gender. The mean for the male in D5B is 0.33 mm less compared to the mean for the females. In D5L the mean for the male is 0.42 mm larger compared to the mean for the females. While in D5I the mean for the male is 0.37 mm less compared to the mean for the females.

The interest was in determining if there was any significant difference in the mean between these two gender and Independent samples t-test was used to compare the means for D5B and D5I. Non Parametric Kruskal-Wallis Test was utilized to compare the means for D5L. Results showed no statistical significant difference between the two gender for all aspects at D5 location.

4.7.3 Comparison of D5 value by ethnicity and gender

4.7.3.1 Descriptive summary of D5 by gender among Malays

Table 4.33 Comparison of D5 mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D5B	4.44(0.93)	3.80(0.86)	0.63(0.06,1.21)	2.244(38)	0.031
D5L	2.26(1.83)	2.20(1.20)	0.05(-0.93,1.05)	0.122(38)	0.525*
D5I	15.03(4.13)	13.95(4.12)	1.07(-1.57,3.71)	0.821(38)	0.417

* Non Parametric test

Table 4.33 summarizes the D5 length mean for the Malay males and the Malay females. Independent T-test results indicated that there was a difference in the measurements of D5B between gender among Malays (p=0.031), whereas there was no difference in the measurements of D5L and D5I with P values 0.904 and 0.904 respectively.

The mean for the Malay males is greater than the mean for the Malay females in all aspects as shown in the 2^{nd} and 3^{rd} column in the above table.

4.7.3.2 Descriptive summary of D5 by gender among Chinese

Table 4.34 Comparison of D5 mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D5B	4.43(1.50)	5.84(1.63)	-1.40(-2.41,-0.39)	-2.827(38)	0.007
D5L	2.53(1.28)	1.53(0.81)	1.00(-0.31,1.69)	2.963(38)	0.008*
D5I	15.80(3.100)	16.30(4.04)	-0.49 (-21.80,1.80)	-0.438(38)	0.664

* Non Parametric test

Table 4.34 summarizes the D5 length mean for Chinese males and Chinese females. Independent T-test results indicated that there was no difference in the measurements of D5I between gender among Chinese (p=0.664), whereas significant differences were found in D5B and D5l with P values 0.007 and 0.008 respectively.

Non parametric test was utilized to compare abnormally distributed means for D5L. Such abnormality in distribution assumptions was confirmed by Kolmogorov-Smirnov statistical test which led us to use non-parametric t-test (Mann-Whiteny U test) to compare means of female and male groups among Chinese. Results showed that there was a significant difference in D5L measurements between gender among Chinese.

The mean for the Chinese males is greater than the mean for Chinese females in D5L aspects only whereas means of other measurements were greater for Chinese females as shown in the 2nd and 3rd column in the above table.

4.7.3.3 Descriptive summary of D5 by gender among Indians

Table 4.35 Comparison of D5 mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D5B	3.35(1.68)	3.59 (1.51)	-0.24(-0.01,1.69)	-0.480(38)	0.634
D5L	2.21(1.70)	1.99(1.29)	0.22(-0.62,1.11)	0.464(38)	0.968*
D5I	14.25(5.32)	15.94(4.02)	-1.69(-2.64,0.59)	-1.135(38)	0.263

* Non Parametric test

Table 4.35 summarizes the D5 length mean for Indian males and Indian females. Independent T-test results was conducted for D5B and D5I and results indicated that there was no significant difference between gender among Indians (p=0.634 and P=0.263) respectively, whereas non parametric test was conducted for D5L and also no significant difference was found between gender among Indians.

The mean for the Indian males is greater than the mean for the Indian females in D5L only whereas in D5B and D5I, the mean of Indian males is 0.24 mm and 1.69 mm less than the mean for Indian females.

4.7.4 Comparison of D5 value with age groups

Table 4.36 Comparison of D5 mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics (df)	P value
	21-30 years (n=12)	31-40 years (n=22)	41-50 years (n=38)	51-60 years (n=48)		
D5B	3.84 (1.96)	4.57(1.42)	4.16 (1.80)	4.27(1.40)	0.596(3)	0.919
D5L	2.23 (1.20)	2.83(1.89)	1.92(1.07)	1.93(1.34)	2.544(3)	0.256*
D5I	11.80(3.69)	14.26(3.33)	15.76(4.24)	16.07(4.18)	4.269(3)	0.007

* Non parametric test

The comparison of D5 length mean measurements between age groups is summarized in Table 4.36. Statistical test was conducted for each aspect and P value was listed in the last column.

There was a statistical difference in the measurements of D5I among age groups (p=0.007). Post-hoc Bonferroni's procedure indicates that there was a significant difference in the measurements of D5I between age group 21-30 years and age group 41-50 years at p= 0.021, and there was a difference in the measurements of D5I between age group 21-30 years and age group 51-60 years at p= 0.008.

4.8 Descriptive summary of the mandibular canal diameter

Table 4.37 Descriptive statistics of the mandibular canal diameter measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D1MCd	2.25	0.47	120	2.23	1.06	3.45	0.095	-0.31	0.86
D2MCd	2.01	0.42	120	1.96	1.26	3.19	0.57	-0.18	0.27
D3MCd	2.10	0.37	120	2.08	1.35	3.24	0.22	-0.14	0.79
D4MCd	2.18	0.42	120	2.13	1.14	3.83	0.68	1.35	0.57
D5MCd	2.25	0.43	120	2.20	1.34	3.91	0.92	2.27	0.33
MCd average	2.16	0.30	120	2.14	1.54	2.98	0.30	-0.24	0.76

Table 4.37 summarizes the MC diameter value for five locations considered in this study (D1-D5). There were 120 measurements for each location (60 on the left side and 60 on the right side) as the total was 600 measurements.

Based on the skewness and kurtosis values the data is fairly symmetrical, the Kolmogorov-Smirnov tests of normality for each location showed above in (Table 4.37), and all values were more than 0.05, so the five locations values can be considered approximately normally distributed.

Paired sample t-test was used to compare statistical difference between right and left side MC diameter average measurements. Results showed that there is significant difference of 0.16 mm between the 2 sides, which is of no value clinically. Figure 4.2A shows mandibular canal diameter measurement taken from this study sample.

4.8.1 Comparison of the mandibular canal diameter between ethnicity (Race)

Table 4.38 Comparison of the MC diameter mean measurements by ethnicity (race)

	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value*
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D1MCd	2.30(0.45)	2.19(0.41)	2.28(0.55)	2.25(0.47)	0.62(2)	0.53
D2MCd	2.00(0.05)	1.98(0.06)	2.04(0.07)	2.01(0.42)	0.22(2)	0.79
D3MCd	2.10(0.05)	2.04(0.06)	2.16(0.05)	2.10(0.37)	1.09(2)	0.33
D4MCd	2.27(0.07)	2.12(0.06)	2.14(0.05)	2.18(0.42)	1.41(2)	0.24
D5MCd	2.33(0.53)	2.27(0.28)	2.16(0.43)	2.25(0.43)	1.69(2)	0.18
MCd	2.20(0.28)	2.12(0.29)	2.16(0.33)	2.16(0.30)	0.69(2)	0.50

* One-way ANOVA

Table 4.38 summarizes the MC means measurements for the three races Malays, Chinese and Indians. Five positions were considered (D1-D5).

One-Way ANOVA test indicated that there was no difference in the mean diameter of MC among the races ($p>0.05$).

4.8.2 Descriptive summary of the mandibular canal diameter by gender

Table 4.39 Comparison of the mandibular canal diameter mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1MCd	2.37(0.39)	2.13(0.52)	0.23(0.07-0.40)	2.83(118)	0.005
D2MCd	2.20(0.44)	1.81(0.29)	0.38(0.24-0.25)	5.57(118)	0.00
D3MCd	2.24(0.33)	1.96(0.34)	0.28(0.15-0.40)	4.50(118)	0.00
D4MCd	2.36(0.41)	1.99(0.35)	0.36(0.22-0.50)	5.23(118)	0.00
D5MCd	2.34(0.49)	2.16(0.33)	0.17(0.02-0.32)	2.28(118)	0.02
MCd average	2.37(0.39)	2.13(0.52)	0.29(0.18-0.38)	5.93(118)	0.00

Table 4.39 summarizes the mandibular canal diameter measurements for the 5 locations among gender. The mean for the male in all locations was significantly larger compared to the mean for the females.

The statistical test for all positions indicated that there were a strong difference in the diameter of the mandibular canal measurements between the two gender (p=<0.05).

4.8.3 Comparison of the MC diameter value by ethnicity and gender

Table 4.40 Comparison of the MC mean measurements between gender among races

Malays	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.42(0.41)	2.17(0.45)	0.25(-0.02,0.53)	1.83(38)	0.07
D2MCd	2.06(0.36)	1.94(0.27)	0.12(-0.08,0.33)	1.23(38)	0.22
D3MCd	2.24(0.33)	1.96(0.29)	0.28(0.08,0.48)	2.86(38)	0.007
D4MCd	2.42(0.53)	2.12(0.39)	0.30(0.00,0.60)	2.02(38)	0.049
D5MCd	2.43(0.62)	2.23(0.40)	0.20(-0.13,0.53)	1.20(38)	0.23
MCd average	2.31(0.33)	2.08(0.18)	0.23(0.06,0.40)	2.75(38)	0.019
Chinese	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.38(0.29)	2.00(0.43)	0.38(0.14,0.61)	3.25	0.002
D2MCd	2.30(0.36)	1.66(0.23)	0.63(0.44,0.82)	6.60	0.000
D3MCd	2.25(0.37)	1.83(0.33)	0.42(0.19,0.65)	3.77	0.001
D4MCd	2.36(0.36)	1.88(0.25)	0.47(0.27,0.67)	4.80	0.000
D5MCd	2.29(0.32)	2.24(0.24)	0.04(-0.13.0.22)	0.52	0.606
MCd average	2.32(0.22)	1.92(0.20)	0.39(0.25,0.53)	5.74	0.000
Indians	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.32(0.46)	2.24(0.65)	0.08(-0.27,0.44)	0.46(38)	0.643
D2MCd	2.24(0.56)	1.84(0.32)	0.39(0.10,0.69)	2.71(38)	0.691
D3MCd	2.23(0.32)	2.09(0.37)	0.13(-0.08,0.36)	1.25(38)	0.217
D4MCd	2.30(0.31)	1.98(0.37)	0.31(0.10,0.53)	2.95(38)	0.005
D5MCd	2.30(0.50)	2.02(0.30)	0.28(0.01,0.54)	2.15(38)	0.038
MCd average	2.28(0.35)	2.03(0.25)	0.24(0.04,0.44)	2.48(38)	0.17

Table 4.40 summarizes the mandibular canal diameter mean for the three races among gender. Independent T-test results indicated that there was no difference in mandibular diameter measurements between gender among Malays at D1, D2 and D5 with P value 0.07, 0.22, and 0.23 respectively. While significant differences were found between gender among Malays at D3 and D4 with P values 0.007 and 0.049 respectively. The mean for the Malay males was greater than the mean for Malay females in all positions as shown in the 2nd and 3rd column in the above table.

While among Chinese, there was no difference in the diameter of the mandibular canal at D5MCd between gender (p=0.606), whereas there were strong significant differences in the MC diameter for the other positions (D1MCd-D4MCd). The MC diameter mean for the Chinese males is greater than the mean for Chinese females in all positions as shown in the 2nd and 3rd column in the above table.

Furthermore, results among Indians showed that there was no difference in the MC diameter at D1MCd, D2MCd and D3MCd; whereas there were significant differences in the MC diameter measurements at D4MCd and D5MCd with P values 0.005 and 0.038 respectively. The mandibular canal mean measurements for the Indian males are greater than the mean for Indian females in all positions.

4.8.4 Comparison of the MC diameter with age groups

Table 4.41 Comparison of the MC mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 (n=12)	31-40 (n=22)	41-50 (n=38)	51-60 (n=48)		
D1MCd	2.24(0.50)	2.28(0.32)	2.18(0.50)	2.30(0.51)	0.40	0.71
D2MCd	2.38(0.65)	1.99(0.40)	1.95(0.38)	1.97(0.35)	3.73	0.12*
D3MCd	2.28(0.38)	2.12(0.33)	2.16(0.41)	2.00(0.32)	2.49	0.06
D4MCd	2.26(0.31)	2.27(0.39)	2.14(0.50)	2.14(0.39)	0.68	0.56
D5MCd	2.30(0.55)	2.29(0.37)	2.21(0.36)	2.26(0.47)	0.25	0.85
MCd average	2.29(0.40)	2.19(0.24)	2.13(0.30)	2.13(0.29)	1.10	0.35

* Kruskal-Wallis test used

The comparison of the mandibular canal diameter mean between age groups is summarized in Table 4.41. One-Way ANOVA statistical test was conducted for each position (except D2MCd) and P value was listed in the last column. Kruskal-Wallis test was used for D2MCd since One-Way ANOVA assumption was not met.

4.9 Descriptive summary of the mandibular foramen diameter

Table 4.42 Descriptive statistics of the mandibular foramen diameter measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
ManFd	2.55	0.43	120	2.50	1.62	3.69	0.49	-0.16	0.555

Table 4.42 summarizes the mandibular foramen diameter value for 120 sides (60 on the left side and 60 on the right side). Paired sample t-test was used to indicate any significant difference between right and left mandibular foramen diameter. Results showed a P value of 0.58, so no significant difference was found between the two sides. Based on the skewness and kurtosis values the data was approximately symmetrical, the Kolmogorov-Smirnov tests of normality for mandibular foramen diameter (Table 4.43), and the value

was more than 0.05, so it can be considered as normally distributed. Figure 4.2B shows mandibular foramen diameter measurement taken from this study sample.

4.9.1 Comparison of the mandibular foramen diameter between ethnicity (Race)

Table 4.43 Comparison of the mandibular foramen diameter mean measurements by ethnicity (race)

	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
ManFd	2.71(0.43)	2.50(0.40)	2.43(0.44)	2.55(0.43)	4.83(2)	0.010

Table 4.43 summarizes the mandibular foramen diameter mean measurements for the three races Malays, Chinese and Indians. One-Way ANOVA test indicated that there were a significant differences in the diameter of the mandibular foramen (p=0.001). Further post-hoc Bonferroni's procedure indicated that there was a difference in the mandibular foramen diameter between Malays and Indians (p=0.01).

4.9.2 Descriptive summary of the mandibular foramen diameter by gender

Table 4.44 Comparison of the mandibular foramen diameter mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
ManFd	2.63(0.39)	2.46(0.46)	0.17(0.01,0.32)	2.16(118)	0.032

Table 4.44 summarizes the mandibular foramen diameter measurements among gender. The mean for the male is 0.17 mm larger compared to the mean for the females.

Independent T-test indicated that there were significant difference in the diameter of mandibular foramen measurements between the two gender (p=0.032).

4.9.3 Comparison of the mandibular foramen diameter value by ethnicity and gender

Table 4.45 Comparison of the MF diameter mean measurements between gender among races

Malays	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
ManFd	2.61(0.42)	2.82(0.42)	-0.21(-0.48,0.05)	-1.62(38)	0.11
Chinese	Male (n=20 Mean(SD)	Female (n=2) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
ManFd	2.57(0.38)	2.42(0.41)	0.14(-0.10,0.40)	1.18(38)	0.24
Indians	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
ManFd	2.72(0.37)	2.14(0.29)	0.58(0.36,0.79)	5.46(38)	0.00

Table 4.45 summarizes the mandibular foramen diameter mean for the Malay males and the Malay females. Independent samples T-test results indicated that there was no difference in mandibular foramen diameter measurements between gender among Malays. The mean for the Malay males was 0.21 mm less than the mean for Malay females as shown in the 2nd and 3rd column in the above table.

Among Chinese, independent samples T-test results indicated that there was no difference in the diameter of mandibular foramen among gender in Chinese (p=0.24). The mandibular foramen diameter mean for the Chinese males is 0.14 mm greater than the mean for Chinese females as shown in the 2nd and 3rd column in the above table.

While among Indians, independent Samples T-test results indicated that there was a strong statistical difference in the mandibular foramen diameter between the two gender among Indians. The mandibular foramen mean measurements for the Indian males is 0.58 mm greater than the mean for Indian females.

4.9.4 Comparison of the mandibular foramen diameter value with age groups

Table 4.46 Comparison of the mandibular foramen diameter mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 (n=12)	31-40 (n=22)	41-50 (n=38)	51-60 (n=48)		
ManFd	2.58(0.34)	2.75(0.45)	2.53(0.39)	2.46(0.46)	2.30	0.081

The comparison of the mandibular foramen diameter mean between age groups was summarized in Table 4.46. One-Way ANOVA statistical test showed that there was no statistical difference in the diameter of mandibular foramen among age groups.

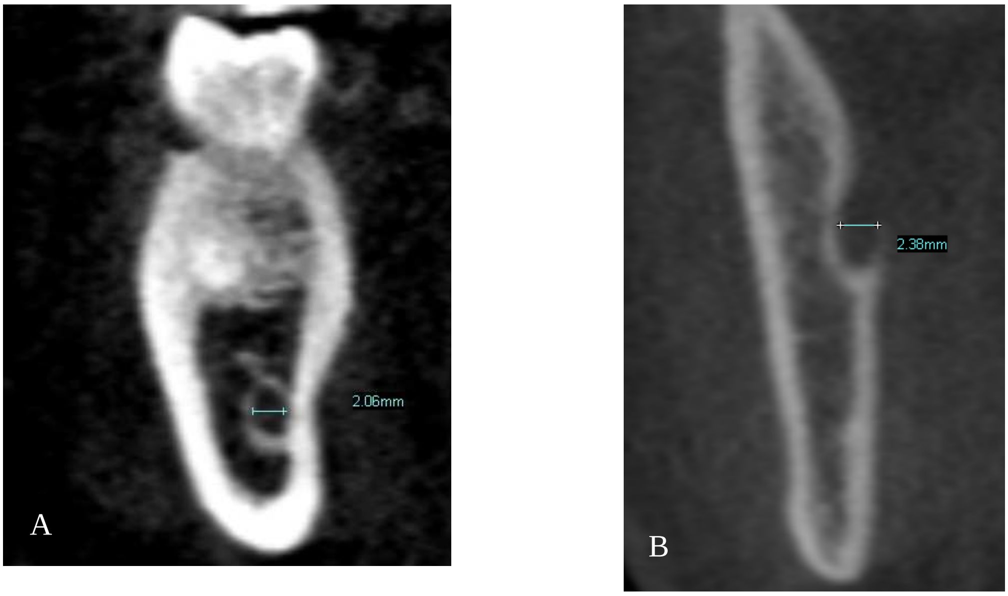

Figure 4.2: A: Mandibular canal diameter measurement . B: mandibular foramen diameter measurement – coronal view of CBCT image improved with SimPlant software.

4.10 Bifid mandibular canal

Table 4.47 Frequency and Percentage of the bifid canal in the sample studied

Ethnicity(race)	Gender	N	Frequency of bifid canal	Percent of bifid canal
Malays	Male Female	20 20	10 8	50 40
Chinese	Male Female	20 20	0 0	0 0
Indians	Male Female	20 20	7 2	35 10
Total		120	27	22.50

Table 4.47 shows that Malays have the greater percentage of seen bifid mandibular canal among the races (n=18), followed by Indians (n=9), while no bifid canal was seen in the Chinese sample of this study. Figure 4.5 shows bifid mandibular canals taken from this study sample.

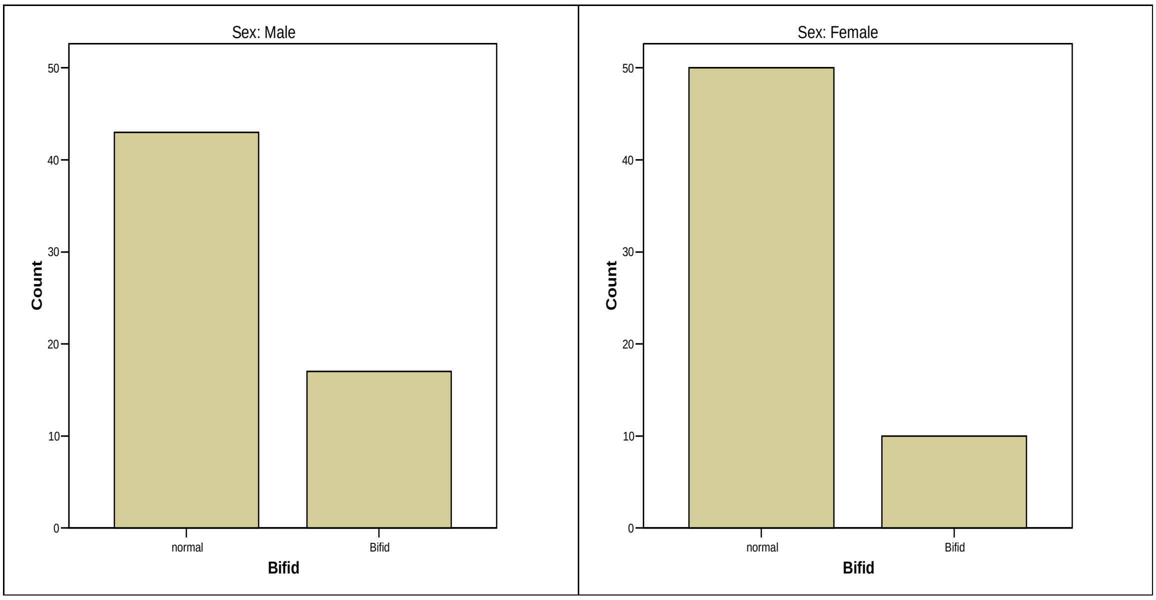

Figure 4.3: Bifid mandibular canal frequencies among gender

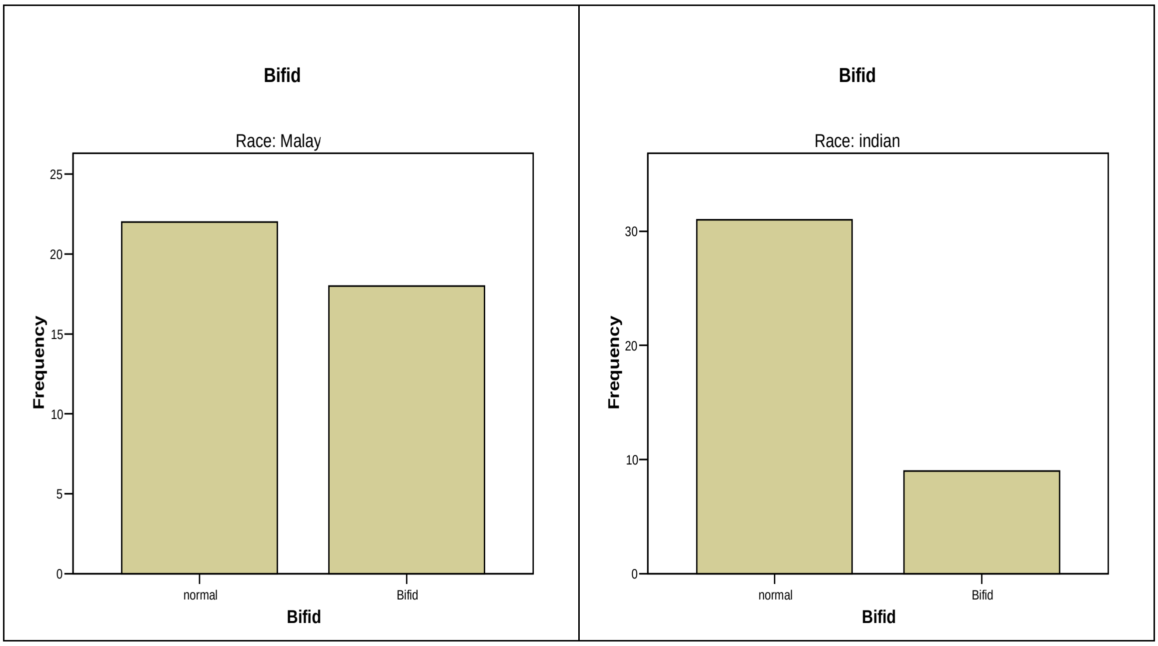

Figure 4.4: Bifid mandibular canal frequencies among Malays and Indians

4.10.1 Association between the bifid mandibular canals with ethnicity (Race)

Table 4.48 Frequency and Percentage of the bifid canal among races

Ethnicity(race)	N	Normal MC freq (%)	Bifid MC freq(%)
Malays	40	22(55)	18(45)
Chinese	40	40(100)	0(0)
Indians	40	31(77.50)	9(22.50)

Due to unmet assumption of Chi-square, statistically P-Value was not valid to be interpreted. Thus the results will be represented descriptively.

A shown above in (Table 4.48), Malays are more prone to have bifid mandibular canal followed by Indians and no case of bifid MC was seen among Chinese.

4.10.2 Comparison of the bifid mandibular canal between gender

Table 4.49 Comparison of the bifid canal among gender

Ethnicity(race)	N	Normal MC freq (%)	Bifid MC freq(%)	X2 stat a(df)	P value
Male	60	43(71.7)	17(28.3)	2.34(1)	0.126
Female	60	50(83.3)	10(16.7)		
Total	120	93(77.50)	27(22.50)		

Chi-square test were utilized to check for any association between gender and number of bifid mandibular canal and there was no significant difference found between the two gender in Malaysian population (p>0.05) as shown in last column (Table 4.49).

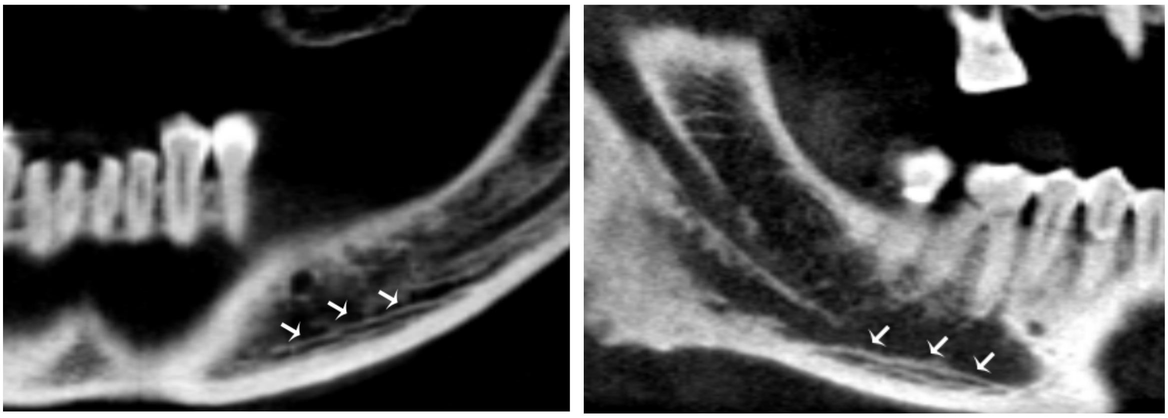

Figure 4.5: Bifid mandibular canal (White arrow) – panoramic view of CBCT image improved with SimPlant software.

CHAPTER 5

DISCUSSION

5.1 Rational for choice of the study topic

The current study was designed to clearly determine the path of the mandibular canal, the mandibular canal diameter, the mandibular foramen diameter and the frequency of bifid mandibular canal in Malaysian population using appropriate application of CBCT and SimPlant software.

The presence and contents of the neurovascular bundles were clearly identified in studies done by Deng et al.(2008), using High-Resolution Magnetic Resonance Imaging (HR-MRI). As such the function and importance of those structures became evident and their correlation to the majority of the pre-surgical and post-surgical complications that occurred in the mandibular region was better understood.

The choice of this topic was based on four reasons. Firstly, a perusal of data and records revealed that no such studies had previously been done in a Malaysian population and therefore the present study would act as a pilot to lay down primary data on the mandibular canal pathway among Malay, Chinese and Indians. Dentists worldwide who are treating people of Malaysian origin can then use this data.

Secondly, the number of practitioners performing implant surgery has increased dramatically over the last fifteen years. As confidence is gained they tend to accept increasingly challenging cases and it is to be expected that the incidence of problems and complications will increase (Worthington, 1995).

Thirdly, studies showed that IAN is the most commonly injured nerve in the mandible (64.4%), followed by the lingual nerve (28.8%) (Tay and Zuniga, 2007).

Lastly, the use of CBCT as the imaging technique was chosen as it is non-invasive, emits low radiation and has been successfully applied in several areas of dentistry such as oral surgery, endodontics, oral medicine, periodontology, restorative dentistry and orthodontics (Rigolone et al., 2003; Nakagawa et al., 2002; Hamada et al., 2005; Ogawa et al., 2005; Maki et al., 2003; Hatcher et al., 2003; Sato et al., 2004; Tsiklakis et al., 2004).

Though intra-oral radiographs have remained the most popular in dental clinics for a long time and have been used in some studies (Denio et al., 1992), the technique is limited by the fact that images are produced only in 2D. Furthermore, such images if taken on patients could be elongated or shortened thus compounding the actual size of the specimen under study. In addition, superimposition of structures could occur. On the other hand, CBCT produced 3D images with no geometrical distortion since the image is at a ratio of l:1, implying that the image produced is the same size as the object. Furthermore, there is good resolution and problems of superimposition can be eliminated.

CT has also been used to improve depiction of the mandibular canal (Naitoh et al., 2008; Yang et al., 1999) .However, compared to CBCT, CT equipment has been found to be very bulky, emitted high radiation and scatter, and are quite expensive. The use of CBCT in oral and maxillofacial surgery has been well documented as stated earlier. However, a paucity of data exists on its use to determine the mandibular canal metrical path analyses hence it's the choice for the present study.

5.2 Specimen selection

A total of sixty (60) suitable patients records were selected based on gender, ethnicity and age groups. Males or females from racial groups, Malays, Chinese and Indians aged between twenty (20) and sixty (60) with permanent dentition were included since most patient seeking implant treatment in this age period. Also patients with systemic health problems or are medically compromised and not having undergone any radiotherapy were also included.

While samples with mixed racial origin, with history of severe trauma or fracture of the mandible, existing pathological disorder at mandible, with genetic disorder or congenital abnormalities, samples with post surgical cases such as orthognathic surgery, or samples with severely atrophied mandible were excluded from the sample collection. The exclusion criteria in this study were very strict to get an ideal sample size that provides excellent results and that is why it took long period for proper sample selection.

5.3 Technique

5.3.1 The imaging system

CBCT was chosen as the imaging technique of choice since it has been documented to provide excellent 3-dimensional images at reduced radiation, scan time and cost in clinical studies (Scarfe et al., 2006b; Yajima et al., 2006; Ziegler et al., 2002; A. Schramm and J. Du¨ kerb, 2005). In addition CBCT was shown in some clinical studies to be more accurate and provided higher resolution compared to CT (Cotton et al., 2007). It is comparable to direct digital caliper measurements of various distances surrounding the mandibular canal (Kamburoglu et al., 2009) and was found to be reliable for linear evaluation measurements of structures closely associated with dental and maxillofacial imaging (Lascala et al., 2004).

SimPlant software tools allow the marking to be done in any of the axial, cross sectional, panoramic and 3D view. It also permitted scrolling through the entire volume with simultaneous viewing of axial, coronal and sagital sections.

5.3.2 Landmarks, Base line and Measurements

The mandibular canal was used as landmark for measurements in most of the cadaveric and radiographic studies. However, cadavers are processed specimen and fixed in formalin and because of this the nerve (being soft tissues) is prone to deformation and therefore becomes an inexact landmark. In contrast radiographic studies, the presence of cortical lining forming the wall of the mandibular canal act as a factor for their visualization (Rothman et al., 1988). Cone-Beam computed tomography allows a precise demonstration of the mandibular canal in relation to the alveolar crest, inferior border and bucco-lingual directions of the mandible.

We adapted the diameter of the canal to be 2.50 mm in our metrical studies of the position of the canal and this was set as default in the SimPlant software program. This was done as this was the diameter reported by Rajchel et al. in a study in 1986.

5.3.3 Reliable landmarks for mandibular canal position

The CBCT images selected in this study were all taken with Frankfort plane parallel to the floor. The interactive SimPlant software was used to produce dynamic high resolution cross-sectional and 3-D images, which allowed the visualization of the mandibular canal from any viewpoint on the computer screen.

The SimPlant software allows access to a measurement tools for linear measurements of the mandibular canal. The main concern in this study was selecting appropriate landmarks and base lines to allow optimum standardization and reproducibility.

The buccal line, lingual line, inferior line and superior line were introduced and selected as base lines in the present study. The preliminary studies showed good standardization and reproducibility of the base lines and measurements. The data analyzed for reliability of the measurements showed Cronbach alpha coefficient as r=0.91, and the value of measurement errors, s(i) were 0.05 mm or less for all compared data, which strongly suggested the present method of obtaining data is considered as reliable and accurate.

The superior aspect for D5 was excluded from this study because there was no superior alveolar crest (only ramus) and there was no way of determining the superior margin as done in other locations.

5.4 Comparison of data between right and left jaw

One of the objectives of this research is to study the significance of data collected from right and left side of the mandible and to determine whether it is suitable to use data from both side of the jaw in conducting clinical researches. The mean values obtained for right and left sides of all D's (D1-D5) were identical and the P-values of the pair-samples T-test showed a value of more than 0.05 (Table 4.1).

This result strongly concludes that the measures on the right are similar to the measures on the left side of the jaw as also stated by Levine et al. (2007), Narayana and Vasudha (2004) and Kieser et al. (2005). Recording the measurement on both sides of the jaw in clinical studies may then produce cluster sampling as well as duplication of the data, which then becomes unnecessary in metrical analyses. One side is therefore sufficient in future studies.

5.5 Position of the mandibular canal

In this study the position of the mandibular canal at all D's (D1-D5) location were measured at four aspects which are the buccal, lingual, inferior and superior measurements respectively (except D5S), and statistical comparison were done based on race, gender, race versus gender and age groups.

5.5.1 Apicocoronal position of the mandibular canal

Many studies were done to measure and locate mandibular canal position using different imaging techniques ranging from periapical radiography to CBCT technique (Table 5.1). One of the interesting clinical and radiographic study among US population was done by Levine et al. (2007) using the CT imaging technique. They reported tha the mandibular canal was 17.4 ± 3.00 mm from the superior cortical surfaces of the mandible at the mandibular first molar.

In this study the superior measurement of the position of the mandibular canal was 14.85 ± 3.64 mm at D1, 13.94 ± 3.85 mm at D2, 12.99 ± 4.08 mm at D3 and 14.22 ± 1.52 mm at D4, while the inferior measurement of the canal was 9.37 ± 1.69 mm at D1, 8.24 ± 1.69 mm at D2, 7.96 ± 1.93 mm at D3, 9.65 ± 2.54 at D4 and 15.21 ± 4.18 mm at D5.

Ensuing a study on the vertical position of the mandibular canal, statistical comparisons were done based on race and gender. According to race comparison, it was found that there was no significant difference in the location of the canal at D1 position superiorly. However, when we advance posteriorly in the mandible there was an obvious variation of the position of the canal amongst the races especially from the inferior border of the mandibular canal to the mandibular base until D5I where subsequently no significant difference were found among races; therefore clinicians should be aware of these variations in the position of the canal 1cm posterior to the mental foramen. While measurement from superior border of the canal to the crestal bone was almost the same throughout ($p>0.05$) among the three races (Appendix 1-B).

From the above, the canal became closer to the inferior mandibular border the more distal it travels from mental foramen reaching closest at D3 location. While the superior measurement was least at D3 indicating the canal became closer to the crestal bone of the alveolus. We also noticed that the canal maintain approximately constant position in axial view but changes occured in the bone (Figure 5.1).

Furthermore, it is interesting to mention that the minimum superior measurement was at D3 which is the site most likely to be involved in accidental damage to mandibular canal during root canal therapy as similarly indicated by Denio et al.(1992).

Therefore, prior to any surgical intervention at mandibular canal region, it is very important to hypothesize the position of the mandibular canal is at least 8 mm from the inferior mandibular border. However the standard deviation of these measurements are large and surgeons therefore must consider that a large variation in the mandibular canal position is possible as reported by Narayana and Vasudha (2004). Thus, it is very important to individually assess the position of the canal on a case by case basis in order to avoid any possible surgical complications.

Table 5.1 Comparison of studies locating the mandibular canal vertically

Authors	N	Materials & Methods	Location of MC
(Heasman, 1988)	96	-Plain films -Dried mandibles	68% MC passed along an intermediate course between the mandibular root apices and the IBM.
(Rajchel et al., 1986)	45	-Cadavers -Cross-sectional	Mean distance of 10 mm between the MC and the IMB, proximally to the third molar region.
(Littner et al., 1986)	46	-paralleling technique radiography	Upper border of the MC to root apices of 6: 3.5mm Upper border of the MC to root apices of 7: 5.4mm
(Denio et al., 1992)	22	-Cadavers -Sectioning	MC to the apices of 7 : 3.7 mm MC to the first molar : 6.90 mm MC to premolars : 4.7 mm
(Sato et al., 2005)	39	- Macroscopic cadaveric dissection - CT or panoramic X-ray observation	vertical position of MC was closer to the apices of the first and the second molars than that to the distance of the IBM
(Carter and Keen, 1971)	8 80	- Dissection - Unilateral radiographs	Classified the three vertical positions of the course of the IAN. According to Type l, the nerve has a course near the apices of the teeth, where in Type ll, the main trunk is low down in the body, finally type III, the main trunk is low down in the body of the mandible with several smaller branches to the molar teeth.
(Nortjě et al., 1977b)	3612	- Panoramic radiograph	Categorized finding into: 1) 47% of cases high MC (within 2mm of the apices of the 6 & 7), 2) 3% intermediate MC, 3) 49% of cases low MC, and 4) other variations.
(Kieser et al., 2004)	39	micro-dissections	In 30.7% of the cases, the IAN was located in the superior part of the body of the mandible, and in 69.3% of the cases the IAN was half-way or closer to the inferior border of the mandible.
(Levine et al., 2007)	50	- Axial computed tomography - SimPlant software	superior aspect of the MC was 17.4 mm inferior from the alveolar crest
(Watanabe et al., 2009)	79	cross-sectional CT images	Distance from alveolar crest to the MC ranged from 15.3 to 17.4 mm
Present study (2011)	120	- CBCT - SimPlant software	D1/S : 14.85± 3.64 mm D1I : 9.37± 1.69mm D2/S : 13.94± 3.85 mm D2I : 8.24± 1.69mm D3/S : 12.99± 3.08 mm D3I : 7.96± 1.93mm D4/S : 14.22± 4.02 mm D4I : 9.65± 2.54mm D5/S: - D5I : 15.21± 4.18mm

Another interesting finding of this study when comparing mandibular canal position among gender was that male mandibular canal was more coronal than females and in general females had lesser measurements than males at D1, D2 and D3, while no significant difference were found for the other positions among gender.

5.5.2 Buccolingual position of mandibular canal

This study is considered to be a benchmark study in the buccolingual location of the mandibular canal. The data obtained from this study measures the thickness of the bone buccal and lingual to the mandibular canal in 5 different locations along the course of the canal.

According to Levine et al. (2007) mentioned earlier, the mandibular canal was 4.90 ± 1.3 mm from the buccal cortical surfaces of the mandible at the mandibular first molar (Table 5.2).

In this study statistical comparison for buccolingual position of the mandibular canal were conducted based on race, gender, race versus gender and age group. A variety of significant differences were observed among the three races and the two gender according to their measurements (Appendix 1-C). The obtained mean for the position of mandibular canal were 3.89 ± 1.00 mm (buccal) and 4.33 ± 1.25 mm (lingual), 5.59 ± 1.20 mm (buccal) and 3.35 ± 1.20 mm (lingual), 6.71 ± 1.34 mm (buccal) and 3.25 ± 1.32 mm (lingual), 5.68 ± 1.63 mm (buccal) and 3.08 ± 1.46 mm (lingual), 4.24 ± 1.59 mm (buccal) and 2.12 ± 1.40 mm (lingual) at D1,D2,D3,D4 and D5 respectively.

From the above findings, it was noted that the buccal length increased until D3 after which it is reduced while lingual length reduced all the way from D1 to D5. As such the mandibular canal deviates more lingually the more distal the canal travels, with its lowest reading lingually at D4 (30 mm from the mental foramen) (2.12 ± 1.4 mm) (Figures 5.1 and 5.2). Thus, prior to any surgical intervention at this area, this research demonstrated that the buccal aspect of the mandibular canal has more bone material than on the lingual aspect. As mentioned earlier because the standard deviation of the measurement in this study is large so surgeons must consider that the variation in the mandibular canal position to be quite evident and it is crucial to individually assess the position of the mandibular canal bucco-lingually on a case-by-case basis.

It is interesting to mention that Chinese (7.07 ± 1.38 mm) had the largest buccal bone mean measurement among the three races, followed by Malays (6.84 ± 1.22 mm), and the lowest value was obtained from Indians (3.43 ± 0.88 mm). Again Chinese too had the largest lingual bone measurement among the three races (4.39 ± 1.10 mm), followed by Malays (4.38 ± 1.29 mm), and the lowest value was noticed among the Indians samples (2.10 ± 1.49 mm).

Another interesting finding from this study on the measurement among the races was that the buccal measurement was statistically different ($p<0.05$) while lingually measurement were almost the same with no much statistical difference except at D3L location ($p=0.02$).

One of the objectives of this research is to study the gender differences of mandibular canal position and it was found that there was no statistical difference of the position of the canal between the two gender, except for D4B (p=0.006). It was also noted that males have bigger buccolingual measurements than females in all locations except at D5.

These findings are similar to that published by Kieser et al.(2005) as they showed that the pattern of distribution of the mandibular canal does not significantly differ between the sexes, between the sides of the jaw, or with age.

Table 5.2 Comparison of studies locating the mandibular canal horizontally

Authors	**N**	**Materials & Methods**	**Location of MC**
(Rajchel et al., 1986),	45	-Cadavers -Cross-sectional	MC when proximal to the third molar region, courses approximately 2.0 mm from the inner lingual cortex, 1.6 to 2.0 mm from the medial aspect of the buccal plate.
(Levine et al., 2007)	50	- Axial computed tomography - SimPlant software	The mean buccal aspect of the MC was 4.9 mm from the buccal cortical margin of the mandible
Present study (2011)	120	- CBCT - SimPlant software	D1/B : 3.89 ± 1.00 mm D1L : 4.33 ± 1.25mm D2/B : 5.59± 1.20 mm D2L : 3.35 ± 1.20mm D3/B : 6.71± 1.34 mm D3L : 3.25± 1.32mm D4/B : 5.68± 1.63 mm D4L : 3.08± 1.46mm D5/B : 4.24± 1.59 mm D5L : 2.12± 1.40mm

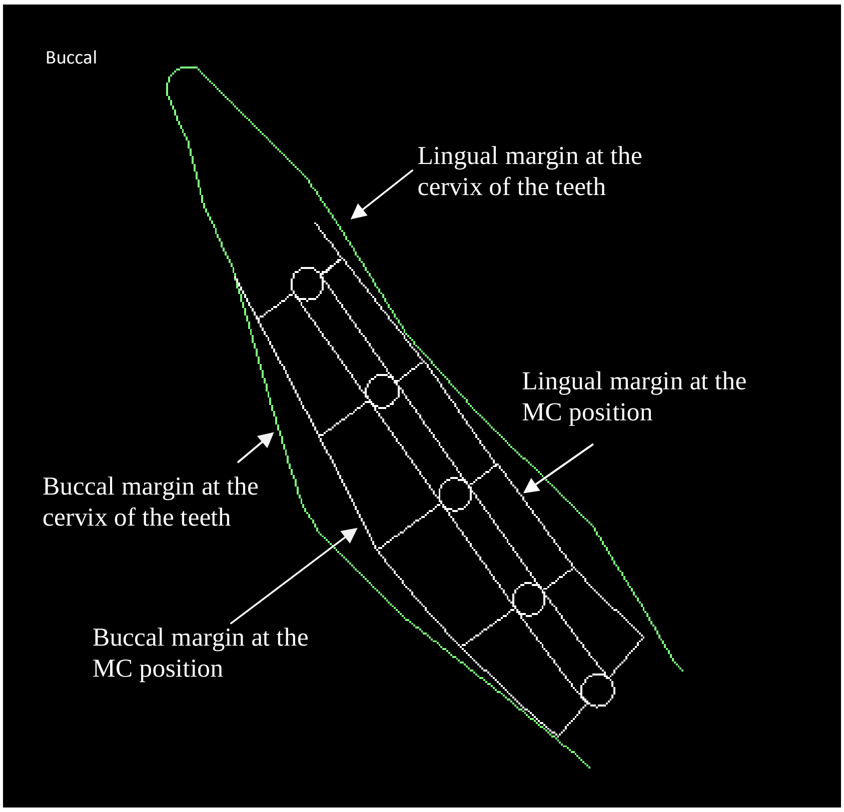

Figure 5.1 Illustrated diagram of the mandibular canal path – axial view

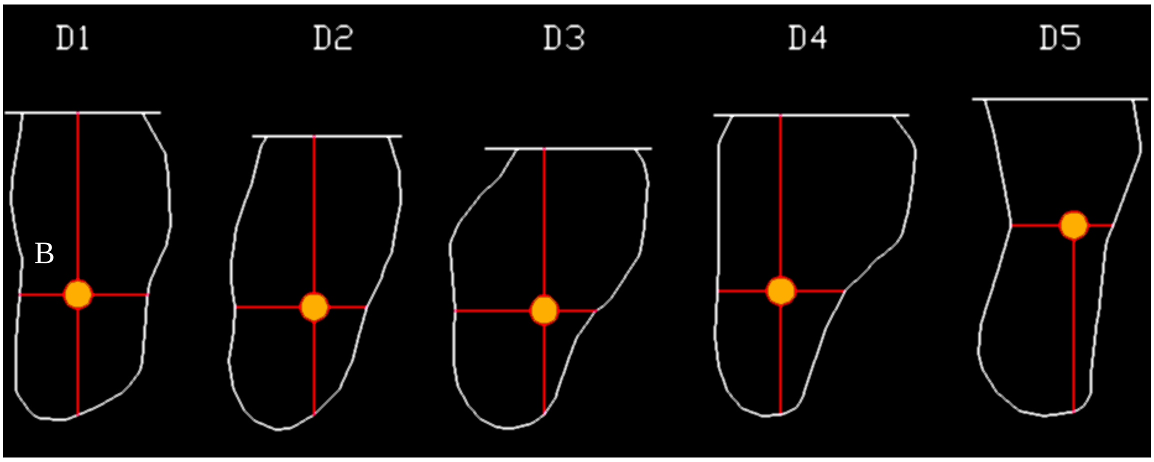

Figure 5.2 Illustrated diagram of the mandibular canal path – coronal view

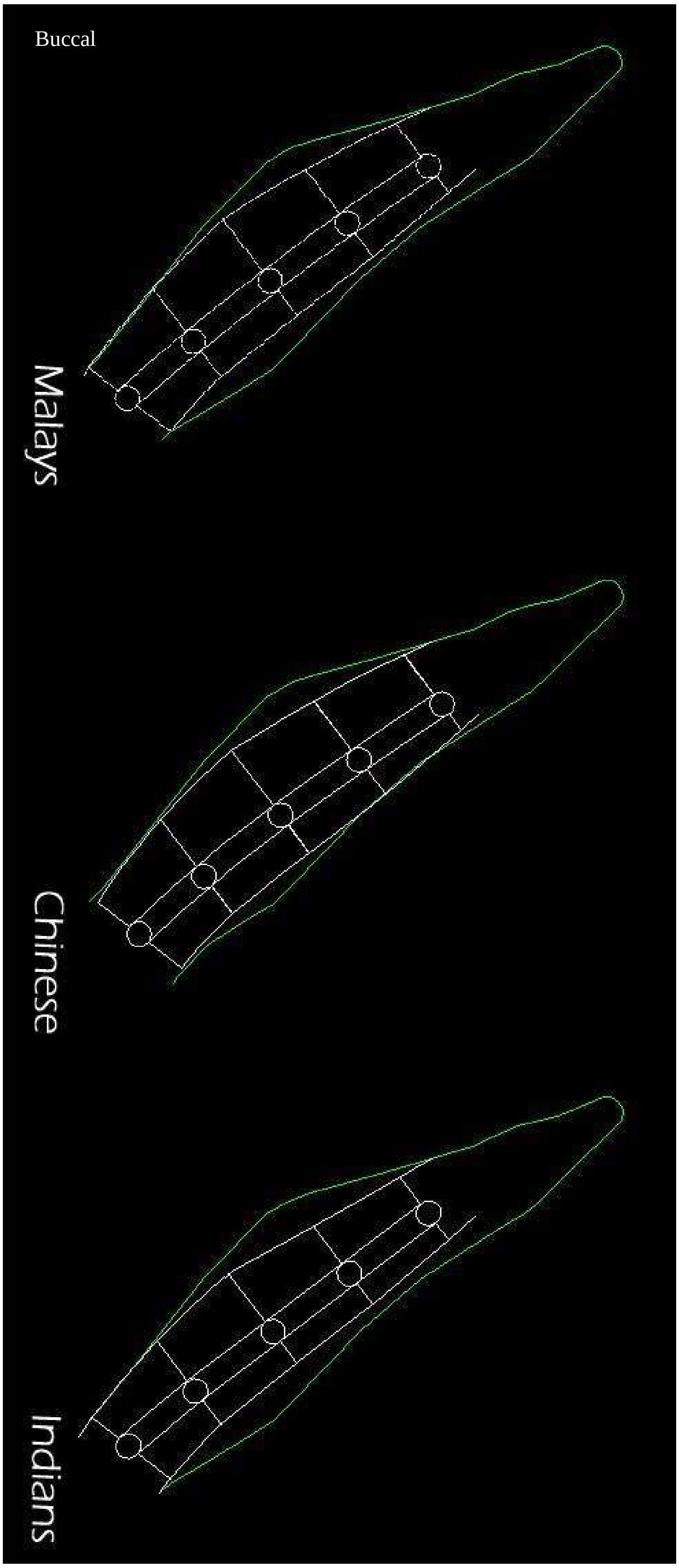

Figure 5.3 Illustrated diagram of the mandibular canal path among race – axial view

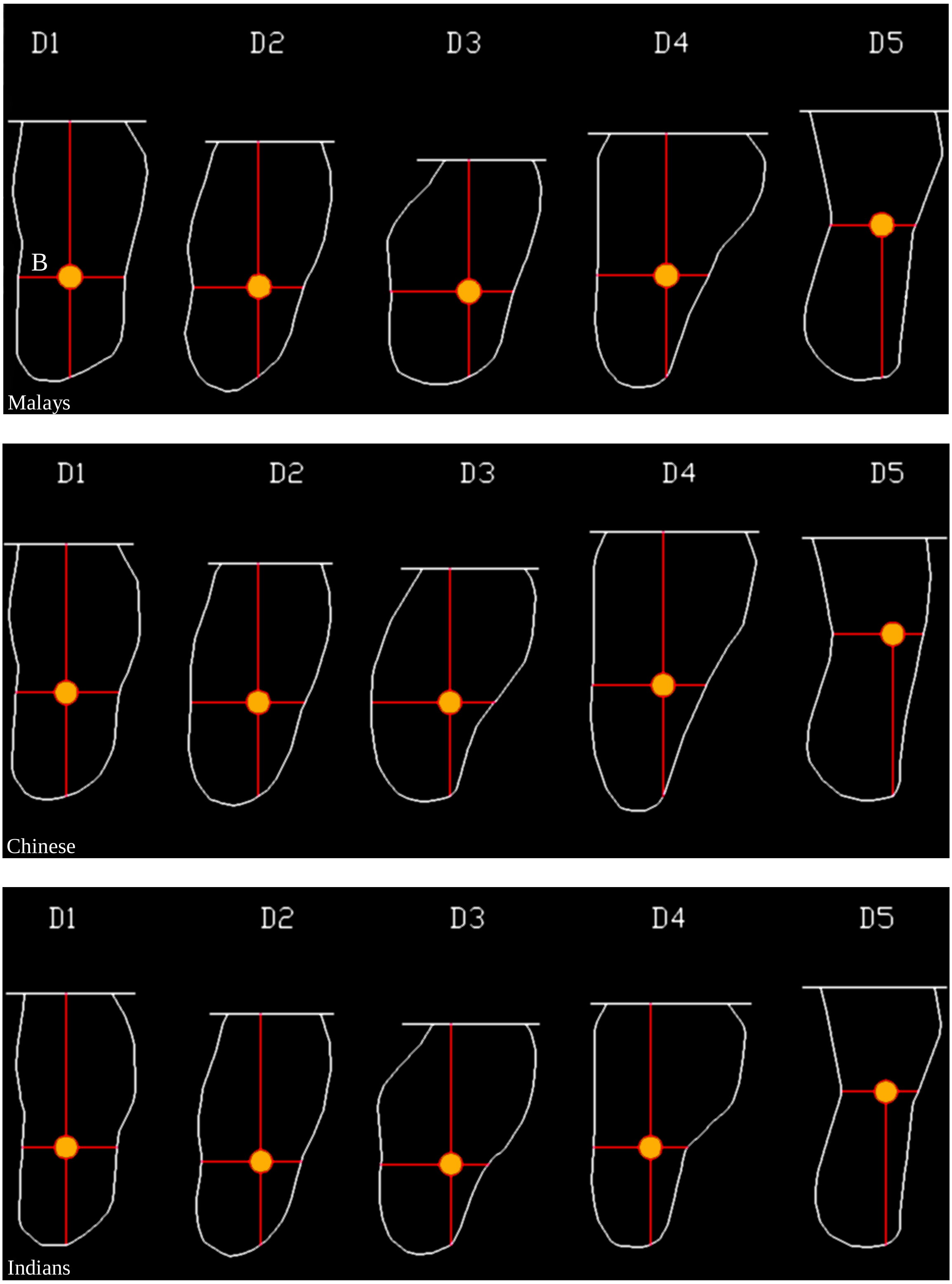

Figure 5.4 Illustrated diagram of the mandibular canal path among race – coronal view

5.6 Age group

One of the objectives of this research is to study the significance of data collected from 4 age groups (Figure 5.5) to determine whether it is suitable to use data from one age group in conducting clinical procedure on other age group.

The present research showed that there is almost a significant difference among age groups and the superior measurement decreased as we advanced in age because of bone resorption with age, while the inferior measurement increased as we advanced in age.

Another interesting finding is that the measurements near the mental foramen (D1) and the mandibular foramen (D5) do not change significantly with age. However we found that at other positions D2, D3 and D4 the buccal and lingual measurements varied with different age groups.

Levine et al. (2007) reported that older patients, on average, have less distance between the buccal aspect of the canal and the buccal mandibular border. This finding is similar to our finding, thus to minimize the risk of IAN injury, age of the patient should be considered when planning mandibular surgical procedure.

However, this was refuted by Kieser et al.(2005) who stated that there was no difference of the mandibular canal position due to age.

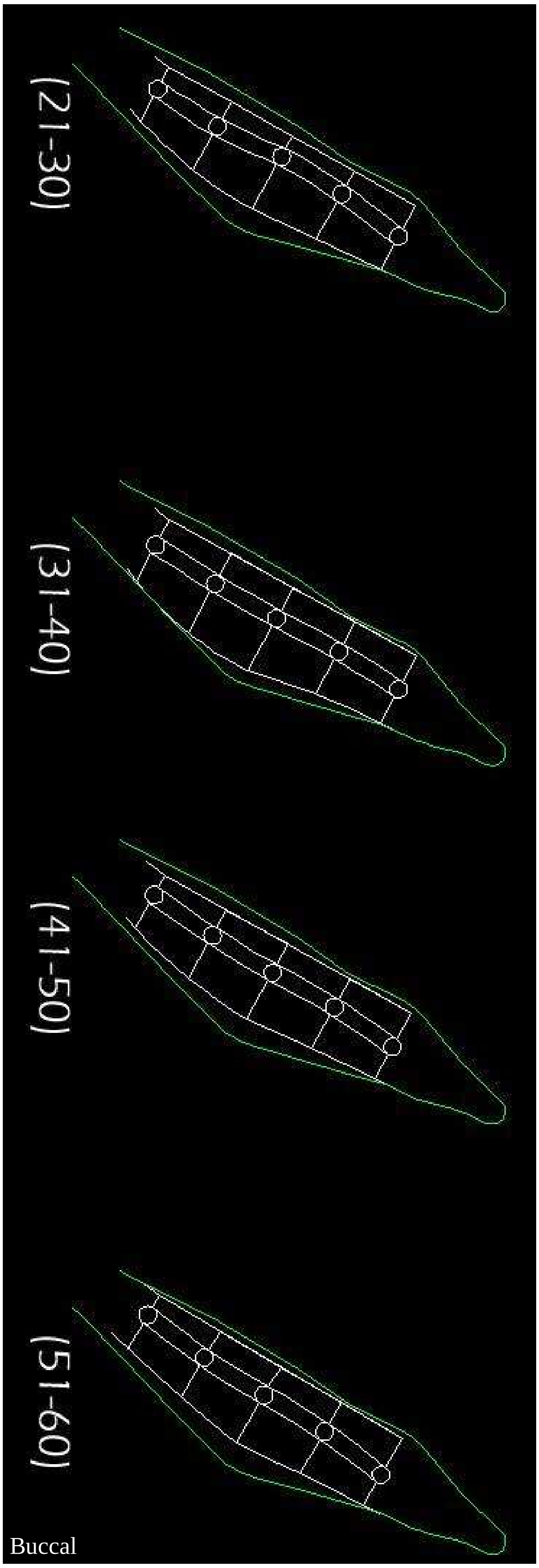

Figure 5.5 Illustrated diagram of the mandibular canal path among age groups – axial view

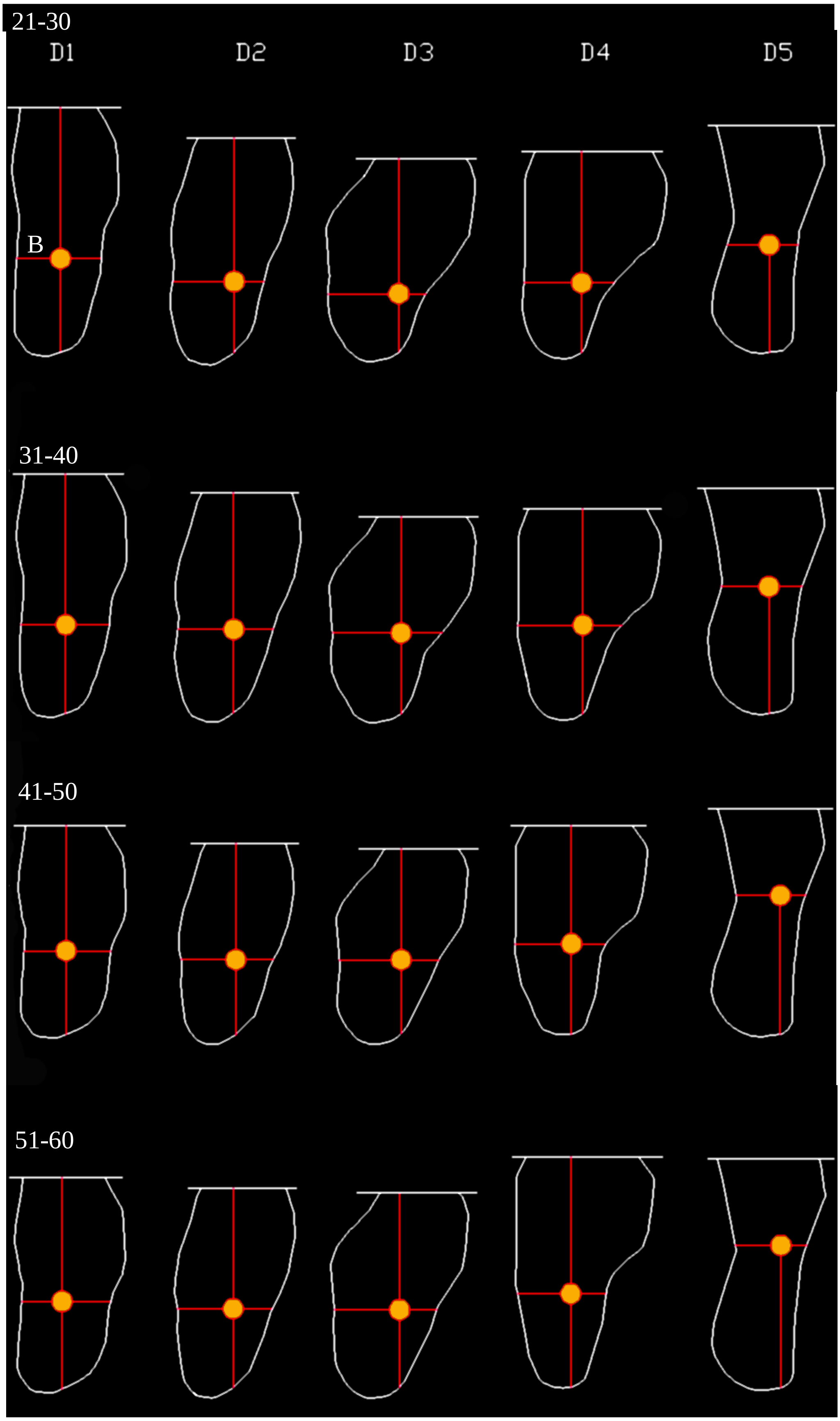

Figure 5.6 Illustrated diagram of the mandibular canal path among age groups – coronal view

5.7 Diameter of the mandibular canal

One of the objectives of this research is to determine mandibular canal diameter in Malaysian population so MC diameter was measured for each location (D1-D5) and average diameter mean for all locations were calculated (Table 4.37).

A number of previous research studies measured the MC diameter (Table 5.3) and the minimum diameter recorded was 2.00 mm and the maximum was 3.40 mm. In this study the average mean was 2.16 ± 0.30 mm with the minimum diameter at D2 location (2.01 ± 0.42 mm) and a the maximum diameter at D1 (2.25 ± 0.47 mm) and D5 (2.25 ± 0.43 mm).

The MC diameter for the right side and left side of the mandible were measured and statistical test results showed that there was a significant difference of 0.16 mm between the two sides (p=0.006), which is of no value clinically.

One of the interesting findings of this study is that comparison of MC diameter among races showed no significant difference for all locations considered whereas, significant difference were observed among gender. The mean for males in all locations was significantly larger compared to the mean for the females.

The final finding concerning the MC diameter in this study was that the canal diameter generally maintains the same diameter and does not change as we advanced in age.

Table 5.3 Comparison of the MC diameter among different research studies.

Authors	No. of specimens	MCd length	Locations
(Rajchel et al., 1986)	45	2.00 – 2.4 mm	3rd Molar
(Obradovic et al., 1993)	105	2.6 mm	Average diameter in mandibular canal region
(Ikeda et al., 1996)	6	3.4 mm	Average diameter in mandibular canal region
Present study (2011)	120	2.16 mm	Average diameter in mandibular canal region

5.8 Diameter of the mandibular foramen

One of the objectives of this research was to determine the mandibular foramen diameter in Malaysian population and this was measured to be having a diameter of 2.55 ± 0.43 mm.

The MF diameter for the right side and left side of the mandible were measured and statistical test results showed that no significant difference was found between the two sides ($p=0.241$).

Comparison of the MF diameter among races indicated that there was a difference in the mandibular foramen diameter between Malay and Indian races ($p=0.01$). Furthermore comparison of the MF diameter among gender indicated that there were significant difference in the diameter of the mandibular foramen measurement ($p=0.032$) with males showing larger values.

One of the interesting findings of this study is that the MF diameter generally maintains the same diameter and does not change as Malaysians advanced in age. This finding is similar to MC diameter with age group mentioned earlier.

5.9 Bifid Canal

Many studies (Table 5.4) were done on the mandibular canal region and researchers reported that bifid canals are rare radiological findings and some considered it as atypical mandibular canal. This can be clearly identified using three-dimensional imaging techniques (Rouas et al., 2007).

Table 5.4 Comparison of the bifid mandibular canal occurrence in different studies

Authors	**No. of specimens**	**Percentage of bifid canals**	**Radiological examination method**
(Nortjĕ et al., 1977b)	3612	0.9	Panoramic radiographs
(Grover and Lorton, 1983)	5000	0.08	Panoramic radiographs
(Langlais et al., 1985)	6000	0.95	Panoramic radiographs
(Sanchis et al., 2003)	2012	0.35	Panoramic radiographs
(Naitoh et al., 2009a)	122	65	CBCT
Present study (2011)	120	22.50	CBCT

It is interesting to mention that Malays have the greater percentage of bifid mandibular canals among the races (n=18), followed by Indians (n=9), while no bifid canal was seen in Chinese sample of this study (Table 4.52).

No significant difference was found between the gender among Malaysian population for the frequency of bifid mandibular canal cases.

CHAPTER 6

CONCLUSION, IMPLICATIONS AND SUGGESTIONS

6.1 Introduction

This study investigated the metrical path way of the mandibular canal among Malaysian population at every 10 mm starting from the mental foramen backward. There was also an attempt to determine the MC diameter at each location, MF diameter and frequency of bifid canal. The following are the summary of findings, implications of the study as well as recommendations for further studies.

6.2 Summary of the findings

The research was specifically focused to study six objectives and the results obtained were as follows:

(i) The mandibular canal was identified as a major big canal in all the samples with 100% superb visibility.

(ii) The inferior border of the mandible showed high reliability as a landmark for mandibular incisive canal position.

(iii) The mean apicocoronal position of the mandibular canal was 10.08 mm from the inferior border of the mandible and 14.00 mm from the alveolar crestal bone.

Mandibular canal curving downward towards the inferior mandibular border untill D3 and then it curves upwards.

(iv) The mean buccolingual position of the mandibular canal was 5.22 mm away from the buccal cortical plate and 3.65 mm away from the lingual cortical plate. The mandibular canal curves toward the lingual side the more distally we measure the MC away from mental foramen.

(v) The mean mandibular canal diameter was 2.16 ± 0.30 mm in the Malaysian population.

(vi) The mean mandibular foramen diameter was 2.55 ± 0.43 mm in the Malaysian population.

(vii) Bifid mandibular canal was identified using CBCT technology with prevalence of 22.50% in the Malaysian population.

(viii) The data from the right side of the jaw were approximately similar to the data from the left side of the jaw for all measured structures in this study.

(ix) CBCT proved a reliable means of analyzing mandibular canal position, determining MC and MF diameter and distinguishing the bifid canal.

6.3 Implications of the study

The research clearly showed variations in the position of the mandibular canal and it should not be assumed that there is a fixed position at which it is safe for surgical intervention. Thus, it is highly recommended that the surgeons familiarize themselves with the anatomic variation at the mandibular canal region prior to any surgical intervention in order to avoid hemorrhage or neurosensory disturbances, as well as to safeguard themselves from unexpected medicolegal complications. Computed Tomography or cone beam computed tomography (CBCT) is recommended for preoperative planning to overcome the shortfalls observed in other radiography.

6.4 Recommendations for further research

Many studies have attempted to measure or estimate the amount of radiation doses delivered to radiosensitive organs in the maxillofacial area, such as salivary gland thus, the risk of the ionizing radiation involved with radiographic techniques has been widely investigated. The CBCT has a very short exposure time (10-70) seconds and radiation dosage is 15 times less than the conventional CT scan.

Deng et al. (2008) have recommended the use of High Resolution Magnetic Resonance Imaging (HR-MRI) to investigate the neurovascularization of the anterior jaw bone and surrounding soft tissue. It is similarly recommended using HR-MRI or ultrasound to visualize the canal in the Malaysian population. These imaging modalities do not use ionizing radiation and are considered non-invasive.

6.5 Closure

As a healthcare provider, it is our ethical duty to provide a harmless treatment to our patients. We have to anticipate and recognize the neurovascularization of the mandible to avoid or minimize any complications. Great care must be considered as these vasculatures are more complex and more variable than previously thought. Constant development of modern imaging modalities has improved tremendously our diagnostic capabilities.

CHAPTER 7

DEVELOPMENT OF THE MANDIBULAR CANAL SIMULATION SOFTWARE

A fast interactive application to know the location of the mandibular canal according to this study has been developed and uploaded online (http://mcsim.mandibularcanal.com temporarily access password: UMMCSIM123).

This application can be considered as a fast reference to get the results of this study. The buccal, lingual, inferior and superior measurements of the mandibular canal location at each position selected in this study was included in the software (Figure 7.1).

Practioners can get the values with axial and coronal image for the MC in general among the Malaysian population, and also they can specify to view the results according to age, gender, race and race versus gender for each position (D1-D5).

Mandibular canal diameter was also included in the software at each position for the age, gender, race and race versus gender.

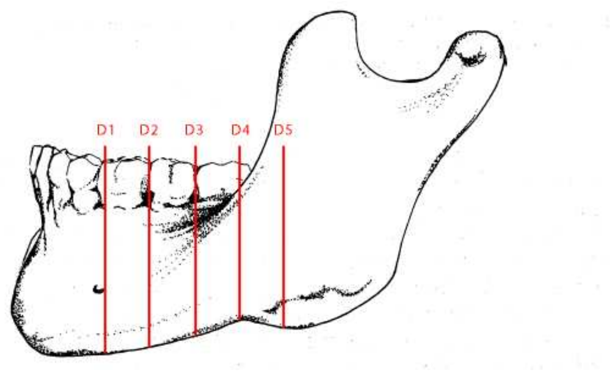

Figure 7.1 Illustrated diagram showing positions included in the application

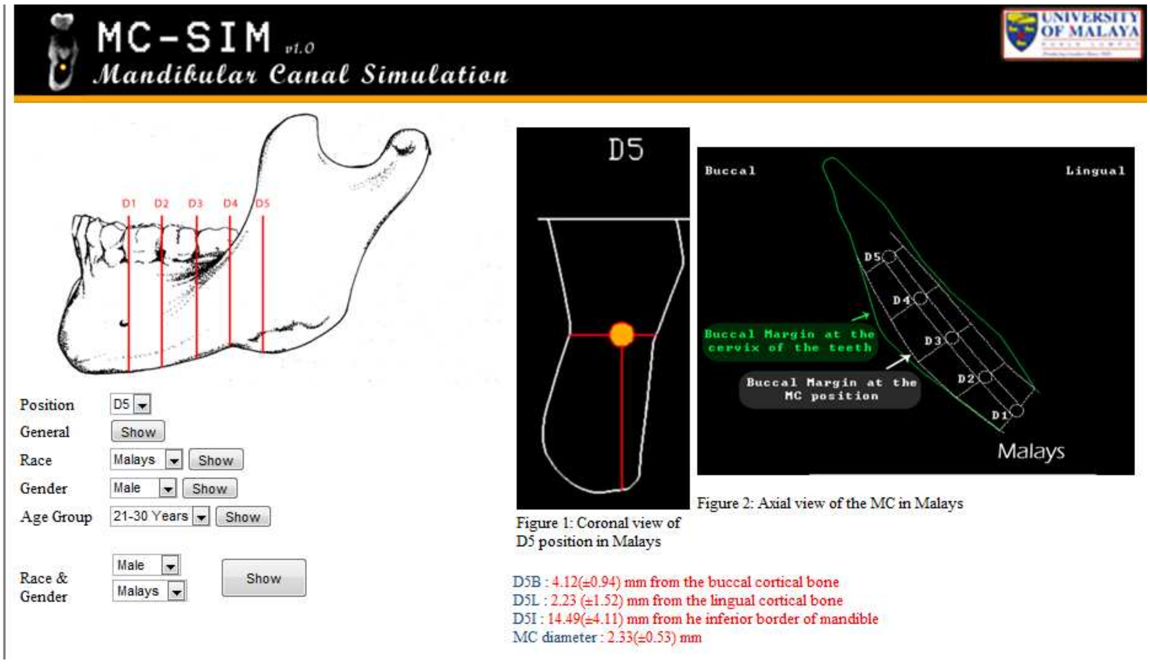

Figure 7.2 Screenshot from the developed software

The above Figure shows the variety of options available in the software on the left side. Position D5 and Malays race were selected and the output results with illustration diagrams in the coronal and axial view of the mandible appeared on the right side.

The application was developed using ASP.NET 4.0 technology and the data was stored on MSSQL 2008 database. Conditional construct was built for each category at each location considered.

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Appendix 1

A- Descriptive Statistics of the mandibular canal length measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D1B	3.89	1.00	120	3.83	1.69	7.60	0.50	0.76	0.712
D1L	4.33	1.25	120	4.28	1.75	7.96	0.244	-0.011	0.986
D1I	9.37	1.69	120	9.16	4.23	14.34	0.180	0.23	0.569
D1S	14.858	3.64	120	15.32	2.11	23.79	-0.794	1.529	0.095
D2B	5.59	1.20	120	5.46	2.45	8.83	0.362	0.218	0.712
D2L	3.35	1.20	120	3.20	0.62	6.15	0.051	-0.578	0.986
D2I	8.24	1.69	120	8.23	5.05	12.98	0.148	-0.452	0.569
D2S	13.94	3.85	120	14.25	1.92	22.47	-0.596	0.844	0.095
D3B	6.71	1.34	120	6.55	2.58	10.01	0.22	0.12	0.316
D3L	3.25	1.32	120	3.18	0.77	6.81	0.29	-0.40	0.762
D3I	7.96	1.93	120	7.80	2.91	12.48	-0.01	-0.08	0.937
D3S	12.99	4.08	120	13.46	1.35	22.37	-0.34	-0.27	0.343
D4B	5.68	1.63	120	5.69	2.42	9.15	0.146	-0.510	0.832
D4L	3.08	1.46	120	2.98	.48	7.03	0.423	-0.464	0.329
D4I	9.65	2.54	120	9.76	2.09	15.60	-0.203	0.377	0.625
D4S	14.22	4.02	120	14.32	3.78	24.90	-0.020	0.105	0.890
D5B	4.24	1.59	120	4.02	1.09	8.83	0.381	-0.064	0.600
D5L	2.12	1.40	120	1.74	0.00	6.54	1.011	0.820	0.021
D5I	15.21	4.18	120	14.99	3.49	25.99	0.157	0.291	0.479

B- Comparison of the MC mean measurements by ethnicity (Race)

D1	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value*
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D1B	4.15(1.01)	4.09(0.96)	3.43(0.88)	3.89(1.00)	7.14(2)	0.001
D1L	4.38 (1.29)	4.39 (1.10)	4.20 (1.38)	4.33 (1.25)	0.29(2)	0.749
D1I	9.12(1.84)	9.82(1.34)	9.15(1.79)	9.37(1.69)	2.21(2)	0.114
D1S	14.86(3.92)	14.56(3.51)	15.14(3.56)	14.85(3.64)	0.251(2)	0.779
D2B	5.62(1.08)	6.01(1.13)	5.14(1.24)	5.59(1.20)	5.56(2)	0.005
D2L	3.34(1.13)	3.63(1.17)	3.06(1.25)	3.35(1.20)	2.28(2)	0.106
D2I	8.11(1.73)	8.90(1.51)	7.71(1.63)	8.24(1.69)	5.46(2)	0.005
D2S	13.75(4.36)	13.54(3.98)	14.52(3.12)	13.94(3.85)	0.704(2)	0.497
D3B	6.84(1.22)	7.07(1.38)	6.22(1.28)	6.71(1.34)	4.57(2)	0.012
D3L	3.39 (1.26)	3.57 (1.23)	2.78 (1.38)	3.25 (1.32)	4.06(2)	0.020
D3I	7.70(1.83)	8.81(1.55)	7.35(2.03)	7.96(1.93)	6.81(2)	0.002
D3S	12.34(4.41)	12.92(4.18)	13.7(3.59)	12.99(4.08)	1.140(2)	0.323
D4B	5.92(1.60)	6.30(1.56)	4.83(1.38)	5.68(1.63)	9.98(2)	0.000
D4L	3.18 (1.64)	3.38 (1.32)	2.67(1.34)	3.08 (1.46)	2.57(2)	0.081
D4I	9.24(2.77)	10.59(2.04)	9.13(2.54)	9.65(2.54)	4.31(2)	0.016
D4S	13.49(4.34)	15.04(3.91)	14.13(3.73)	14.22(4.02)	1.52(2)	0.223
D5B	4.12(0.94)	5.14(1.71)	3.47(1.58)	4.24(1.59)	13.379(2)	0.000
D5L	2.23 (1.52)	2.03 (1.17)	2.10(1.49)	2.12 (1.40)	0.205(2)	0.990
D5I	14.49(4.11)	16.05(3.56)	15.10(4.73)	15.21(4.18)	1.427(2)	0.244

*One way-ANOVA

C- Comparison of the MC mean measurements by gender

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1B	4.05(1.01)	3.73(0.97)	0.32(-0.40,0.68)	1.75(118)	0.081
D1L	4.42(1.40)	4.23(1.10)	0.19(-0.26,0.64)	0.83(118)	0.405
D1I	10.09(1.65)	8.64(1.40)	1.45(0.89,2.00)	5.17 (118)	0.00
D1S	16.48(2.75)	13.23(3.72)	3.25(2.06,4.43)	5.43(118)	0.00
D2B	5.67(1.21)	5.51(1.19)	0.157(-0.27,0.59)	0.718(118)	0.474
D2L	3.38(1.30)	3.31(1.10)	0.06(-0.37,0.50)	0.28(118)	0.774
D2I	8.96(1.63)	7.52(1.43)	1.43(0.88,1.99)	5.13(118)	0.00
D2S	15.64(3.01)	12.23(3.86)	3.41(2.16,4.66)	5.39(118)	0.00
D3B	6.88(1.44)	6.53(1.21)	0.35(-0.12,0.83)	1.46(118)	0.146
D3L	3.36(1.50)	3.14(1.12)	0.22(-0.25,0.70)	0.92(118)	0.356
D3I	8.46(1.93)	7.45(1.81)	1.00(0.32,1.68)	2.94(118)	0.004
D3S	14.11(3.89)	11.88(3.98)	2.23(0.81,3.65)	3.10(118)	0.002
D4B	6.09(1.69)	5.28(1.47)	0.80(0.23,1.38)	2.78(118)	0.006
D4L	3.26(1.65)	2.90(1.23)	0.36(-0.16,0.89)	1.36(118)	0.174
D4I	9.86(2.46)	9.45(2.62)	0.40(-0.51,1.32)	0.86(118)	0.388
D4S	14.61(4.18)	13.84(3.84)	0.76(-0.68,2.22)	1.04(118)	0.297
D5B	4.07(1.48)	4.41(1.69)	-0.33(-0.91,0.23)	-1.160(118)	0.248
D5L	2.34(1.60)	1.91(1.13)	0.42(-0.07,0.93)	1.691(118)	0.324
D5I	15.03(4.25)	15.40(4.12)	-0.37(-1.89,1.14)	-0.488(118)	0.626

D- Comparison of the MC mean measurements between gender among Malays

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value*
D1B	4.16(0.99)	4.15(1.06)	0.01(-0.64,0.67)	0.048(38)	0.962
D1L	4.79(1.28)	3.98(1.19)	0.80(0.01,1.60)	2.05(38)	0.047
D1I	10.30(1.35)	7.95(1.49)	2.34(1.42,3.26)	5.18(38)	0.000
D1S	17.33(2.37)	12.38(3.60)	4.95(2.99,6.90)	5.12(38)	0.000
D2B	5.64(1.07)	5.60(1.13)	0.037(-0.66,0.74)	0.107(38)	0.915
D2L	3.56(1.25)	3.13(0.99)	0.425(-0.29,1.14)	1.190(38)	0.241
D2I	9.31(1.36)	6.91(1.13)	2.40(1.59,3.20)	6.048(38)	0.000
D2S	16.39(2.73)	11.12(4.12)	5.27(3.03,7.51)	4.77(38)	0.000
D3B	7.24(0.91)	6.44(1.38)	0.79(0.04,1.55)	2.14(38)	0.038
D3L	3.60(1.42)	3.19(1.08)	0.41(-0.39,1.22)	1.03(38)	0.310
D3I	8.98(1.24)	6.42(1.37)	2.55(1.71,3.39)	6.15(38)	0.000
D3S	14.09(3.57)	10.59(4.54)	3.49(0.87,6.11)	2.70(38)	0.010
D4B	6.64(1.20)	5.20(1.65)	1.44(0.52,2.37)	3.161(38)	0.003
D4L	3.40(2.00)	2.96(1.20)	0.44(-0.61,1.50)	0.845(38)	0.403
D4I	10.45(2.01)	8.03(2.94)	2.42(0.81,4.03)	3.041(38)	0.004
D4S	13.93(4.02)	13.05(4.69)	0.88(-1.91,3.68)	0.637(38)	0.528
D5B	4.44(0.93)	3.80(0.86)	0.63(0.06,1.21)	2.244(38)	0.031
D5L	2.26(1.83)	2.20(1.20)	0.05(-0.93,1.05)	0.122(38)	0.525
D5I	15.03(4.13)	13.95(4.12)	1.07(-1.57,3.71)	0.821(38)	0.417

* Independent sample t-test

E- Comparison of the MC mean measurements between gender among Chinese

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value*
D1B	4.34(1.10)	3.84(0.74)	0.50(-0.10,1.10)	1.68(38)	0.100
D1L	4.38(1.21)	4.41(1.02)	-0.02(-0.74,0.69)	0.06(38)	0.951
D1I	10.18(1.55)	9.47(1.02)	0.71(-0.13,1.55)	1.70(38)	0.096
D1S	15.76(2.84)	13.36(3.77)	2.40(0.26,4.54)	2.27(38)	0.029
D2B	6.06(1.12)	5.95(1.17)	0.109(-0.62,0.84)	0.302(38)	0.765
D2L	3.87(1.22)	3.39(1.10)	0.486(-0.26,1.23)	1.371(38)	0.196
D2I	9.40(1.54)	8.40(1.34)	1.00(0.076,1.93)	2.19(38)	0.035
D2S	14.89(3.81)	12.20(3.77)	2.69(0.266,5.12)	2.24(38)	0.031
D3B	7.08(1.53)	7.05(1.25)	0.02(-0.86,0.92)	0.06(38)	0.947
D3L	3.90(1.42)	3.24(0.92)	0.65(-0.11,1.42)	1.73(38)	0.091
D3I	9.07(1.66)	8.56(1.63)	0.51(-0.54,1.57)	0.98(38)	0.331
D3S	13.46(4.52)	12.38(3.84)	1.07(-1.61,3.76)	0.81(38)	0.423
D4B	6.37(1.89)	6.23(1.20)	0.13(-0.88,1.15)	0.271(38)	0.788
D4L	3.59(1.46)	3.18(1.16)	0.41(-0.43,1.25)	0.979(38)	0.334
D4I	10.49(1.93)	10.69(2.20)	-0.19 (-1.52,1.13)	-0.295(38)	0.769
D4S	14.84(4.07)	15.24(3.83)	-0.39(-2.93,2.14)	-0.316(38)	0.754
D5B	4.43(1.50)	5.84(1.63)	-1.40(-2.41,-0.39)	-2.827(38)	0.007
D5L	2.53(1.28)	1.53(0.81)	1.00(-0.31,1.69)	2.963(38)	0.008
D5I	15.80(3.100)	16.30(4.04)	-0.49 (-21.80,1.80)	-0.438(38)	0.664

* Independent sample t-test

F- Comparison of the MC mean measurements between gender among Indians

	Male (n=20) Mean(SD)	Female (n=20) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value*
D1B	3.65(0.85)	3.20(0.87)	0.44(-0.11,0.99)	1.60(38)	0.117
D1L	4.10(1.64)	4.31(1.08)	-0.20(-1.10,0.68)	-0.466(38)	0.644
D1I	9.80(2.02)	8.51(1.26)	1.29(0.21,2.37)	2.43(38)	0.020
D1S	16.34(2.90)	13.94(3.81)	2.40(0.22,4.57	2.23(38)	0.031
D2B	5.31(1.36)	4.98(1.11)	0.828(0.47,1.12)	0.828(38)	0.413
D2L	2.70(1.19)	3.42(1.23)	-0.721(-1.49,0.05)	-1.87(38)	0.068
D2I	8.17(1.75)	7.25(1.40)	0.91(-0.10,1.93)	-1.81(38)	0.077
D2S	15.65(2.21)	13.38(3.52)	2.26(0.381,4.148)	2.434(38)	0.020
D3B	6.34(1.67)	6.10(0.75)	0.24(-0.59,1.07)	0.58(38)	0.562
D3L	2.58(1.41)	2.98(1.36)	-0.39(-1.28,0.49)	-0.90(38)	0.374
D3I	7.33(2.28)	7.38(1.80)	-0.04(-1.36,1.27)	-0.07(38)	0.944
D3S	14.78(3.58)	12.65(3.35)	2.13(-0.09,4.35)	1.94(38)	0.060
D4B	5.25(1.65)	4.41 (0.89)	0.83(-0.01,1.69)	1.989(38)	0.054
D4L	2.79(1.40)	2.55(1.31)	0.24(-0.62,1.11)	0.562(38)	0.577
D4I	8.62(2.94)	9.64(2.02)	-1.02(-2.64,0.59)	-1.280(38)	0.208
D4S	15.05(4.57)	13.22(2.43)	1.82(-0.52,4.16)	1.574(38)	0.124
D5B	3.35(1.68)	3.59 (1.51)	-0.24(-0.01,1.69)	-0.480(38)	0.634
D5L	2.21(1.70)	1.99(1.29)	0.22(-0.62,1.11)	0.464(38)	0.968
D5I	14.25(5.32)	15.94(4.02)	-1.69(-2.64,0.59)	-1.135(38)	0.263

* Independent sample t-test

G- Comparison of MC mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value*
	21-30 (n=12)	31-40 (n=22)	41-50 (n=38)	51-60 (n=48)		
D1B	4.08(0.68)	4.19(0.89)	3.90(0.88)	3.70(1.17)	1.37(3)	0.254
D1L	3.71(2.02)	4.13(1.05)	4.24(1.15)	4.64(1.13)	2.23(3)	0.088
D1I	10.08(2.24)	9.61(1.61)	8.95(1.50)	9.41(1.68)	1.68(3)	0.174
D1S	17.09(2.21)	17.16(2.30)	14.12(3.85)	13.82(3.63)	7.17(3)	0.000
D2B	6.19(1.32)	5.59(1.13)	5.48(1.09)	5.53(1.27)	1.16(3)	0.328
D2L	2.36(1.22)	3.59(1.30)	3.33(1.18)	3.49(1.07)	3.42(3)	0.020
D2I	7.38(1.76)	8.99(1.80)	7.94(1.38)	8.35(1.73)	3.06(3)	0.031
D2S	16.18(1.44)	15.42(2.59)	12.98(4.50)	13.46(3.84)	3.70(3)	0.014
D3B	7.29(1.39)	7.16(1.08)	6.34(1.37)	6.64(1.33)	2.67(3)	0.050
D3L	1.94(0.99)	3.73(1.71)	3.32(1.16)	3.30(1.14)	5.47(3)	0.001
D3I	5.85 (1.41)	8.60(1.72)	7.93(1.91)	8.21(1.84)	6.66(3)	0.000
D3S	15.15(1.97)	12.98(3.43)	12.33(4.82)	12.98(4.01)	1.46(3)	0.227
D4B	5.78 (1.53)	6.71(1.14)	5.63(1.51)	5.23(1.75)	4.549(3)	0.005
D4L	2.72 (1.29)	3.56(1.79)	2.93(1.36)	3.07(1.40)	1.158(3)	0.329
D4I	7.18(1.53)	9.58(2.24)	9.82(2.93)	10.17(2.21)	4.973(3)	0.003
D4S	14.66(2.60)	12.94(3.60)	13.23(4.28)	15.48(3.98)	3.319(3)	0.022
D5B	3.84 (1.96)	4.57(1.42)	4.16 (1.80)	4.27(1.40)	0.596(3)	0.919
D5L	2.23 (1.20)	2.83(1.89)	1.92(1.07)	1.93(1.34)	2.544(3)	0.256
D5I	11.80(3.69)	14.26(3.33)	15.76(4.24)	16.07(4.18)	4.269(3)	0.007

*One Way-ANOVA test

H- Descriptive statistics of the mandibular canal diameter measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
D1MCd	2.25	0.47	120	2.23	1.06	3.45	0.095	-0.31	0.86
D2MCd	2.01	0.42	120	1.96	1.26	3.19	0.57	-0.18	0.27
D3MCd	2.10	0.37	120	2.08	1.35	3.24	0.22	-0.14	0.79
D4MCd	2.18	0.42	120	2.13	1.14	3.83	0.68	1.35	0.57
D5MCd	2.25	0.43	120	2.20	1.34	3.91	0.92	2.27	0.33
MCd	2.16	0.30	120	2.14	1.54	2.98	0.30	-0.24	0.76

I- Comparison of the MC diameter mean measurements by ethnicity (race)

	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
D1MCd	2.30(0.45)	2.19(0.41)	2.28(0.55)	2.25(0.47)	0.62(2)	0.53
D2MCd	2.00(0.05)	1.98(0.06)	2.04(0.07)	2.01(0.42)	0.22(2)	0.79
D3MCd	2.10(0.05)	2.04(0.06)	2.16(0.05)	2.10(0.37)	1.09(2)	0.33
D4MCd	2.27(0.07)	2.12(0.06)	2.14(0.05)	2.18(0.42)	1.41(2)	0.24
D5MCd	2.33(0.53)	2.27(0.28)	2.16(0.43)	2.25(0.43)	1.69(2)	0.18
MCd	2.20(0.28)	2.12(0.29)	2.16(0.33)	2.16(0.30)	0.69(2)	0.50

J- Comparison of the mandibular canal diameter mean measurement between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
D1MCd	2.37(0.39)	2.13(0.52)	0.23(0.07-0.40)	2.83(118)	0.005
D2MCd	2.20(0.44)	1.81(0.29)	0.38(0.24-0.25)	5.57(118)	0.00
D3MCd	2.24(0.33)	1.96(0.34)	0.28(0.15-0.40)	4.50(118)	0.00
D4MCd	2.36(0.41)	1.99(0.35)	0.36(0.22-0.50)	5.23(118)	0.00
D5MCd	2.34(0.49)	2.16(0.33)	0.17(0.02-0.32)	2.28(118)	0.02
MCd	2.37(0.39)	2.13(0.52)	0.29(0.18-0.38)	5.93(118)	0.00

K- Comparison of the MC means measurements between gender among races

Malays	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.42(0.41)	2.17(0.45)	0.25(-0.02,0.53)	1.83(38)	0.07
D2MCd	2.06(0.36)	1.94(0.27)	0.12(-0.08,0.33)	1.23(38)	0.22
D3MCd	2.24(0.33)	1.96(0.29)	0.28(0.08,0.48)	2.86(38)	0.007
D4MCd	2.42(0.53)	2.12(0.39)	0.30(0.00,0.60)	2.02(38)	0.049
D5MCd	2.43(0.62)	2.23(0.40)	0.20(-0.13,0.53)	1.20(38)	0.23
MCd	2.31(0.33)	2.08(0.18)	0.23(0.06,0.40)	2.75(38)	0.019
Chinese	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.38(0.29)	2.00(0.43)	0.38(0.14,0.61)	3.25	0.002
D2MCd	2.30(0.36)	1.66(0.23)	0.63(0.44,0.82)	6.60	0.000
D3MCd	2.25(0.37)	1.83(0.33)	0.42(0.19,0.65)	3.77	0.001
D4MCd	2.36(0.36)	1.88(0.25)	0.47(0.27,0.67)	4.80	0.000
D5MCd	2.29(0.32)	2.24(0.24)	0.04(-0.13.0.22)	0.52	0.606
MCd	2.32(0.22)	1.92(0.20)	0.39(0.25,0.53)	5.74	0.000
Indians	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
D1MCd	2.32(0.46)	2.24(0.65)	0.08(-0.27,0.44)	0.46(38)	0.643
D2MCd	2.24(0.56)	1.84(0.32)	0.39(0.10,0.69)	2.71(38)	0.691
D3MCd	2.23(0.32)	2.09(0.37)	0.13(-0.08,0.36)	1.25(38)	0.217
D4MCd	2.30(0.31)	1.98(0.37)	0.31(0.10,0.53)	2.95(38)	0.005
D5MCd	2.30(0.50)	2.02(0.30)	0.28(0.01,0.54)	2.15(38)	0.038
MCd	2.28(0.35)	2.03(0.25)	0.24(0.04,0.44)	2.48(38)	0.17

L- Comparison of the MC mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 (n=12)	31-40 (n=22)	41-50 (n=38)	51-60 (n=48)		
D1MCd	2.24(0.50)	2.28(0.32)	2.18(0.50)	2.30(0.51)	0.40	0.71
D2MCd	2.38(0.65)	1.99(0.40)	1.95(0.38)	1.97(0.35)	3.73	0.12
D3MCd	2.28(0.38)	2.12(0.33)	2.16(0.41)	2.00(0.32)	2.49	0.06
D4MCd	2.26(0.31)	2.27(0.39)	2.14(0.50)	2.14(0.39)	0.68	0.56
D5MCd	2.30(0.55)	2.29(0.37)	2.21(0.36)	2.26(0.47)	0.25	0.85
MCd average	2.29(0.40)	2.19(0.24)	2.13(0.30)	2.13(0.29)	1.10	0.35

M- Descriptive statistics of the mandibular foramen diameter measurements

	Mean (mm)	Std. Deviation	N	Median	Minimum	Maximum	Skewness	Kurtosis	KS value
ManFd	2.55	0.43	120	2.50	1.62	3.69	0.49	-0.16	0.555

N- Comparison of the mandibular foramen diameter mean measurements by ethnicity (race)

	Mean Measurements (SD)			Total Mean (SD) N=120	F-statistics (df)	P value
	Malays (n=40)	Chinese (n=40)	Indians (n=40)			
ManFd	2.71(0.43)	2.50(0.40)	2.43(0.44)	2.55(0.43)	4.83(2)	0.010

O- Comparison of the mandibular foramen diameter mean measurements between males and females

	Male (n=60) Mean(SD)	Female (n=60) Mean(SD)	Mean difference (95% CI)	t-statistics(df)	P value
ManFd	2.63(0.39)	2.46(0.46)	0.17(0.01,0.32)	2.16(118)	0.032

P- Comparison of the MF diameter mean measurements between gender among races

Malays	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
ManFd	2.61(0.42)	2.82(0.42)	-0.21(-0.48,0.05)	-1.62(38)	0.11
Chinese	**Male (n=20 Mean(SD)**	**Female (n=2) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
ManFd	2.57(0.38)	2.42(0.41)	0.14(-0.10,0.40)	1.18(38)	0.24
Indians	**Male (n=20) Mean(SD)**	**Female (n=20) Mean(SD)**	**Mean difference (95% CI)**	**t-statistics(df)**	**P value**
ManFd	2.72(0.37)	2.14(0.29)	0.58(0.36,0.79)	5.46(38)	0.00

Q- Comparison of the mandibular foramen diameter mean measurements between age groups

Aspect	Length measurements Mean (SD)				F-Statistics	P value
	21-30 (n=12)	31-40 (n=22)	41-50 (n=38)	51-60 (n=48)		
ManFd	2.58(0.34)	2.75(0.45)	2.53(0.39)	2.46(0.46)	2.30	0.081

R- Comparison of the bifid canal among gender

Ethnicity(race)	N	Normal MC freq (%)	Bifid MC freq(%)	X2 stat a(df)	P value
Male	60	43(71.7)	17(28.3)	2.34(1)	0.126
Female	60	50(83.3)	10(16.7)		
Total	120	93(77.50)	27(22.50)		