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RADIOGRAPHIC AND CADAVERIC DETERMINATION OF THE MENTAL FORAMEN POSITION IN ADULTS IN GHANA

BY

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DECLARATION

I hereby declare that except for references to the work of other researchers, which have been referenced accordingly, this original project is a product of my own research carried out under supervision in accordance with the regulations of the school of Graduate Studies, University of Ghana. I further declare that this thesis has neither in whole nor in part been presented for another degree elsewhere and that I am solely responsible for any flaws in this work.

Signature…… Date……

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DECLARATION BY SUPERVISORS

We declare that the practical work and presentation of this thesis were supervised by us in accordance with guidelines on supervision of thesis laid down by the University of Ghana.

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DEDICATION

To my Blessed Lord and family.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
MF	Mental Foramen
OPG	Orthopanthomograph
BC-SB	Distance from the buccal cusp tip of the second lower premolar to the superior border of the mental foramen
BC-LMB	Distance from the buccal cusp tip of the second lower premolar to the lower mandibular border
AMF	Accessory Mental Foramen
AMN	Accessory Mental Nerve

ABSTRACT

Background: The mental foramen which transmits mental nerve is an important anatomical landmark in mental nerve block and other invasive procedures in the oral and maxillofacial region. Variations in the position of the mental foramen exist between populations and even among inhabitants of common geographic environment. There have been reports of alteration in sensations following dental procedures such as implant placement and orthognathic surgeries probably due to inaccurate localization of the mental foramen. Despite its clinical significance, little is known about its position in adults in Ghana.

Aim: This study investigated the anatomy of the mental foramen on the mandibles of adults in Ghana using radiographs and cadaveric subjects.

Methodology: Twenty-four (24) dissected cadaver mandibles and four hundred and five (405) archived dental panoramic radiographs of individuals with full skeletal development were examined. The horizontal position of the mental foramen was determined in relation to the mandibular teeth using a rule and the dimensional tool of the proprietary radiographic software (CS software version 7) respectively. Other anthropometric characteristics of the mental foramen such as the number of foramina present, shape, size and orientation of its opening were examined. Data obtained were stored in excel and analyzed using S.P.S.S version 22.

Results: The mental foramen was found to be most prevalent at the apex of the second mandibular premolar in both radiographs (52.1%) and cadavers (50%). The position between the second mandibular premolar and first molar was the second most common (radiographs=28.4%, cadavers=39.6%). In about four-fifth of the mandibles, the mental foramen position was bilaterally symmetrical in both subject groups. Bilateral foramina type was most common in both radiographic (98.77%) and cadaveric (100%) subjects. A unilateral

foramen (0.25%) and unilateral accessory mental foramina (0.99%) were noted in the rest of the radiographs examined. From the cadavers, the mental foramen was predominantly oval, with mean size of 3.17mm horizontally and 2.47mm vertically and its opening, postero-superiorly directed.

Conclusion: This study, being the first on the mental foramen in Ghana, has established that the MF is most commonly positioned at the apex of the second lower premolar in adults in Ghana.

CHAPTER 1

INTRODUCTION

1.1 Background

The mental foramen (MF) is an opening on the antero-lateral surface of the mandible marking the termination of the mandibular canal. The inferior alveolar neurovascular bundle exits the mental foramen as the mental nerve and blood vessels to supply the ipsilateral lower lip, labial mucosa, mandibular canine and premolars (Greenstein & Tarnow, 2006; Lipski et al., 2013; Moore et al., 2014).

The mental foramen shows variations in terms of shape, direction of its opening, the number of foramina and position (Fabian, 2007; Haghanifar & Rokouei, 2009; Sankar et al., 2011). Morphologically, it may be round or oval and the direction of its opening has often been reported as postero-superior. Numerically, it may be absent, unilateral or bilateral and multiple on one or both sides on the mandible in some cases (Kieser et al., 2002; çağırankaya & Kansu, 2008; Haghanifar & Rokouei, 2009). According to Igarashi et al., (2004), a single foramen exists on each side of the mandible in most cases but the number may differ in different ethnic groups ranging from one to three foramina. In terms of position, normal adults with intact teeth in most cases have the MF positioned midway between the lower mandibular border and the alveolar crest along a vertical line that passes through the supraorbital notch. In 50% of these cases, the MF is positioned inferior to the apex of the second mandibular premolar; in 20%-25%, it is positioned between the apices of the first and second mandibular premolars and in 24%, it is posterior to the second mandibular premolar (Shah, Vaze, & Kinhal, 2010).

A review of two standard anatomy and radiology textbooks however, shows discrepancies in statements regarding the position of the MF (Hiatt & Gartner, 2001; Sinnatamby & Last, 2006). Also, various published investigations on the MF position are incongruent (Adejuwon et al., 2012; Loyal et al., 2014; Parnami et al., 2015). According to Ngeow & Yuzawati, (2003), Cutright et al., (2003) and Koppe, (2012), race as defined by Turner II, (1987), is one of the determinants of these variations. In Mongoloids, the MF has been reported to be localized on the longitudinal axis of the second mandibular premolar. In Negroids, it is posteriorly placed; between the second mandibular premolar and the first mandibular molar while in Caucasoids, it is between the first and second mandibular premolars (Cutright et al., 2003; Koppe, 2012). The variations in the MF position among the ethnic groups, according to Yesilurt at al., (2008), may be attributed to their different dietary habits which consequently affects mandibular growth and development.

Ari et al., (2005) reported further that the position of the MF does not only vary among ethnic groups but also vary among inhabitants of common geographic environment. A study in a Nigerian population for example, revealed that the most prevalent position of the MF was between the first and second mandibular premolars (Bello et al., 2018). In a Zimbabwean population however, the MF was seen mostly below the second mandibular premolar on the right side and between the second mandibular premolar and first molar on the left side (Mbajiorgu et al., 1998). According to Prado & Caria, (2007), in addition to the different feeding habits, factors such as shape or size of the face and cranium, teeth structure, head position, socioeconomic and environmental factors may contribute to the variations in mandibular anatomy among populations of common geographic setting.

The morphology of the mandible, thus the mental foramen, has also been reported to vary between males and females (Cutright et al., 2003, Vinay et al., 2013). The superior and

inferior borders of the MF in relation to the lower mandibular border have been reported to be higher in male than females (Chandra et al., 2013; Suragimath et al., 2016). Other parameters such as gonial angle, bi-condylar breadth and the height of the mandible also vary between the genders (Mahima et al., 2009; Chandra et al., 2013; Suragimath et al., 2016). Differences in occlusal forces and the growth or development of the mandible that occurs in males and females have been attributed to these variations (Huumonen et al., 2010; Thakur et al., 2014).

The MF nonetheless, is of great significance in clinical procedures involving the mandibular region. Also, knowledge of its variations in position is imperative during differential diagnosis of small radiolucencies in the mandibular premolar and molar region (Ngeow & Yuzawati, 2003; Parnami et al., 2015).

Many dental procedures require accurate knowledge of the number, position and morphology of mental foramina for safe and effective care (Budhiraja et al., 2013). These dental and maxillofacial procedures include periapical surgeries, root canal treatment, enucleations, apicocurretage of mandibular premolars and retrograde amalgam filling and other surgical procedures of the lower lip where blockage of the mental nerve by local anaesthesia is preferred to general anaesthesia (Fabian, 2007; Von Arx et al., 2013; Singh et al., 2014).

Also, Dental Professionals make use of the position of the MF with reference to the horizontal (horizontal position) or the vertical (vertical position) plane to facilitate dental implant fixture or placement. Mandibular implant techniques and orthognathic surgeries are on the rise and have become common in modern dentistry. While implant techniques and materials have been devised to aid good outcomes, complications may likely arise during or after the placement of these dental implants. It is reported that implant failure may result only as complication after the procedure but temporal or permanent sequalae may occur as

complication during the procedure due to violation of the anatomical structures (Yosue & Brooks, 1998; Neiva et al., 2004).

The identification of the MF can be difficult. There are no absolute anatomical landmarks for reference and the foramen cannot be clinically visualized or palpated (Shankland, 1994; Agarwal & Gupta, 2011). Different methods have therefore been employed in the attempt to evaluate and estimate its position. These include macroscopic examination of dried mandible, computed tomography and dental panoramic radiographs (Agthong et al., 2005; Mendonça Amorim et al., 2008; Voljevica, 2015; Ishii et al., 2016)

Panoramic radiographs are commonly used by the dental practitioners prior to planning of implant placement or surgery (Moraes et al., 2008). MF, on a conventional dental panoramic radiograph, appears as a radiolucent area in the inferior region of the mandibular teeth (Greenstein & Tarnow, 2006; Neves et al., 2010).

Panoramic radiographs (Orthopanthomograph-OPG), though are cost effective and are of low radiation; it has been reported to increase the size of the MF by 36% (Forni, Sánchez-Garcés, & Gay-Escoda, 2012) and the position of the MF shifted by 23% (Philips et al., 1992).

Other authors, however reported that MF location determined on OPG is as accurate as that determined using CBCT and periapical radiographs (Aminoshariae et al., 2014). Also, other than absolute dimensions, the anteroposterior position of the MF examined in in-situ (dry skulls) have been reported to closely correlate to its position on radiographs (Yosue & Brooks, 1989; Al Jasser, 1998). It is however, strongly advised that the OPG operator should be highy skilled and the patients head positioned properly to achieve reliable radiographic image (Akcam & Altiok, 2003; Laster, 2005; Monsour & Dudhia, 2008).

Knowledge gathered so far, shows a dearth of published studies on the MF morphology and its common position among adults in Ghana. The variations of the MF morphology among ethnic groups and populations of common geographic environment, coupled with its clinical significance thus necessitates its finding among adults in Ghana.

1.2 Problem statement

Adequate knowledge of the position and morphology of the MF and the exit point of the mental nerve for all populations is crucial in planning and carrying out safe dental procedures such as endodontic procedures, orthognathic surgeries, implant placement and construction of complete denture in the mandible (Neiva et al., 2004; Shah et al., 2010).

Without this, complications such as neurosensory dysfunctions of the mental nerve have been reported to follow these procedures. Its incidence ranged from 8.5% to 24% (Gianni et al., 2002; Mendonça Amorim et al., 2008; Soheilifar et al., 2016; Clark et al., 2017). The causes of these complications are improper implant placement and orthognathic surgeries probably due to inaccurate localization of the MF (Walton, 2000; Gianni et al., 2002; Soheilifar et al., 2016).

The mental foramen varies in position, shape and number between ethnic groups and populations in different geographical locations. While data for the Caucasians and other Negroid populations abound, the same cannot be said of the Ghanaian population. The variation in the anthropometry of the MF between races and geographical locations makes it difficult to apply the landmarks for the identification of the MF in one race or geographical location to another. Furthermore, the radiological investigative methods that must be employed to ascertain the MF position are expensive and not readily available in the Ghanaian setting. These therefore, necessitate the need for establishment of a local or

baseline data. This study therefore sought to investigate the common position of the mental foramen in adults in Ghana.

1.3 Justification

The actual position, size and number of MF are of great significance in many clinical dental procedures. Risk of complications following surgeries in the oral and maxillofacial region can be minimized with knowledge on the position of the MF. Also, iatrogenic injuries can then be prevented (Fabian, 2007).

The MF is known to be usually located inferior to the second mandibular premolar. Its direction of opening is posterior and upwards (Oğuz & Bozkir, 2002; Haghanifar & Rokouei, 2009). This knowledge however is based on findings from populations other than Ghana but evidences suggest that the MF shows variations between populations of different geographic zones and even among inhabitants of common geographic environment (Ari et al., 2005). Evaluation of reports from the many studies on MF shows inconsistency of the foramen as an anatomical landmark. Furthermore, it is impossible to palpate the MF during dental procedures.

Different methods have been employed by different studies for the determination of the MF position. Panoramic radiography is one of the common imaging technique that has been used.

This study will help elucidate the common location of the MF in adults in Ghana with the view of carrying out mental nerve block and performing other dental surgical procedures safely.

1.4 Hypothesis

Null hypothesis: The number, position, size, orientation and shape of the mental foramen among adults in Ghana does not vary significantly from that in other pouplations.

Alternative/working hypothesis: The number, position, size, orientation and shape of the mental foramen among adults in Ghana varies significantly from that in other populations.

1.5 Aim

- To study the anatomy of the mental foramen in adults in Ghana using radiograph and cadaveric subjects.

1.6 Specific Objectives

Primary Objective

- To describe the pattern (number, position, orientation of its opening and shape) of mental foramen in adults in Ghana using radiographs and cadavers.

Secondary Objectives

- To determine if the position of the mental foramina varies between the right and the left sides (symmetry) of the mandibles on radiographs and cadavers.
- To determine the gender differences in the horizontal position of the mental foramen in adults in Ghana.
- To determine the difference in the vertical position of the mental foramen between the sides when measured on the cadaver and on radiographs.

CHAPTER 2

LITERATURE REVIEW

This Chapter reviewed existing literatures on the embryology and anatomy of the mandible with its mental foramina, the MF variations and its clinical significance, the factors that influence the MF position and the various techniques that have been employed for the MF position determination. Scientific papers were searched and accessed using search engines such as Pubmed, Scopus, Google Scholar, Medline and Sciencedirect. "Mental foramen and it position, variations of the mental foramen, importance of the mental foramen, mental foramen and panoramic radiographs" were the main key words entered for the databases search.

2.1 Gross anatomy of the mandible and the teeth

2.1.1 The mandible

The mandible is the strongest and largest bone of the face (Müller et al., 2004; Moore et al., 2014). It supports the lower teeth and assists in mastication. The mandible forms the skeleton of the lower jaw and articulates with the temporal bone of the skull at the temporomandibular joint which permits mobility. The bone is U-shaped and is located inferior to the maxilla. The mandible consists of a body in front and right and left vertical ramus posteriorly (Figure 1). The body meets the ramus at the angle of mandible (Müller et al., 2004; Moore et al., 2014).

The body is horseshoe-shaped and forms the anterior border of the mandible. It is bounded by two borders and two surfaces namely; alveolar and inferior borders and external and internal surfaces. The alveolar border which is its superior border supports the lower teeth within alveolar sockets. The inferior border, which is its base, creates the lower jawline and contains a small groove in which the facial artery traverses (Standring, 2004; Moore et al., 2014).

The external surface of the body possesess a symphysis menti at the midline, which is detected as a subtle median ridge in adults. At the inferior portion of the ridge is the mental protuberance, a midline depression. The edges are elevated forming the mental tubercle. Situated lateral to ridge and beneath the incisive teeth is a depression, the incisive fossa. The MF is usually positioned below either between the lower premolars or at the second lower premolar (Müller et al., 2004; Standring, 2004).

On the internal surface of the body, is a median ridge flanked on both sides by mental spines. From the midline, the mylohyoid line arises and courses superiorly and posteriorly to the alveolar border (Standring, 2004; Breeland et al., 2020).

The ramus forms the latero-posterior portion of the mandible on both sides. On the superior aspect of the ramus is an anterior coronoid process and a posterior condylar process; both separated by a mandibular notch. The ramus is bounded by four borders and two surfaces. These are the superior, inferior, posterior and anterior border and lateral and medial surfaces (Müller et al., 2004; Breeland et al., 2020).

The inferior border of the ramus is continuous with the inferior border of the mandibular body. The posterior border is also continuous with the inferior border of the ramus superiorly. The anterior border is continuous with an oblique line arising from the external surface of the body of the mandible (Breeland et al., 2020).

The lateral surface possesses part of the oblique line and serves as an attachment for the Masseter muscle. The medial surface contains the mandibular canal through which the inferior alveolar neurovascular bundle traverses into the mandibular canal. At the anterio-superior and postero-inferior aspect of the mandibular foramen is the lingula of the mandible, a sharp process and the mylohyoid groove respectively (Lipski et al., 2013; Breeland et al., 2020).

The temporalis inserts on the coronoid process while the inferior head of the Lateral Pterygoid, on the condyloid process. The Medial Pterygoid muscle inserts on the medial surface of the angle of the mandible and ramus. The Masseter inserts on the lateral surface of the ramus while the Platysma, the inferior border of the mandible (Müller et al., 2004).

The Metalis and Orbicularis oculi originates from the incisive fossa while the Depressor labii inferioris and the Depressor anguli oris, the oblique line. The Geniohyoid and the Genioglossus arise from the mental spines and the Mylohyoid, the mylohyoid line. The anterior belly of the Digastric and the Buccinator arises from the digastric fossa and the alveolar process respectively (Lipski et al., 2013; Moore et al., 2014)

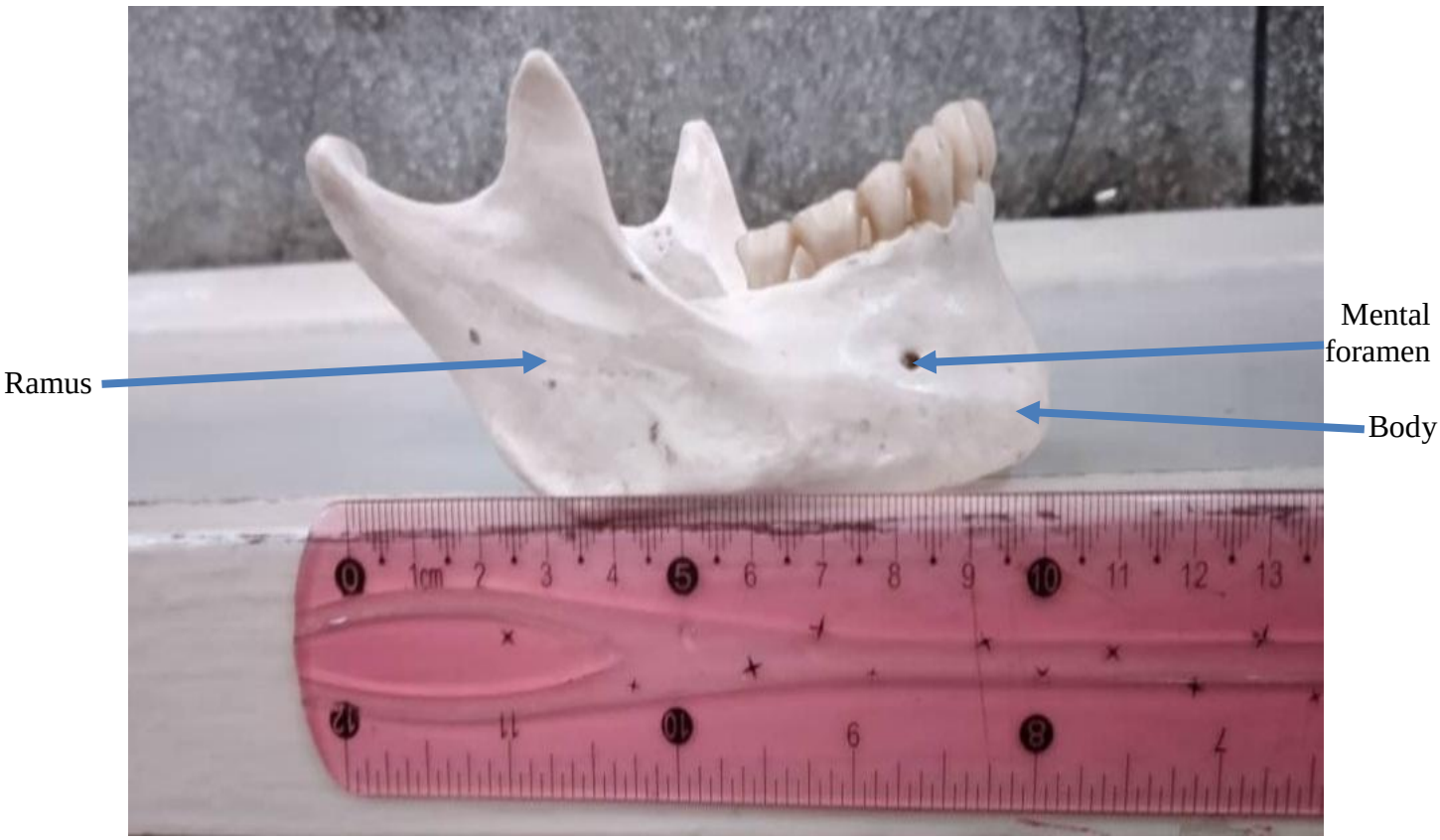

Figure 1: Picture of a mandible

2.1.2 The gross anatomy of the teeth

The teeth are borne in sockets in the alveolar process of the mandible and maxillae. Before eruption, the developing teeth, known as tooth buds, reside in the alveolar arches (Moore et al., 2014). By characteristics, there are four types of teeth namely: incisors which have thin cutting edges; prominently cone-shaped canines; premolars which are bicuspid and molars which are have three or more cusps (Müller et al., 2004). Four incisors, two canines and four molars in each jaw comprise the primary or deciduous teeth seen in children. Tooth eruption begins at about the sixth month after birth and is completed by the end of age two.

Secondary dentition or permanent teeth which are made up of four incisors, two canines, four premolars and six molars in each jaw, begins at age six (Müller et al., 2004). The mandibular teeth usually appear first before the maxillary teeth.

Structurally, a tooth possesses a crown, a neck and a root. The crown is the part of the tooth covered by enamel and projects from the gingiva. The root is the part covered by cementum and fixed in the alveolar sockets. The tip of the root forms the tooth apex. Between the crown and the root is the neck, in a sinuous outline called, cemento-enamel junction. Most of the tooth is composed of dentine with a pulp cavity beneath. The pulp canal or root canal conducts the superior and inferior alveolar nerves, arteries and veins to the pulp cavity through the apical foramen (Müller et al., 2004; Moore et al., 2014).

2.2 Embryology of the mandible

The mandible is the second bone to ossify after the clavicle during the sixth week of intrauterine development. The first pharyngeal arch gives rise to the Meckel's cartilage which serves as the template for the formation of the mandible. A fibrous membrane covers the ventral ends of the left and right Meckel's cartilages. In the sixth week in-utero, ossification begins in each half from a center near the mental foramen. The body and ramus are then

formed respectively as ossification spreads medially and postero-cranially. Bone replaces the Meckel's cartilage below the incisive rudiments by the 10th week. Condylar cartilage and other secondary cartilages which appear later are replaced with bone by late fetal stage. At birth, the two halves of the mandible are joined at the symphysis menti with the mandibular canal lying close to the lower mandibular border and the MF below the deciduous molar teeth. At this stage, the MF opening is directed forwards. With chin development, elongation of the body of the mandible behind the MF results and by the second year, the MF opening changes to be posteriorly directed to conduct the emerging mental nerve. In adulthood, the mandibular canal parallels the mylohyoid line and MF becomes placed midway between the superior and inferior borders of mandible. Consequential loss of teeth and resorption of alveolar bone in old age results in the mandibular canal and MF coming to lie close to the superior border of the mandible (Lee et al., 2001; Standring, 2004; Lipski et al., 2013).

2.3 Mental foramen

The MF is the exit of the mandibular canal on the anterolateral surface of the mandible. It is a funnel-like opening through which the mental neurovascular bundle emerges (Moore et al., 2014). Generally, the MF lies approximately midway between the superior and inferior borders of the mandible and can be located between the apices of the lower premolars or at the apex of the second lower premolar (Yeşilyurt et al., 2008; Loyal et al., 2014). Occasionally, it is found positioned between the apices of the second lower premolar and first lower molar or the apex of the first lower molar (Von Arx et al., 2013; Iwanaga & Choi, 2019).

The MF is an important anatomical landmark of clinical and anthropological relevance. Adequate knowledge of foramen's precise position and morphology is therefore important (Fabian, 2007; Budhiraja et al., 2013).

2.3.1 Clinical Significance of Mental Foramen

The MF is relevant in the facilitation of different clinical procedures such as local anaesthetic drug administration, implant placement, peri-apical surgeries in the region of the MF and orthognathic surgeries (Greenstein & Tarnow, 2006; Von Arx et al., 2013).

In local anaesthetic drug administration at the oral and maxillofacial region, knowledge of the accurate position of the MF is of immense significance in blocking the terminal incisive branches of the inferior alveolar nerve and the mental nerve. Effective anaesthesia can be achieved when the MF is precisely identified and the local anaesthetic agent injected directly into tissues around it (Philips et al., 1992).

For implant surgeries, osteotomies or other invasive surgeries in the mental region, complications such as haemorrhage and sensation impairment in the lower lip, labial mucosa and surrounding skin result upon trauma to the mental neurovascular bundle (Ngeow & Yuzawati, 2003; Fabian, 2007; Mendonça Amorim et al., 2008).

In implant placement in the mandible, temporary loss of sensations of pain, tactile sensation or temperature in the peri-oral soft tissues are common complications that may arise. Incidence report of implant related temporal hypoesthesia and anaesthesia range from 0 to 43.5% and 0 to 13% for permanent sensory changes (Walton, 2000; Ellian et al., 2005). Transient or temporal sensory changes, when prolonged have showed from literature to lead to permanent sensory deficit (Walton, 2000; Givol et al., 2002; Ellian et al., 2005). It has been stipulated that the minimum distance between the MF and the implant, should be 6mm (Kuzmanovic et al., 2003; Greenstein & Tarnow, 2006). Insertion of dental implants, most often, necessitate that the alveolar ridge be vertically and/or horizontally augmented in order to facilitate dental fixture placement. Measurement of the distance from the alveolar crest to the most coronal aspect of the mandibular canal and estimation of certain depths based on

periapical or panoramic radiographs are some common technical measures taken in order to avoid injury to the inferior alveolar neurovascular bundle during such procedures. Adequate knowledge of mandibular anatomical landmarks as such cannot be overemphasized (Neiva et al., 2004; Greenstein & Tarnow, 2006).

In edentulous people, the MF approaches the alveolar crest as atrophy advances and this may pose difficulty in the wearing of dentures. The MF region thus necessitates special attention in order to avoid complication during and after implant placement (Neiva et al., 2004; Greenstein & Tarnow, 2006; Budhiraja et al., 2013).

In apicocurretage of the lower premolars, the procedure the dental surgeon follows depends on the MF location in relation to the lower premolar, the corpus of the mandible and the ramus. Such procedure on the mandibular premolars may damage the mental nerve with consequent paraesthesia or anaesthesia of the region supplied by the nerve if the accurate position of the MF is not known (Nkenke et al., 2001; Sbordone et al., 2009).

Open reductions of mandibular fractures also requires knowledge of the MF position in order to prevent mental nerve injury. According to Shah et al., (2010), the knowledge of anatomical variations in this vital structure does not only help in it salvaging but even in orthognathic surgeries, it will necessitate modifications in the placement of osteotomy cuts.

The MF may also be incorrectly interpreted as a pathosis on a radiograph if its common position is not known. MF presentation on panoramic radiographs appears radiolucent, similar as radiographic lesions. Accurate knowledge of its position will help prevent its presence on a panoramic radiograph to be misinterpreted as a lesion (Parnami et al., 2015).

Hasan, (2011) also added that ‘‘the MF anatomy is important for evaluating the morphometric symmetry of the mental triangle, microscopic and macroscopic morphology

and maturity of the human mandible, bone remodeling activity and paleoanthropological features of the facial skeleton in different populations''. This helpful in the determination of age and sex of an individual; factors which are critical in forensic identification.

2.3.2 Variations in the Mental Foramen

Determination of the accurate position of the MF can be challenging. This can be attributed to the fact that the MF shows uniqueness among races, populations and even among inhabitants of the common geographic environment (Sankar et al., 2011; Udhaya et al., 2013; Voljevica, 2015).

The features of the MF which are population specific are position (Fabian, 2007; Sankar et al., 2011; Budhiraja et al., 2013; Eboh & Oliseh, 2014; Voljevica, 2015); number (Sankar et al., 2011; Udhaya et al., 2013; Paraskevas et al., 2015; Voljevica, 2015) and shape (Fabian, 2007; Sankar et al., 2011; Budhiraja et al., 2013; Eboh & Oliseh, 2014). Also bilateral symmetry or asymmetry, presence of accessory foramina and even absent MF which are unusual have also been reported (Eboh & Oliseh, 2014; Paraskevas et al., 2015).

In terms of the number of mental foramina, the MF has been shown to vary from being absent, single, or multiple foramina on one or both sides of the mandible (Kieser et al., 2002; çağırankaya & Kansu, 2008). In most cases, a single foramen is bilaterally present (Haghanifar & Rokouei, 2009). However, multiple foramina ranging from two to three foramina may also exist in different races (Igarashi et al., 2004). Furthermore, on one side of a mandible, where multiple foramina are present, they may be closely or widely separated from each other or clustered (Paraskevas, Mavrodi, & Natsis, 2015).

Absent mental foramen, though a rare anatomical variation, has been reported (Hasan, 2013; Matsumoto & Araki, 2012). Few studies have identified unilateral (Maria, Ramos, & Rubira-bullen, 2011; Ulu, Ertas, Gunhan, Atici, & Akcay, 2016) and bilateral absence (Coutant &

Ella, 2014). Analysis of reports from Brazilian, African and British population on MF unilateral absence range from 0.08% to 0.95% in frequency but it is statistically negligible for that of bilateral absence (Da Silva Ramos Fernandes et al., 2011; Hasan, 2013; Ulu et al., 2016).

The mental foramen may present in various shapes. The common shapes of MF that have been reported are oval, round and irregular shape (Al-khateeb, 2007; Al-Shayyab, Alsoleihat, Dar-Odeh, Ryalat, & Baqain, 2016).

The direction or orientations of the MF opening reported from many studies are varied. The various reported orientations of the MF opening include anterior, posterior, superior, lateral and postero-superior. The postero-superior orientation has been commonly reported as predominant in most populations (Kieser et al., 2002; Haghanifar & Rokouei, 2009; Agarwal & Gupta, 2011).

Accessory mental foramen (AMF) is also a rare anatomical variation and is formed from an accessory bony canal arising from the mandibular foramen. They differ from nutrient foramina which has no continuity to the mandibular canal (Naitoh et al., 2009). Compared to the MF, AMF varies in terms of dimensions and relative position to the mandibular teeth (Katakami et al., 2008; Naitoh et al., 2011). Its incidence also varies from race to race (Göregen et al., 2013). Among American Whites and Asian Indians, Sawyer et al., (1998) reported prevalences of 1.4% and 1.5% respectively and higher incidences; in African Americans (5.7%), in pre-Colombia Nazca Indians (9%), in Negros (7.6%) and Melanesians (9.7%). Like MF, it conducts neurovascular bundle; as such, it is of equal relevance even as the MF in dental and maxillofacial procedures. Awareness of the possibility of its encounter can help prevent mental nerve injury, enhances effective local anaesthesia and also prevent

incorrect diagnosis of lesion on dental panoramic radiographs (Toh et al., 1992; Imada et al., 2014).

On the mental foramen position, anatomical landmarks that have been used for it reports are variable. Generally, reports on the position of the foramina are with respect to bony and soft tissue landmarks. These anatomical reference landmarks include the alveolar and lower mandibular borders, symphysis menti, cheilion and the mandibular teeth (Neiva et al., 2004; Agthong et al., 2005; Song et al., 2007; Guo et al., 2009).

The mandibular teeth have been used by most studies for the description of the MF location. Table 1. outlines studies that investigated the MF position in relation to the lower teeth among various populations. Majority of the groups had the MF prevalently positioned between the apices of the lower premolars or at the apex of the second lower premolar. However, there are other variations in the positions which range from the apex of the mandibular canine to the mesio-buccal root of the first mandibular molar (Jasser & Nwoku, 1998; Shah et al., 2010).

Table 1. Summary of studies on the mental foramen position undertaken in some populations.

Author	Sample size	Population	Anterior to 1st premolar (%)	In line with 1st premolar (%)	Between 1st and 2nd Premolar (%)	Apex of 2nd premolar (%)	Between 2nd premolar and 1st Molar (%)
Tebo & Telford, (1950)	100	North Americans	0	3.5	23	49.4	24.1
Mbajiorgu et al.,	32	Zimbabweans	0	0	12.4	56.3	0

(1998)							
Gungor et al., (2006)	722	Turkey	1.2	3.2	71.5	22.4	1.7
Mwaniki et al., (1992)	79	Kenyan	0	31.9	56.1	12.1	0
Chkoura et al., (2013)	794	Moroccans	0.4	1.32	30	62.8	5.2
Adejuwon et al., (2012)	78	Nigeria (Yoruba)	0	1.3	3.9	61.5	21.8
Ngeow & Yuzawati, (2003)	169	Malaysia	0	3.4	19.6	69.2	7.7
Currie, et al., (2016)	100	Uk-based	0	0	76	20	4
Oğuz & Bozkir, (2002)	44	Turks	0	0	44.1	55.9	0
Igbigbi et al., (2005)	70	Malawians	0	2.8	10	62.9	24.3

2.4 Factors that Influence the Position of the Mental Foramen

Factors such race, age, gender, alveolar bone resorption and tooth wear or loss are known to influence the position of the MF (Igbigbi & Lebona, 2005; Parnami et al., 2015).

The anteroposterior position of the MF varies with age with a positive linear correlation (Cabanillas Padilla et al., 2014). It is reported that the MF becomes positioned more posterior with advancement in age (Al-shayyab et al., 2015). The apparent posterior shift in the mental foramen position has been attributed to attrition of the interproximal surfaces of the teeth that occurs in advancing age (Agthong et al., 2005; Al-Khateeb et al., 2007).

In the vertical plane, prior to tooth eruption in children, the MF is positioned close to the alveolar margin. During tooth eruption period, it becomes positioned mid-distance between the alveolar margin and the inferior mandibular border. In adults with dentition, it has however been shown to be positioned a little lower than the mid-distance between the upper and lower mandibular border (Lipski et al., 2013).

The position of the MF in edentulous individuals has been reported to be affected when compared to dentate individuals. The cause has been attributed to possible atrophic changes such as reduction in the angle of the mandible, coronoid process size and resorption of medial surface of mandibular condyles that occurs in edentition (Reich et al., 2011). Mendonça Amorim et al., (2008) in a study on the position of MF in 91 dentate and 79 edentulous mandibles, observed that dentate mandibles had higher dimensions between the mental foramen to the symphysis menti and to the lower mandibular border than in edentulous mandibles. The higher dimensions observed in dentate mandibles are explained to be due to increased osseous deposition in response to mechanical forces of mastication (Oğuz & Bozkir, 2002). According to Gershenson et al., (1986) ‘‘the MF moves upwards closer to the alveolar border with teeth loss and bone resorption. In extreme cases of resorption, the MF and the adjacent part of the mandibular canal are open at the alveolar margin. The mental nerve and the final part of the inferior alveolar nerve can be found directly under the gums in extreme degrees of resorption’’.

The mandible is known to express a high degree of sexual dimorphism (Verlag, 2002; Hu, Koh, Han, 2006). Differences in the MF position and other parameters such as gonial angle, height of mandible and bi-condylar breadth have been found to exist between males and females (Vodanović et al., 2007; Gupta, Gowri & Anbalayan, 2013). Apart from a study by Sveučilište et al., (2006) which revealed that, the distance from the inferior border of the MF

to the lower border of the mandible exhibits no sexual dimorphism; outcome from other studies supports sexual dimorphism of the mandible. The dimension between the MF to the inferior mandibular border exhibits sexual dimorphism with dimensions, higher in males than in females according to Suragimath et al., (2016) and Chandra et al., (2013). Mahima, Patil, & Srivathsa, (2009) in a South Indian population, deduced that an individual is 99% likely to be a male if the dimension between the lower mandibular border to the inferior and superior border of the MF is above 1.48cm and 1.7cm respectively. Similarly an individual is 99% likely to be a female if the dimensions between the lower mandibular border to the inferior and superior border of the MF are less than 1.30cm and 1.69cm respectively. According to Huumonen et al., (2010) and Thakur et al., (2014), anatomical variations of the mandible in terms of gender can be attributed to factors such as differences in occlusal forces and the different mandibular growth and development that occurs in males and females.

2.5 Study approaches of the mental foramen

Many studies on the MF position have been done using dried mandible (Agthong et al., 2005; Voljevica, 2015), cadavers (Mendonça Amorim et al., 2008), radiographic x-rays (Al Talabani, Gataa, & Jaff, 2008), magnetic resonance imaging (Chau, 2011), computed tomography scans (Ishii et al., 2016) and cone beam computed tomography (Matsumoto & Araki, 2012; Göregen et al., 2013; Imada et al., 2014). While panoramic radiographs are easily available and thus commonly used, sophisticated radiological techniques like the computed tomography and cone beam computed tomography are more common in advanced settings (Ahmed et al., 2007; Vazquez et al., 2008).

2.6 Panoramic Radiograph (Orthopanthomograph)

Panoramic radiography gained popularity and has been very useful in clinical dentistry since the 1960s. When compared to the conventional radiographs, its dosage of radiation is low and

produces wide field of projected structures with little superimposition of intervening tissues. Orthopanthomograph (OPG) however is known to vary in accuracy and proportion owing to it being a laminographic type of radiograph (Moraes et al., 2008; Gupta et al., 2015).

According to Singh et al., (2014), there are intrinsic drawbacks of its imaging plane in capturing the complete region accurately. The quality of image is affected due to a compression phenomenon (Yasar, Apaydin, & Yilmaz, 2012). Also, the curvature and the angulation of the mandible are not factored into the equipment's operation. Inappropriate posture assumed by a patient therefore affects its visibility (Philips et al., 1992; Kim et al., 2006). There are also reports of horizontal distortions (Moraes et al., 2008; Suphangul et al., 2016). Phillips et al., (1990) in a study, reported that the MF appeared larger in size by 23% and shifted distally on a panoramic radiograph.

Other authors on the other hand, have reported close correlation between dry skulls and radiographs in MF position (Yosue & Brooks, 1989). A study also by Al Jasser, (1998) showed no significant difference between dry skulls and radiographs in the antero-posterior positioning of the MF. However, where absolute measurement or relatives comparisms are concerned, Laster et al., (2005) advised caution should be applied. Good operational skills and proper positioning of the patients head are strongly encouraged to ensure radiographs reliability (Akcam & Altiok, 2003; Monsour & Dudhia, 2008)

Other methods such as the computed tomography and cone beam computed tomography have been reported to be of high accuracy in the assessment of the position, anatomy and demarcations of the mental foramen (Aminoshariae et al., 2014). A less than 1% relative error have been reported when data and value of CBCT were compared to actual physical linear measurement obtained from dry human skull (Stratemann et al., 2008). Also, advantageous in the use of these sophisticated methods is that patient head positioning are

have no effect on the measurement (Luangchana et al., 2015). These advanced techniques, despite their high accuracy, are very costly and others of high radiation doses upon exposure. The high cost thus affects its availability in low income settings.

Panoramic radiographs compared to the sophisticated techniques are simple to operate, easily accessible in many settings and mostly preferred by many dentist professionals prior to implant placement (Vazquez et al., 2008; Kim et al., 2011; Neves et al., 2014).

2.7 Classifications of the Position of the mental foramen

In localizing the mental foramen, studies have either related its position to the mandibular teeth (horizontal position) or to the mandibular body (vertical position). Relating the MF position to the mandibular tooth is the most common and clinically considered convenient (Aktekin, Celik, Celik, Aldur, & Aksit, 2003; Cutright et al., 2003). With this approach, the MF position is referenced to the most adjacent mandibular tooth and its position is documented as being in line with the longitudinal axis of that mandibular tooth or in between the two most adjacent mandibular teeth. Tebo & Telford, (1950) proposed the following as its horizontal classification:

- Position I – situated anterior to the 1st lower premolar
- Position II – in-line with the 1st lower premolar
- Position III - between 1st and 2nd lower premolar
- Position IV – in-line with the 2nd lower premolar
- Position V - between 2nd lower premolar and 1st lower molar
- Position VI – in-line with the 1st lower molar

Figure 2. below shows a mandible and the horizontal classification of the mental foramen.

Relating the MF position to the mandibular body on the other hand involves the mental foramen being referenced to specific points and ratios on the mandible (Oğuz & Bozkir, 2002; Laster et al., 2005; Apinhasmit, et al., 2006).

In a nutshell, though there are contrasting views in the accuracy of panoramic radiography, it is a common investigative technique employed by dental professionals in daily routine procedures many settings. From the literatures, it is obvious that panoramic radiography are accepted and its reliability is supported by many authors even though there are some concerns of dissatisfaction about image errors that might be encountered.

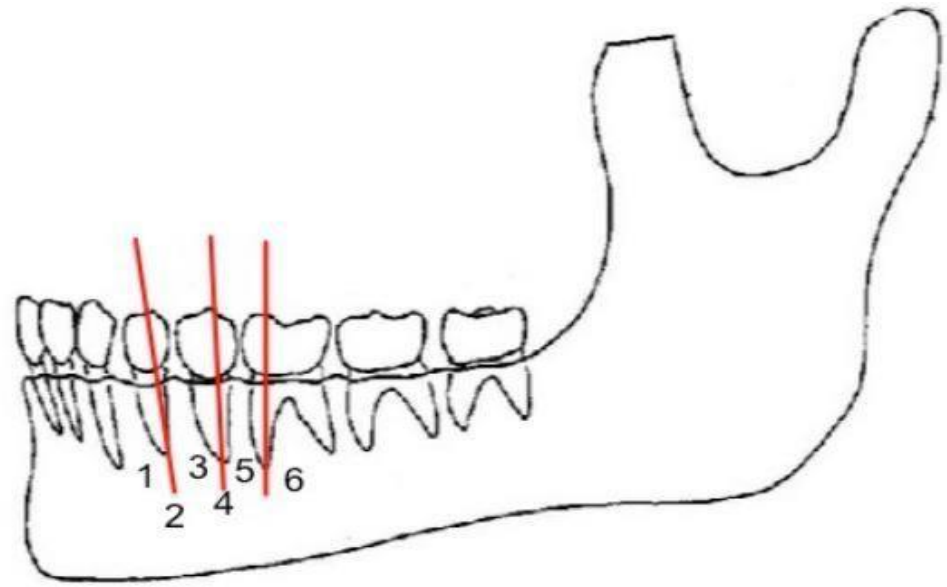

Figure 2: Diagram of a mandible showing classification of the horizontal position of the mental foramen.

Source: (Abed & Bakhsh, 2016).

CHAPTER 3

MATERIALS AND METHODS

The issue of ethics, the study design, site and the population studied are discussed in this chapter. The criteria for the selection of participants, collection of data and the statistical approach used for the data analysis are also elaborated.

3.1 Ethical Consideration

In line with the Ethical guidelines of University of Ghana Office of Research, Innovation and Development (ORID), ethical clearance was obtained from the University of Ghana College of Health Sciences Ethical and Protocol Review Committee (EPRC). A protocol Identification Number CHS-Et/M2 – 4.15/2019-2020 was issued for this study.

The cadavers used in this study were previously acquired and dissected for teaching Medical Students by the Department of Anatomy of University of Ghana Medical School according to the procedures spelt out Human Anatomy Act. Codes only were used to identify each cadaver. Data of Archived radiographs were stored under strict control according to the Data Protection Act. The study was of low risk with no harm caused to any participant in any form since cadavers and archived dental panoramic radiographs were used.

3.2 Study design

The study was a cross sectional descriptive study.

3.3 Study site

The cadaver study was carried out at the Dissection laboratories of the Anatomy Department, University of Ghana Medical School and Family Health Medical College. The radiological study was done at the University of Ghana Dental School Clinic, Korle-Bu and the Holy Trinity Hospital, Kaneshie. These are all located in the Greater Accra region of Ghana.

Ghana is a West African country of about 239460 square kilometers. It is bounded by Burkina Faso to the north, Ivory coast to the west, Togo to the east and the Gulf of Guniea (Atlantic ocean) to the south. It lies 8 ° 00 N and 2 ° 00W of the equator. It widest part measures 560 kilometers between longitude 1° 12 ' east and longitude 3 ° 15 ' west. There are about 28.3 million inhabitants comprising of about 75 ethnic groups. Accra is the capital city. It is a cosmopolitan city with very diverse ethnic groups. The indigenous tribe of Accra are the Ga ethnic group. The people of Accra have many stapple foods including kenkey and fish, fufu, rice, yam, plantain and banku.

3.4 Study population

The study involved adult cadavers of unknown age dissected between May 2019 and March 2020 and archived dental panoramic radiographs (OPG) of adult patients who attended the University of Ghana dental school clinic and the Holy Trinity dental clinic with various conditions within the period of December 2019 and June, 2020.

3.5 Inclusion and exclusion criteria:

3.5.1 Cadavers:

Dissected cadavers that were included in the study had:

- the teeth anterior to the first mandibular molars present.
- Intact alveolar ridge at the premolar area on both sides

Dissected cadavers that were excluded had:

- Deformity of the mandible such as fracture.
- some teeth anterior to the first mandibular molars absent.

3.5.2 Dental panoramic radiographs:

Archived OPGs that were included in the study had the following features:

- the mental foramen was clearly visible.
- the teeth anterior to the first mandibular molars were present.
- there was no radiographic artefact such as radiopaque objects present.

Archived OPGs with the following features were excluded:

- poor clarity of the mental foramen.
- radiographic artefact.

3.6 Sample size determination

3.6.1 Cadavers:

The sample size for the cadaveric measurement was calculated using the following formula:

$N = (Z_\alpha / E)^2 P (1-P)$

P is the expected proportion with characteristic of interest.

Z_α is a value from the normal distribution representing 95% confidence level.

E is the margin of error (Ghimire & Gupta, 2018).

N= sample.

The values for these parameters are as follows:

For $\alpha = 0.05$, $Z_\alpha = 1.96$, p=0.50, E= 0.2; thus $(1.96 / 0.2)^2 0.5 (1-0.5) = 24.01$.

Consequently, a sample size of 24 was chosen for the cadavers.

3.6.2 Dental Panoramic Radiograph:

The sample size for the dental panoramic radiograph data collection was calculated using the following formula:

$$N = \frac{Z_{1-\alpha}{}^2 * p(1-p)}{d^2}$$

$Z_{1-\alpha}$ = standard normal variate (at 5% type 1 error (P<0.05).

p = estimated prevalence rate of the commonest MF position in Africans (Bello et al., 2018).

d = Absolute error or precision.

N= sample.

The values for these parameters are as follows:

For α = 0.05, $Z_{1-\alpha}$ = 1.96; p=0.50, d= 0.05 thus 1.96^2* 0.5(1- 0.5)/0.05^2 = 384.16.

Therefore a sample size of 405 was chosen for the dental panoramic radiographs.

3.7 Collection of Data

3.7.1 Adult Cadaver

The gender of the cadavers were noted and documented. The mental nerve was then systematically exposed with three skin incisions and lateral reflection of the skin flap. The first was a vertical midline incision extending from the midpoint of the superior border of the lower lip to the inferior end of the symphysis menti. The second was a lateral incision extending from the angle of the lip on either side. The third was an inferior incision along the lower border of the mandible from the symphysis menti parallel to the lateral incision. Using blunt dissection, the flap was detached from the bone and reflected laterally until the mental nerve was seen exiting the mental foramen. The mental nerve was excised and the MF exposed. The shape, direction of MF opening and the number of foramina present on a specimen were noted by direct visual inspection and documented.

In relation to the position of the MF, a ruler was placed on the long axis of the most adjacent mandibular tooth. The position of the MF in relation to the longitudinal axis of the mandibular teeth was noted and documented as it coincided with the edge of ruler.

A digital Vernier caliper was used to determine horizontal and vertical diameter of the MF, the distances from the buccal cusp tip of the mandibular tooth to the superior border of the MF and also to the lower border of the mandible (Figure 3).

Figure 3: A Vernier calliper being used to measure the distance from the buccal cusp tip of the second lower premolar to the superior border of the mental foramen.

3.7.2 Dental Panoramic Radiographs

Archived OPGs that were taken with the digital panoramic radiographic equipment OP200D-1-2-1 (Instrumentarium Dental Nahkelantie 160, FI- 04300 TUUSULA, Finland) were assessed. The age and sex were noted and documented. The number of mental foramina was also documented (Figure 4 & 5). With the aid of the dimensional tool integrated in the

proprietary radiographic software (CS software version 7), a line was drawn through the long axis of the mandibular tooth closest to the MF. The position of the MF in relation to the mandibular tooth was noted and documented.

The distances from the buccal cusp tip of the mandibular tooth to the superior border of the MF and to the lower border of the mandible was also determined using the dimensional tool. These measurements were done by two observers; the principal investigator and a certified Radiographer at the University of Ghana Dental School Clinic. The average was calculated to avoid observer-dependent variation.

For both cadaver and the OPG, the horizontal position of the MF was classified using the Tebo and Telford, (1950) criteria: (Refer to the classification of the MF position above, page 22).

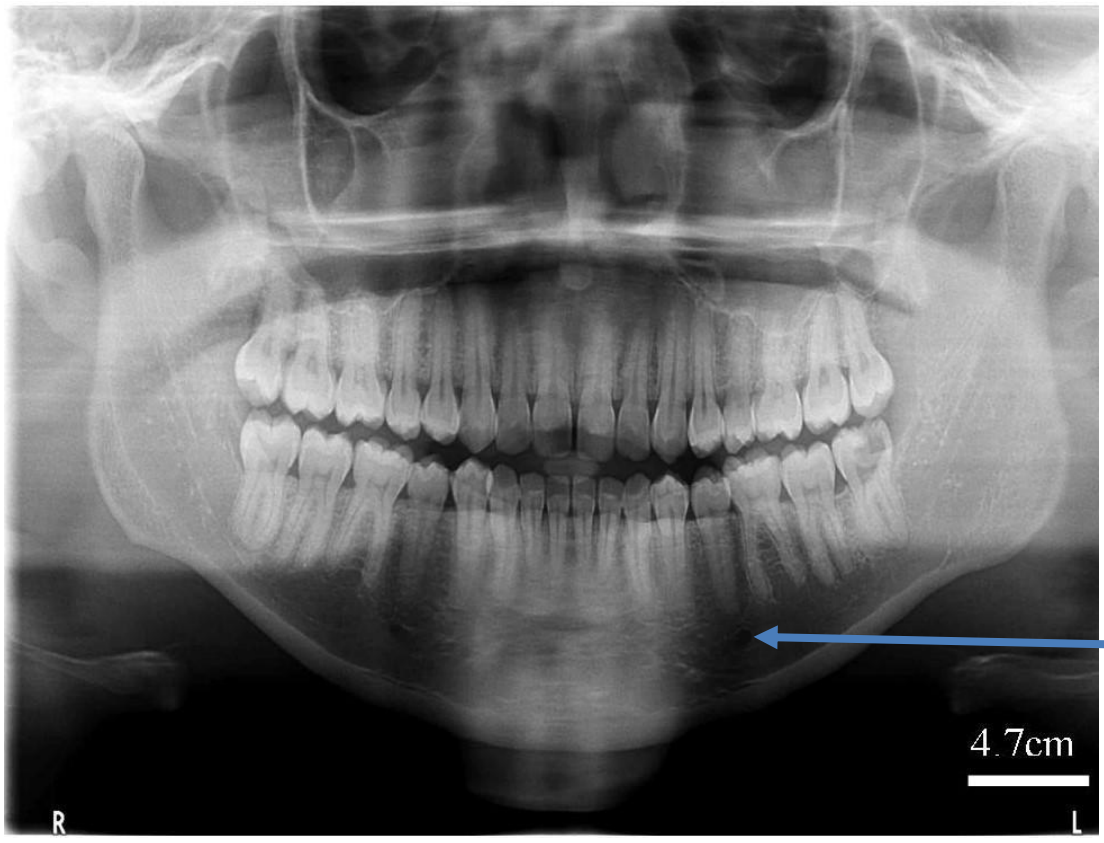

Figure 4: An orthopanthomograph showing the mental foramen

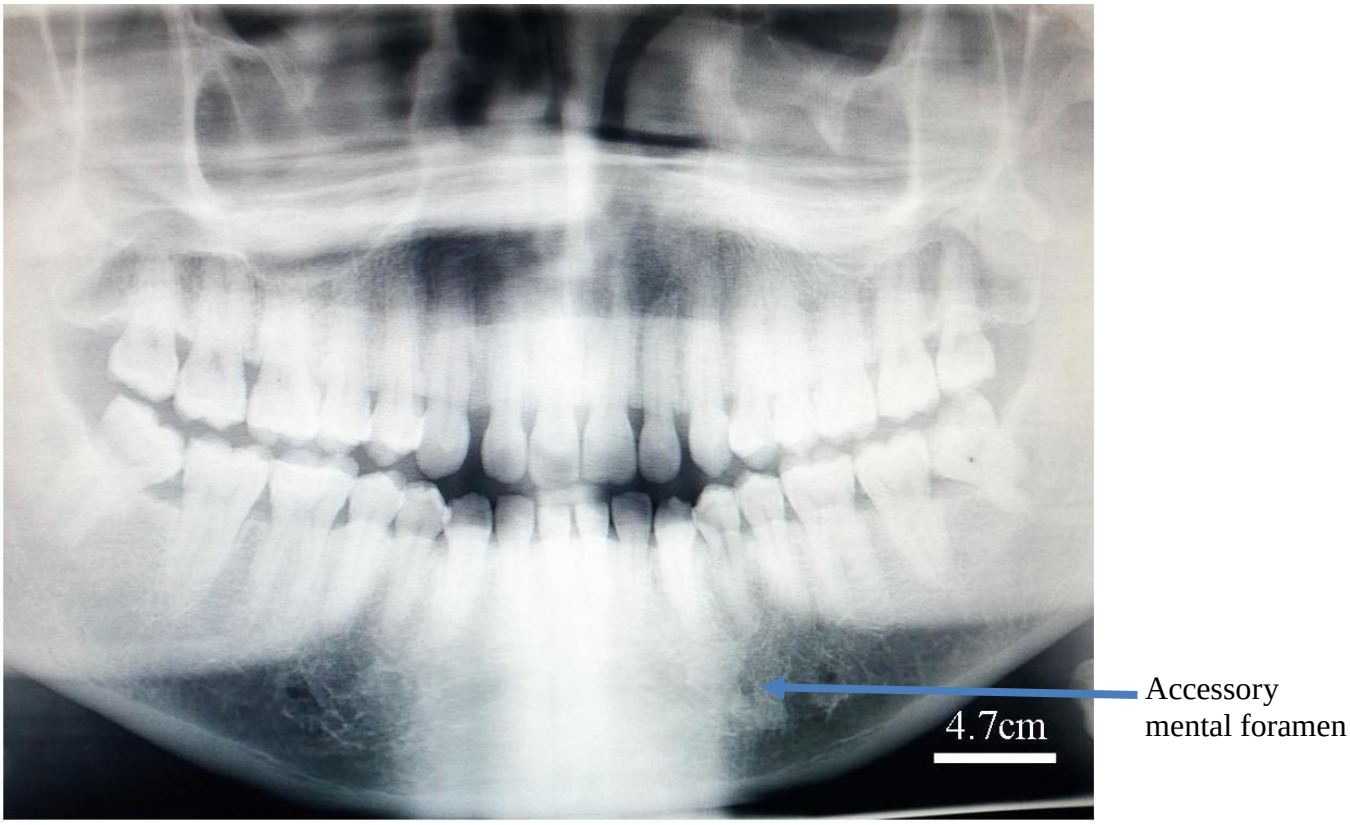

Figure 5: An orthopanthomograph with an accessory mental foramen.

3.8 Statistical analysis

The statistical analysis was done by the principal researcher in consultation with a professional statistician. Data obtained from the cadavers and dental panoramic radiographs were coded and stored in Microsoft excel. The Shapiro-Wilk test of normality on the data for the continuous variables showed the data was normally distributed. The Statistical Package for Social Sciences (SPSS) version 22 was used to analyse the data. Categorical data such as the shape, number, horizontal MF position and orientation of MF opening were presented as frequencies and percentages whiles morphometric data were presented as means and standard deviation. Chi-square was used to determine the relation between the genders and the horizontal position of MF. Paired t-test was used to compare the mean dimensions of MF size and vertical position between sides. A p-value < 0.05 was deemed significant.

CHAPTER FOUR

RESULTS

4.1 Background Characteristics

In this research, 405 panoramic radiographs and 24 cadavers were studied. This was the full sample size as calculated. One (0.25%) panoramic radiograph had a unilateral foramen on the right side, 400 (98.77%) had bilateral foramina and 4 (0.99%) had accessory mental foramina (AMF) on a side. The mandibles of the twenty-four (24) cadavers had bilateral foramina but no unilateral or accessory foramen.

The mental foramen position was determined in the four hundred (200 males and 200 females) dental panoramic radiographs and the mandibles of the 24 (18 males and 6 females) cadavers (Table 2). The remaining five (5) panoramic radiographs of unilateral and accessory foraminia were not included for the MF position determination.

Table 2. Sex distribution of study population

Variable	Number of radiographs	Percentage (%)	Number of cadavers	Percentage (%)
Sex				
Male	200	50	18	75
Female	200	50	6	25
Total	400	100	24	100

4.2 Summary of the ages of individuals whose radiograph were studied.

Table 3. shows the descriptive statistics of the ages of the male and female participants whose radiographs were studied. The mean age of male participants was 37.78 (SD= 13) years while that of females was 35.31 (SD= 12.7) years. The overall mean age was 36.57 (SD = 12.88)

years. The ages of males ranged from 18 to 83 years while that of females, from 18 to 74 years. The modal age group range was 18 to 30 years.

Table 3. Summary of the ages of individuals whose radiographs were studied.

Sex of study population	**Mean ± SD (years)**	**Minimum (years)**	**Maximum (years)**
Male (n=200)	37.78 ± 12.97	18	83
Female (n=200)	35.31 ± 12.74	18	74
Total	36.55 ± 12.90	18	83

4.3 Horizontal position of the Mental Foramen

From the radiographs, out of 800 mental foramina, Position IV (MF in-line with the 2nd lower premolar) was the most common position-type with 417 (52.1%) mental foramina. Position V (MF between the 2nd lower premolar and the 1st lower molar) was the second most common with 227 (28.4%) mental foramina. The positions, III (MF between the 1st and 2nd lower premolar) with 118 (14.8%), VI (MF in-line with the 1st lower molar) with 30 (3.8%), II (MF in-line with 1st lower premolar) with 7(0.9%) and I (MF anterior to the 1st lower premolar) with 1 (0.1%) mental foramen followed in descending (Figure 6).

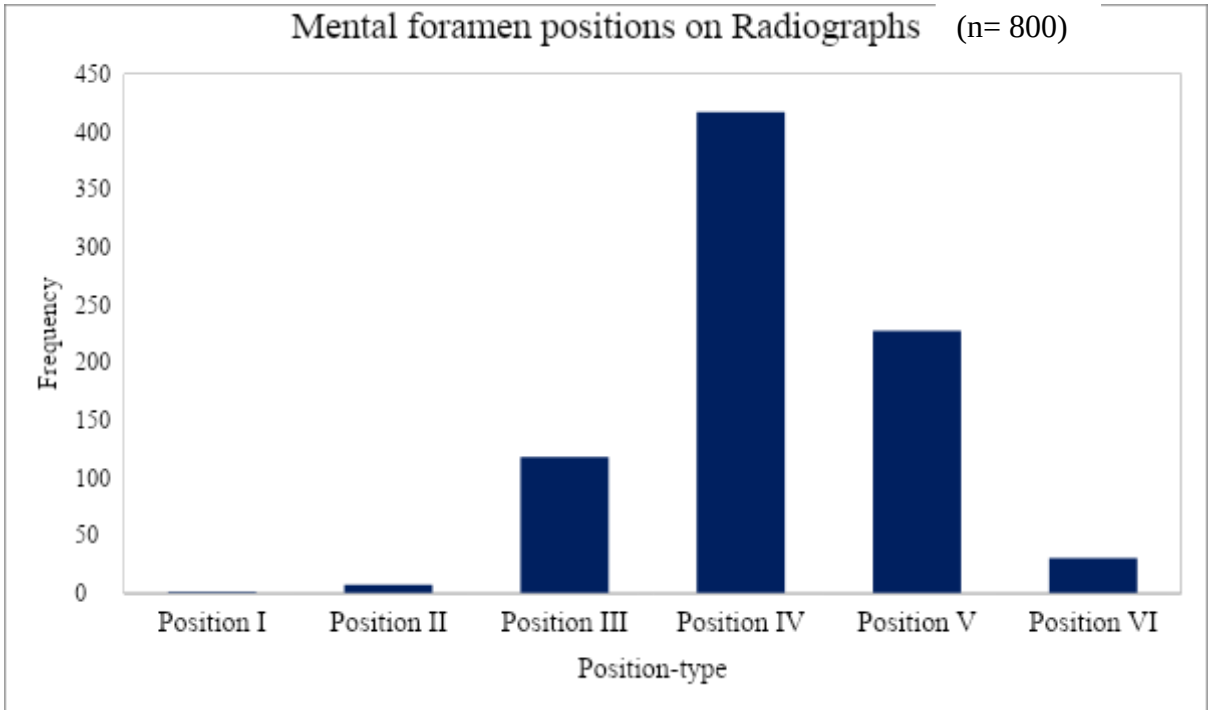

Figure 6: Bar chart showing the distribution of the horizontal positions of the mental foramen in relation to the apices of the mandibular teeth and interdental spaces on radiographs.

From the cadavers, out of 48 mental foramina, Position IV was also the most common-position type with 24 (50%) mental foramina. Position V (19 foramina; 39.6%), VI (3 foramina; 6.3%), III (2 foramina; 4.2%) prevailed in the descending order. There were no foramina recorded at position II and I (Figure 7).

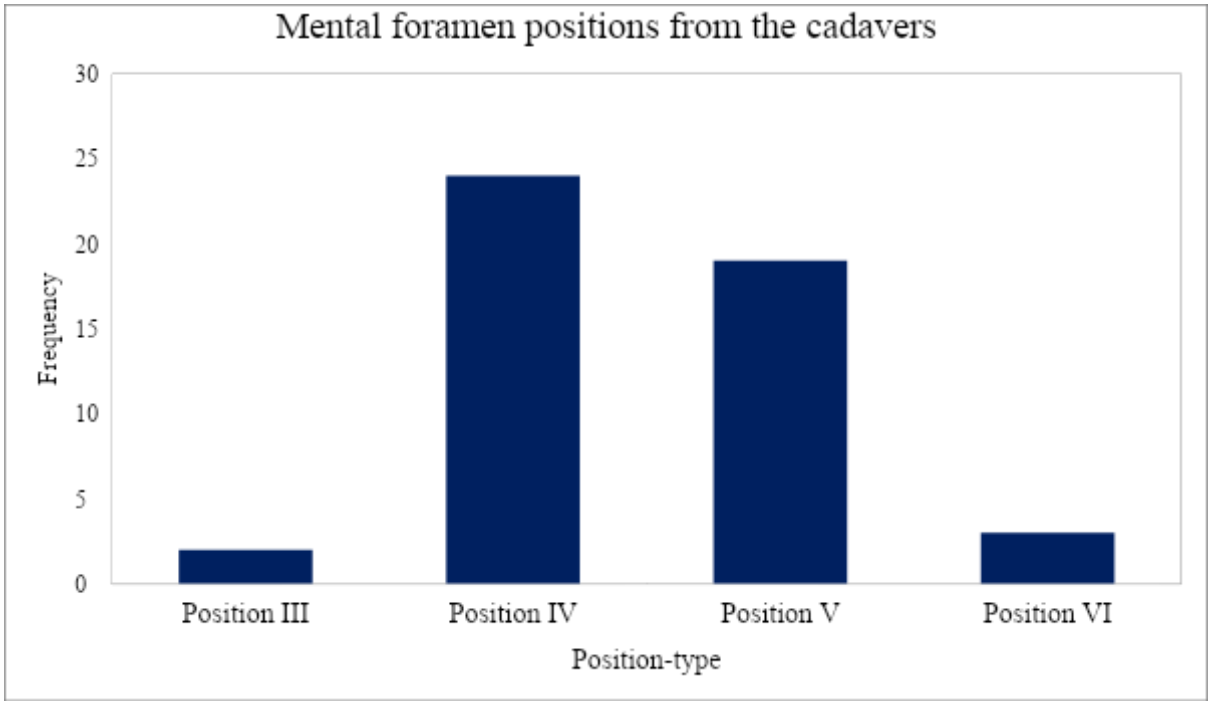

Figure 7: Bar chart showing the distribution of the horizontal positions of the mental foramen in relation to the apices of the mandibular teeth and interdental spaces in cadavers.

4.4 Symmetry in the horizontal position of the mental foramen

From the panoramic radiographs, the horizontal positions of the mental foramen in 312(78%) mandibles were bilaterally symmetrical whiles 88 (22%) were not (Table 4).

Table 4. Symmetry in the horizontal position of the mental foramen in radiographs.

	frequency	**Percentage (%)**
Symmetrical	312	78
Non-symmetrical	88	22
Total	400	100

From the cadavers, the horizontal positions of the mental foramen in 19 (79.2%) mandibles were bilaterally symmetrical and 5 (20.8%), non-symmetrical (Table 5).

Table 5. Symmetry in the horizontal position of the mental foramen in cadavers.

	frequency	**Percentage (%)**
Symmetrical	19	79.2
Non-symmetrical	5	20.8
Total	24	100

For both the panoramic radiographs and the cadavers examined, the mental foramen was bilaterally symmetrical in about four-fifth of the cases and asymmetrical in one-fifth cases.

4.5 Comparison of the horizontal position of the mental foramen on radiographs between gender

A Chi-square test of independence was performed to determine the difference in the horizontal positions of the mental foramen between males and females. There appears to be more mental foramina located at position IV in females than in males but the difference is not statistically significant: $\chi 2 = 4.10$, df= 5, p=0.536. There was no significant relation between gender and the other horizontal positions of the mental foramen. Although the frequency of the position types V, III, VI, II, and I appear to be different for males and females, the difference in the prevalence was not statistically significant. For both males and females, frequencies of position types were V, III, VI, II, and I prevailed in the descending order (Table 6).

Table 6. Gender difference in mental foramen position on radiographs

	Position I	**Position II**	**Position III**	**Position IV**	**Position V**	**Position VI**	***p*-value**
Male	0	4	64	199	115	18	
Female	1	3	54	218	112	12	
							0.536

No significant difference for *P*-value >0.05. Position I= Anterior to 1st lower premolar, position II= In-line with 1st lower premolar, Position III= Between 1st & 2nd lower premolar, Position IV= In-line with 2nd lower premolar, Position V= Between 2nd lower premolar & 1st lower Molar, Position VI= In-line with 1st lower molar.

4.6 Comparison of the vertical position of the mental foramen between the right and left side in cadavers and in radiographs

A paired T-test was conducted to compare the difference in the vertical position between the sides.

In cadavers, paired T-test comparison of the mean distance from buccal cusp tip of the 2nd lower premolar to superior border of mental foramen [BC-SB] difference between the left (M=23.50, SD= 2.72) mm and right (M=23.55, SD=2.79) mm was not significant (t (23)=0.11, *p*=0.913.

Similarly, the comparison of the mean distance from buccal cusp tip of the 2nd lower premolar to lower mandibular border [BC-LMB] on the left (M=40.13, SD=3.34) mm to that of the right (M=40.01, SD=2.87) mm was not significant (t (23) = -0.312, *p*=0.758.

The ratios of these dimensions were also not significantly different between the left (M=58.56, SD= 4.68) mm and right (M=58.86, SD=5.76) mm; t(23)=0.278, *p*=0.784 (Table 7).

However, for similar analysis on the radiographs, the mean of [BC-SB] on the left (M=24.22, SD=2.75)mm was significantly lower than that on the right side (M=24.51, SD=2.67) mm, (t(399)=3.23, *p*=0.001).

The [BC-LMB] on the left (M=37.64, SD=3.30) mm was less than the right side(M=38.31, SD=3.46) mm and this was statistically significant (t(399)=7.17, *p*=0.001).

For the ratio of these two dimensions, there was no significant difference between the left side (M=64.44, SD=5.76), right (M=64.04, SD= 4.67); t(399)= -1.47, *p* = 0.142 (Table 7).

Table 7. Comparison of the vertical position of mental foramen between the right and left side in cadavers and in radiographs

Dimension(mm)	**side**	**Cadaver(mm)**	**Radiograph(mm)**	***p-value*****
BC-SB (A)	Right	23.55 ± 2.79	24.51 ± 2.67	
	left	23.50 ± 2.72	24.22 ± 2.75	
	*p-value**	0.913	0.001	
	Total	23.52 ± 2.73	24.37 ± 2.71	0.042
BC-LMB (B)	Right	40.01 ± 2.87	38.31 ± 3.46	
	Left	40.13 ± 3.34	37.64 ± 3.30	
	*p-value**	0.758	0.001	
	Total	40.07 ± 3.08	37.97 ± 3.39	0.001
Ratio (A/B)%	Right	58.86 ± 5.76	64.04 ± 4.67	
	Left	58.56 ± 4.68	64.44 ± 5.76	
	*p-value**	0.784	0.142	
	Total	58.71 ± 5.20	64.24 ± 5.24	0.001

*p-value** = *p-value* of paired T-test between the sides in both cadaver and radiograph values and *p-value*** = *p-value* of the outcomes of independent (welch) T-test of mean values between the cadaver and radiograph. BC-SB= Buccal cusp tip of the 2nd lower premolar to the superior border of MF; BC-LMB = Buccal cusp tip of the 2nd lower premolar to the lower mandibular border.

4.7 Shape of the mental foramen

The predominant shape of the mental foramen as determined on the cadaver samples was oval shape. In terms of shape of MF on each side of the mandibles, 17(70.8%) oval shaped MF were recorded on the right side, while 7(29.2%) were round in shape. On the left side, 15(62.5%) were oval and 9(37.5%) were round (Figure 8).

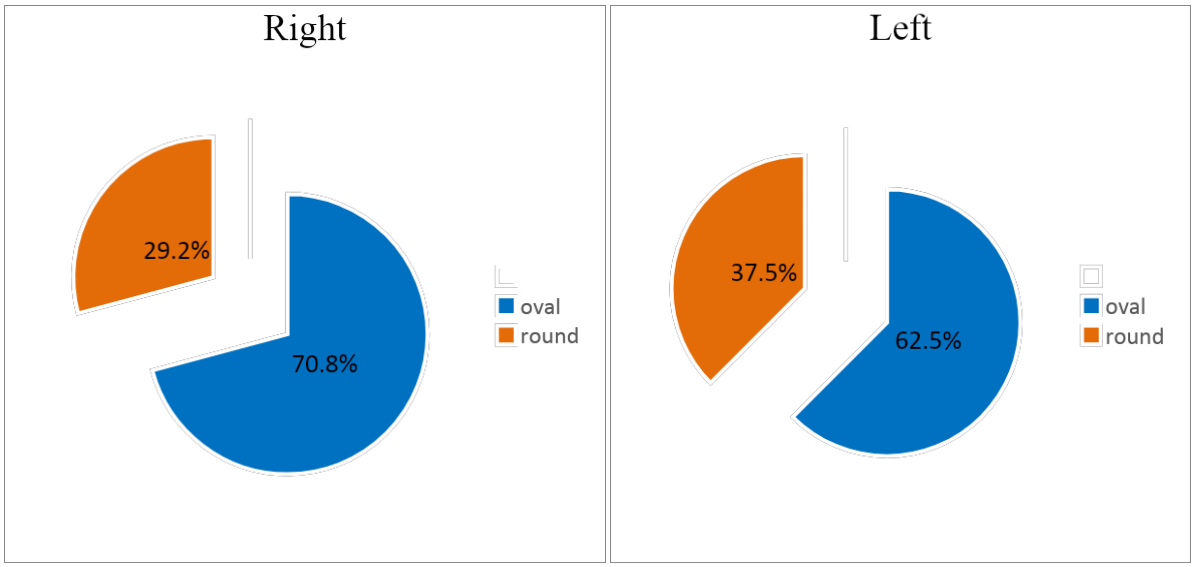

Figure 8: Pie chart showing the mental foramen shape with respect to the sides of the mandible on the cadavers.

4.8 Orientation of the mental foramen opening

From the cadavers, the opening of the mental foramen was found to be predominantly oriented postero-superiorly. On the right side, 21(87.5%) opened postero-superiorly and 3(12.5%) antero-superiorly. On the left side, 19 (79.2%) opened postero-superiorly, 4(16.7%) antero-superiorly and 1(4.2%) superiorly. Figure 9 shows the difference in the right and left side foramen openings from the cadaver.

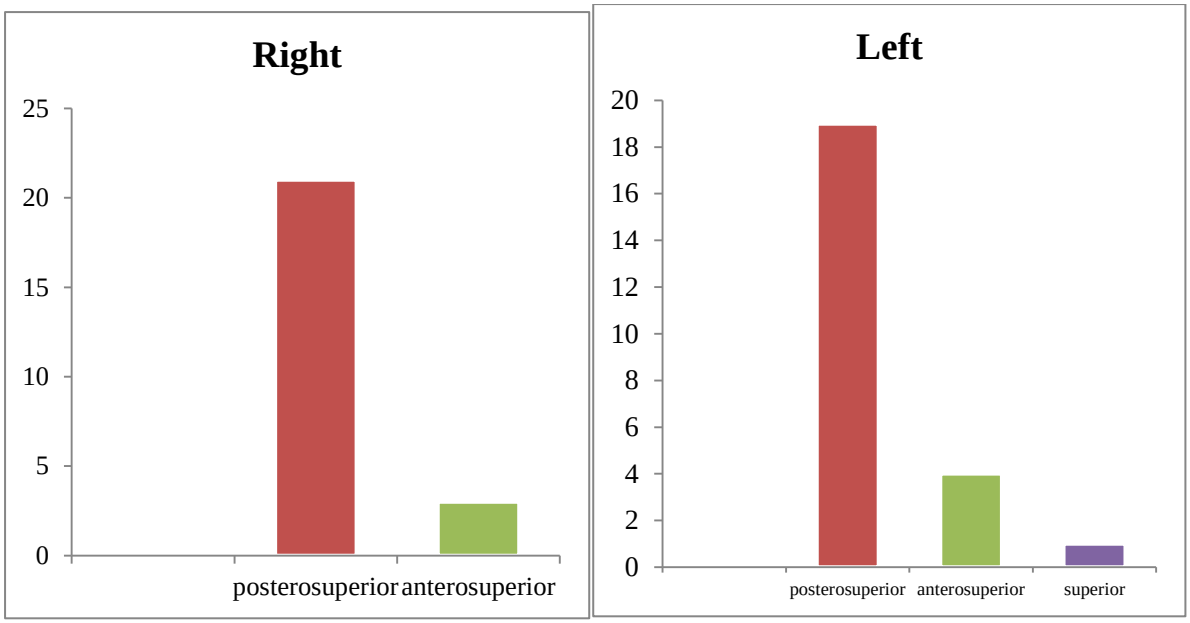

Figure 9: Bar chart showing the difference in directions of the mental foramen opening on the right and left side in cadavers.

4.9 Size of the mental foramen

The mean horizontal diameters of the MF measured on the cadavers were 3.18 (SD = 0.71) mm on the left and 3.15 (SD = 0.64) mm on the right side. These diameters were not statistically different (t = -0.37, *p*=0.718).

Similarly, the mean vertical diameter was 2.42 (SD = 0.32) mm on the left and 2.44 (SD = 0.3)mm on the right side. These were also not significantly different (t = 0.23, *p*=0.819) (Table 8).

For both sides (48 mental foramina), the mean horizontal dimension was 3.17 (SD = 0.66) mm and the mean vertical dimension was 2.43 (SD = 0.31) mm.

Table 8. Mean size of the mental foramen measured on cadavers

Mental foramen Dimensions	**Side**	**Minimum (mm)**	**Maximum (mm)**	**Mean ± SD (mm)**	***P-Value***
Horizontal	left	1.94	5.13	3.18 ± 0.71	0.718
	right	2.18	4.64	3.15 ± 0.64	
Vertical	left	1.94	3.35	2.42 ± 0.32	0.819
	right	1.94	3.49	2.44 ± 0.30	
Total mean dimension	horizontal	1.94	3.18	3.17 ± 0.66	
	vertical	1.94	2.44	2.43 ± 0.31	

p-value >0.05, no significance difference.

CHAPTER 5

DISCUSSION AND CONCLUSION

In this chapter, the outcome of the analysed data and its implication are discussed. It elaborates on the implications of the unilateral and accessory foramina, the horizontal position of the MF as observed in adults in Ghana, the symmetry of the MF horizontal position, comparison of the MF position between the genders, the shape, orientation and the size of the mental foramina. The limitations encountered and recommendations are also outlined.

5.1 Unilateral and multiple foramina

Unilateral absence of MF and accessory mental foramen are rare anatomical variations (Naitoh et al., 2009; Hasan, 2011; Maria et al., 2011; Yovchev et al., 2018). In this study, the mandible of one individual (0.25%) whose dental panoramic radiograph was studied had only one mental foramen. While bilateral absence of MF is very rare, analysis of reports on its unilateral absence range from 0.08% to 0.95% in frequency. Yosue & Brooks, (1989) suggested absence of the mental foramen on one side in a radiograph may be due to the inability to distinguish it from the trabecular pattern seen in complete dentition radiographs and over-exposed radiographs. The implication of this to the dental professional is that, when a MF is not seen on the radiograph, it does not mean it is not present; as such, other higher investigative techniques like the CBCT or CT should be used to ascertain it presence and position.

Accessory mental foramen was noted on four panoramic radiographs (0.99%): three in males and one in a female. Though this number is low compared to 1.4% to 20% reports from earlier studies (Naitoh et al., 2011; Göregen et al., 2013; Khojastepour et al., 2015; Ledzion et al., 2018), they are known to occur in the minority but the possibility of its presence cannot

be overlooked. AMF is due to branching of the mental nerve prior to its passing through the mental foramen (Budhiraja et al., 2013). As such, it is suggested its presence should be verified as part of implant therapy planning to avoid neurovascular bundle injury during surgical dental procedures (Naitoh et al., 2011; Göregen et al., 2013). The presence of AMF is also important in neurectomy for trigeminal neuralgia involving the mental nerve (Jha & Kumar, 2012). AMF means presence of accessory mental nerve (AMN). AMN is likely to be missed resulting in incomplete removal of the mental nerve during routine surgery. This would likely lead to persistence of the symptoms of neuralgia.

5.2 Horizontal position of the mental foramen

For horizontal position, the mental foramen was seen positioned anywhere between the longitudinal axis of the canine to the mesiobuccal root of the first lower molar. This is consistent with findings reported by Jasser & Nwoku, (1998) in Saudi Arabians and Shah et al., (2010) in Indians. However, the foramen was seen mostly at position IV; in 52.1% samples on the radiographs and 50% of the cadaver samples. This is similar to findings reported in Turks (Oğuz & Bozkir, 2002; Yeşilyurt et al., 2008), Malaysians (Ngeow & Yuzawati, 2003), Malawians (Igbigbi & Lebona, 2005), Tanzanians (Fabian, 2007) and Nigerians (Adejuwon et al., 2012).

This however, contradicts Position III which was reported as most common in other populations such as Northern Nigerians (Olasoji, Tahir, Ekanem, & Abubakar, 2004), Southern Arabians (Jasser & Nwoku, 1998), Northern Jordanians (Al-Khateeb et al., 2007), Iranians (Haghanifar & Rokouei, 2009), and most Caucasians from different countries (Moiseiwitsch, 1998; Cutright et al., 2003). Also, Koppe, (2012) from a study comparing the MF position in three populations found that, the foramen was most commonly positioned in line with the second lower premolar (position IV) in Chinese population but most common

between the first and second lower premolar (position III) in the European and Indian population.

This study noted the position V (between the 2nd lower premolar and 1st lower molar) as the second commonest with percentage prevalence of 28.4% on the radiographs and 39.6% in the cadavers. This is in contradiction to earlier works (Oğuz & Bozkir, 2002; Ngeow & Yuzawati, 2003; Neiva et al., 2004; Igbigbi & Lebona, 2005; Fabian, 2007; Yeşilyurt et al., 2008; Adejuwon et al., 2012) who reported other positions as the second most commonest.

Position IV and V together make up at least 80% (radiograph=80.5%, cadaver= 89.6%) of the total MF positions in this study population. This is similar to 87.6% reported in Zimbabweans (Mbajiorgu et al., 1998), 87.2% in Malawians (Igbigbi & Lebona, 2005) and 82.8% in Kenyans (Loyal et al., 2014).

Being the two most commonest positions of the MF in this study population, it can be postulated that there is a very high chance of successfully blocking the mental nerve when local anaesthetic agent is injected around these two positions during clinical procedures (Al-shayyab et al., 2015). This data will also help in avoiding iatrogenic damage of the mental nerve by Dental surgeons when undertaking surgical procedures such as cyst enucleations, apicocurretage, retrograde amalgam filling, periodontal surgeries like flap operations or mandibular body osteotomies. Paraesthesia or anaesthesia of the regions supplied by the nerve due to its damage would be avoided.

The possibility that the mental foramen could be located below the apex of the first lower molar as noted in this study has corroborated in other studies (Jasser & Nwoku, 1998; Al-Shayyab et al., 2016). It important to bear in mind by dental professionals, to help avoid its presence being incorrectly diagnosed as a radiographic lesion or pathosis (Parnami et al., 2015).

Kjaer, (1989), first explained that the different positions of the MF other than that described above could be due to a lag in the developmental changes in the MF location in the postnatal life. This conclusion was drawn because the very early position of the mental foramen is in the alveolar bone between the primary canine and the first molar and that, in a developing jaw, the position of the mental foramen might change in relation to the jaw.

According to Yeşilyurt et al., (2008) the variance in the horizontal position of the mental foramen may be due to different feeding habits which subsequently impact development and growth of the mandible. Prado & Caria, (2007) also added that, factors such as muscular biomechanics, teeth structure, shape or size of the face and cranium, dietary habits or head position, socioeconomic and environmental factors may also affect anatomical characteristics of the mandible.

5.3 Symmetry in the horizontal position of the mental foramen

The horizontal position of the MF was asymmetrical in about one-fifth of the study population (both radiographs and cadavers). Al-Shayyab et al., (2016) reported similar proportions in an Iraqi population from a study on 518 panoramic radiographs. The proportion of asymmetry found in this study however appears to be lower than that reported by Haghanifar & Rokouei, (2009) in Iranians (24.3%) and Al-Khateeb et al., (2007) in Northern Jordanians (33%). Fabian, (2007) and Bello et al., (2018) recorded more than half; 78% in Tanzanians and 51.3% in Nigerians respectively. This may be due to factors such as patient positioning, radiographic quality, the dominant age of the population studied or the criteria used in determining the horizontal symmetry of the MF position.

According to Moxham, (2001), the variability and asymmetry in the horizontal position of the MF can be explained from the developmental and functional point of view. During early development, the first osteogenic center of the mandibular border arises in the first branchial

arch lateral to the Meckel's cartilage and mandibular nerve and forms a groove around the nerve. The bone formed around the mandibular nerve is considered as the primitive mandible or the neural part of the mandible to which the secondary functional units; the alveolar, coronoid process, angular, condylar process and chin are attached. Asymmetry in the MF position has been attributed to the different secondary functional units attaching to the nearly symmetric neural part (Captier, Hospitalier, Montpellier, Bonnel, & Simulation, 2006).

5.4 Comparison of the horizontal position of the mental foramen on radiographs between males and females

Evaluation of the radiographs for gender differences in the mental foramen position showed no significant difference. The frequency of the various horizontal positions of the MF prevailed in the same order in both genders. This is consistent with findings by Kim et al., (2006), Currie et al., (2016) and Thakare et al., (2016). Jasser & Nwoku, (1998), also reported that the MF horizontal position is not gender-dependent.

However, Al-Khateeb et al., (2007) reported that in males, the prevalent horizontal position of the MF was between the 1st and 2nd lower premolar while in females, it was in-line with the long axis of the 2nd lower molar. Haghanifar & Rokouei, (2009) also reported that, in males, the most prevalent position type was that in-line with the 2nd lower premolar whiles in females, that in-between the 1st and 2nd lower premolars. These reports contrast the finding in this study. The disparity may be due to geographically related differences in the degree of bilateralism and sexual dimorphism as reported by Ari et al., (2005).

5.5 Comparison of the vertical position of the mental foramen between the left and right side in cadavers and radiographs

For vertical position, there was also no significant difference between the left and right side in cadavers for all the mean [BC-SB], [BC-LMB] and their ratios. This is consistent with

Apinhasmit et al., (2006) who reported no significant difference between sides in the distance measured from the buccal cusp tip of the 2nd lower premolar to the inferior mandibular border.

On the radiograph samples, though there were significant differences between the sides in the two dimensions, there was no statistically significant difference in their ratios. The significant difference in the dimensions can be attributed to possible technical problems such as inaccurate alignment or positioning or magnification while taking OPG (Schulze et al., 2000).

Juxtaposing the cadaveric and radiographic group, the radiographic dimensions were higher than the cadaveric measurement except for [BC-LMB]. This is similar to the findings by Kim et al., (2006) and Philips et al., (1992) taking into account the intra-population nature of their study. It must be noted that in this study, the radiographs were not for the cadavers but for other individuals. However, it is known that superposition of anatomic structures, low contrast, image distortions, overestimations and inadequate resolutions are some limitations in panoramic radiography (Philips et al., 1992; Dario, 2002; Naitoh et al., 2011; Nejaim et al., 2013; Pancer et al., 2014). These same factors may explain the finding in this study. The low radiographic mean of [BC-LMB] compared to that of the cadaveric measurement in this study can be attributed to the suggestion by Kim et al., (2006) that the magnification rate may be different at the superior and inferior positions of the mental foramen. It has thus been recommended that the determination of the vertical position of the MF using panoramic radiographs should be done with caution and factors such as magnification and positioning should be considered (Schulze et al., 2000; Laster et al., 2005).

5.6 Shape of the mental foramen

The mental foramina observed from the cadavers were predominantly oval in shape on both sides. This is consistent with the findings of studies in Malawians (Igbigbi & Lebona, 2005),

Tanzanians (Fabian, 2007), Brazilians (Oliveira Junior et al., 2009), North Indians (Budhiraja, Rastogi, Lalwani, Goel, & Bose, 2013) and South Indians (Varman Chandramohan et al., 2016). This however is inconsistent with the round shape reported as most prevalent in Jordanians (Al-Khateeb et al., 2007) and Iraq population (Al-Shayyab et al., 2016). There is no scientific explanation for the variations in MF shape currently. Genetics and other factors like race, gender and bone disorders have been speculated to possibly play a role to some extent (Alrahabi & Zafar, 2018).

5.7 Orientation of the mental foramen opening

Knowledge of the orientation of the mental foramen opening is relevant in influencing the direction for which a needle has to be advanced to achieve a mental nerve block (Oliveira Junior et al., 2009). The orientations of the mental foramen opening observed in this study were the postero-superior, antero-superior and the superior direction. Other directions such as anterior, posterior and lateral directions have been reported (Agarwal & Gupta, 2011). The postero-superior direction was the most common in this study. This is similar to reports by earlier studies (Igbigbi & Lebona, 2005; Fabian, 2007; Agarwal & Gupta, 2011; Varman Chandramohan et al., 2016). While the antero-superior direction was the second most prevalent in this study as was in some studies (Fabian, 2007; Varman Chandramohan et al., 2011). Agarwal & Gupta, (2011) however, reported the superior direction as second most prevalent. The MF opening commonly noted as being oriented postero-superiorly may be due to the fact that the mental nerve usually emerges from the foramen postero-laterally (Standring, 2004).

5.8 Size of the mental foramen

The mean size of the foramen in the current study was found to be 3.17mm horizontally and 2.43mm vertically. While reports of the MF size are varied (Souaga, Adou, & Angoh, 2004;

Apinhasmit et al., 2006; De et al., 2010), the dimensions recorded in this study is close to that reported by Oğuz & Bozkir, (2002) in Turks. Oğuz & Bozkir, (2002) from 34 dry mandible, reported a mean horizontal diameter of 3.04mm; (right 2.93mm, left=3.14mm) and mean vertical diameter of 2.43mm (right=2.38mm, left=2.64mm). While the foramen size was slightly larger on the left than the right in Turks, no significant difference was found between the sides in this study.

5.9 Conclusion

This study has established that the horizontal position of the mental foramen varies among populations with the two most common in adults in Ghana being position IV (in-line with the 2nd mandibular premolar tooth) and V (between the 2nd mandibular premolar and the 1st mandibular molar tooth). Also, the foramen is mostly bilateral and the prevalence rate of accessory mental foramen is about 0.99% among the adult population in Ghana.

It has also been established that the horizontal position of the mental foramen did not show sexual dimorphism but demonstrated laterality with asymmetry in about one-fifth of the study population having different horizontal positions on the right and left sides of the same mandible.

Vertical dimension measured on OPG were higher than those measured on real cadaveric mandibles. This is similar to reports from other studies which postulated that estimations of the dimensions on OPG may be associated with some inaccuracies due to limitations imposed by the images. This warrants further investigations.

5.10 Limitations of the study

- Due to the short duration of the study, there was not enough time to collect more data on the cadavers. This resulted in a relatively small sample size of the cadavers.
- Archived radiographs were used and therefore the true nationality of those whose radiographs were used could not be ascertained. The identity of the cadavers could not be determined also since most of them were obtained from unclaimed bodies register of the Ghana Police Service.
- The selection of the participants from only one location in Greater Accra Region of Ghana makes the data not representative of the Ghanaian population.

5.11 Recommendations

- With respect to the current body of knowledge on the MF position in some academic textbooks, I suggest a re-look at the statement that the mental foramen is between the apices of the mandibular premolars or a statement added that this can be different for different populations. Similarly, personal and environmental factors can also account for a different positioning of the MF.
- I recommend that future study should involve a larger sample and also ascertain the true nationality of its participants.
- The selection of participants for future studies should also involve indigenes in other belts of the country.

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APPENDICES

APPENDIX I

DATA EXTRACT SHEET

CADAVERS

Sex: □Male □ Female

Any mental foramen Present □ Yes □No;

Any mandibular tooth loss? □ Yes □ No; Specify loss tooth……..

Variable	**Left**	**Right**
Number of foramina		
Shape of foramina. (Oval, Round, Irregular)		
Orientation of opening		
Horizontal position of Mental Foramen: Position (I, II, III, IV, V, VI)		

Mental Foramen Dimensions:

Diameter	**Left (mm)**	**Right (mm)**
Horizontal		
Vertical		

DIMENSION	**LEFT (mm)**	**RIGHT (mm)**
Buccal cusp tip to lower border of mandible		
Buccal cusp tip to superior border of Mental foramen:		
Inferior border to lower mandibular border		

APENDIX II

DATA EXTRACT SHEET

DENTAL PANORAMIC RADIOGRAPH

Age……

Sex □Male□ Female

Any mental foramen Present □ Yes □No

Any mandibular tooth loss? □ Yes □ No; Specify loss tooth……..

Variable	**Left**	**Right**
Number of foramina		
Horizontal position of Mental Foramen: Position (I, II, III, IV, V, VI)		

DIMENSION	LEFT (mm)	RIGHT (mm)
Buccal cusp tip to lower border of mandible		
Buccal cusp tip to superior border of Mental foramen:		
Inferior border to lower mandibular border		