VARIATIONS ASSOCIATED WITH THE TOPOGRAPHY OF MENTAL FORAMEN IN BLACK SOUTH AFRICAN POPULATION FROM BOTH HUMAN DRY BONE AND CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN MANDIBULAR SAMPLES

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DECLARATION

I, Ivonne Osekeng Stemmer declare that this research is my own. It is submitted as partial fulfilment of the degree of Master of Science in Dentistry in the branch of Maxillo Facial and Oral Radiology at the University of the Witwatersrand, Johannesburg, South Africa

Signature of candidate

22 day of July 2022

DEDICATION

I would like to dedicate this work to my beloved family: My late father; Disang Goitsilwe; your undying support and love throughout my life has made this academic journey a fulfilling one. Thank you very much.

My sisters; Tshenolo Mametja, Mpho Latakgomo, Kgakgamatso Goitsilwe; your love, support and encouragement throughout my studies kept me motivated.

My children: Tshimega, Motheo you were the reason I never wanted to quit.

My helper; Masechaba Majoro.You were my pillar of strength.

Last but not least: My creator, the greatest and my almighty.

THIS IS FOR YOU.

ABSTRACT

The mental foramen is a crucial morphological landmark for multiple clinical or dental techniques. As such, knowing of the topography of the MF will aid clinicians in their clinical dental practice. Hence, the study aimed at determining the frequency of shape, position, number, and size of mental foramen (MF) among black South African population using dry mandibular bones and Cone Beam Computed Tomography (CBCT) scans of the mandible. Furthermore, the study determines influence of age and sex on the topography of mental foramen. The study was conducted on a total of 117 adult dry mandibles from Raymond A. Dart Collection of Human Skeletons based in the School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand and 98 cone beam computed tomography (CBCT) scans of patients from Maxillo Facial and Oral Radiology Department at Wits Oral Health Centre, Charlotte Maxeke Academic Johannesburg Hospital, South Africa. The age range of the study sample and CBCT scan was 18-70 years. The shape, position and number of MF were observed. The metric dimension of MF was measured using a dental digital calliper on dry mandibular bones samples while and radiographic software for CBCT scans.

The predominant location of MF was below the apex of second premolar. The shape of MF was mainly round and mostly bilateral. The vertical dimension of MF ranged between 2.48mm to 2.9mm, while the horizontal dimension was between 2.78mm to 3. 45mm.There were no significant and sex and age variations the topography. In conclusion, MF is located apex mandibular first premolar teeth. Also, no age and sex variation were noted in the topography and location of MF.

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LIST OF ABBREVIATIONS

AMF: Accessory Mental Foramen

ANOVA: Analysis of variance

C: Canine

CBCT: Cone Beam Computed Tomography

HD: Horizontal dimension

IAN: Inferior Alveolar Nerve

LA: Local Anaesthesia

L: Left

MF: Mental foramen

MN: Mental Nerve

M1: First molar

M2: Second molar

P1: First premolar

P2: Second premolar

P1/P2: Between first and second premolar

P2M1: Between the second premolar and first molar.

R: Right

2D: Two dimension

3D: Three dimension

Std: Standard deviation

VD: Vertical dimension

WOHC: Wits Oral Health Centre

APPENDICES

1. CHAPTER ONE: INTRODUCTION

1.1. Background

The mental foramen (MF) is a bony opening that is bilaterally located on anterior aspect of the body of mandible, which acts as a conduit for mental nerve and blood vessels (Agarwal & Gupta 2011; Udhaya *et al.*, 2013). The MF is variable in shape, size, and location (Fabian 2007). MF is generally located, midway between alveolar crest superiorly and inferior border of the mandible (Igbigbi & Lebona 2005). The exact position varies, it may be located anywhere between apices of canine to first molar (Igbigbi & Lebona 2005 & Siddiqui *et al.*, 2011). However, the most common position of MF is either in between apices of first and second premolar or below the second premolar (Moisewitch 1998; Santini & Alayan 2012).

The general shape of the MF is described as either round or oval with a diameter ranging from three and five millimetres in size (Vargas *et al.*, 2018). Most significantly, the MF indicates the termination of mandibular canal, which houses important neurovascular structures (Vargas *et al.*, 2018). The inferior alveolar neurovascular bundle descends from mandibular foramen (located on the posterior internal aspect of the mandible) traverses the mandibular canal along the body of the mandible to exit into the buccal surface of mandible in an oblique direction at the level of the MF (Phillips *et al.*, 1990; Hasan *et al.*, 2010).

Specifically, the inferior alveolar nerve branches as mental (MN) and incisive nerves at the level of MF (Vargas *et al.*, 2018). The MN together with its associated artery and vein provides sensory innervation and nutrition through the blood supply to the chin, lower lip, and gingiva (Moisewitsch 1998; Greenstein & Tarnow 2006; Gupta *et al.*, 2015). The MF is normally a single foramen on each hemisphere of the mandible; however, accessory mental foramina (AMF) have been reported (Sawyer *et al.*, 1998; Udhaya *et al.*, 2013). AMF is described as an addition to the dominant MF and presents as smaller foramina located around the vicinity of mental region (Sawyer *et al.,* 1998; Udhaya *et al.,* 2013). Having knowledge of these anatomical variants of MF is crucial for clinical procedures with the inclusion of imaging diagnostic determinants. Hence, the appearance and interpretation of MF on a radiograph is crucial to avoid misdiagnosis of MF.

MF appears as a radiolucent area in the lower premolar region, sometimes overlapping the apex of the second premolar in both periapical (Phillips *et al.*, 1992a) and panoramic radiographs respectively (Phillips *et al.*, 1992b). Therefore, it is important for clinicians to have an awareness of the radiographic appearance of MF, to avoid misdiagnoses of MF as a radiolucent lesion on the apical area of mandibular premolar teeth (Gupta *et al.,* 2015). In addition, the borders of MF are made up of cortical bone (Malik *et al.,* 2016) and when there is an increase in bone density, MF are difficult to recognise on radiographs. Similarly, Yosue & Brooks (1989) hypothesized that the inability to view MF in periapical radiographs is due to the difficulty in differentiating MF from the surrounding trabecular pattern. Hence, the cortical and trabecular components of the mandible can present a problem in identification of MF with the use of radiographs particularly when viewing them in a two-dimensional (2D) view such as panoramic and periapical radiographs (Phillips *et al.*, 1992c).

Radiographic investigation remains a vital component for preoperative planning and evaluation in dental setting prior to surgery, to achieve a successful surgical outcome. Apart from standard clinical methods of identifying MF, panoramic and periapical radiographs are the most frequently used 2D modalities for diagnosis and preoperative assessment of MF (Gupta *et al.,* 2015; Malik *et al.,* 2016). However, with recent developments of advanced modern clinical technology coming to the forefront, several other 3D imaging modalities have been instrumental in aiding the identification of MF such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT scans), ultrasound as well as Cone Beam Computed Tomography (CBCT) (Naitoh *et al.*, 2009; Imada *et al.*, 2011; Laher *et al*., 2016).

In the current era, introduction, and integration of affordable CBCT into dental practice has added a new element in the diagnostic range for investigation of multidimensional modality. As such, CBCT allows for accurate evaluation of soft and hard tissues of the maxillofacial structure in terms of offering a pre-surgical assessment of the maxillofacial area (Katakami *et al.*, 2008; Imada *et al.*, 2012). In addition, CBCT provides high-quality resolution images with acceptable low radiation doses and scanning is rapid and non-invasive (Naitoh *et al.*, 2011; Khojastepour *et al.*, 2015). However, the above-mentioned benefits of CBCT have limitations as patient exposure to ionising radiation is increased as compared to the widely used digital panoramic and periapical radiograph. (Katakami *et al.*, 2008; Imada *et al.*, 2012). The increased costs of CBCT in comparison to conventional radiography have also hindered its accessibility to patients and dental practitioners in developing countries such as South Africa where resources are limited. Furthermore, CBCT is a relatively modern innovation; as a result, technical teething problems are experienced frequently in terms of loss of data due to inherent system failures or human errors. With the restrictions highlighted for CBCT it is important to have knowledge on the topography and associated morphology of the MF within a given population to enable clinical procedures in the absence of image modalities.

In clinical dentistry, MF is a significant landmark for surgical, local anaesthetic and other invasive procedures (Vargas *et al.*, 2018). The dense buccal cortical plate of mandible is often impermeable to local anaesthetic agents through infiltration methods of anaesthesia of desensitizing mandibular premolars and the surrounding anatomical area (Vargas *et al.*, 2018). Hence, clinicians rely on mental nerve block to anaesthetize the mandibular premolars. The mental nerve block is often achieved effectively by injecting local anaesthetic intraorally through a dental syringe pointing the needle towards mucogingival line of lower premolar area (Al-Khateeb *et al.,* 2007). If a clinician is not familiar with the exact position of MN it may result in higher doses of local anaesthesia being administered or a failed MN block. The consequence of which may increase the risk of haematoma or even permanent MN injury (Smith & Long 2006).

Furthermore, close attention is advised when dealing with AMF and MN during surgical procedures as this may reduce the rate of complications associated with mental region (Naitoh *et al.,* 2009). The contents of AMF have been determined to include nerves and blood vessels, which can result in incomplete anaesthesia if not identified (Hasan *et al.,* 2010). Conversely, complete absence of MF, which is a rare anatomical variation, has also been reported in case studies (Hasan *et al.,* 2010; Lauhr *et al.,* 2015). In the rare occurrence that the MF is absent, the patient may present with neurosensory disturbances in mental periphery and around the lips (Hasan *et al.,* 2010). Hence, the need for a detailed understanding of location and accessory foramina of MF is necessary to aid in management of patients requiring mandibular surgical intervention.

1.2. Demographic Factors Associated with topography of Mental Foramen.

The position of MF in particular warrants considerable investigation as differences have been noted within and between population groups (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005; Fabian 2007; Ukoha *et al.,* 2013; Laher *et al.,* 2016; and Bello *et al.,* 2018;). A study conducted on both the Chinese and British populations identified differences in position of the MF (Santini & Land 1990). The British sample had MF positioned between first and second lower premolars whilst the Chinese group had MF positioned in a more posterior location namely second premolar (Santini & Land 1990). A follow-up study confirmed the same result for the Chinese and British population and in addition reviewed an Indian population sample group, which reflected similarity in position of MF as depicted for the Chinese population (Santini & Alayan 2012).

Similarities in position were also noted in white American and Iranian population groups, with MF identified between first and second premolars (Cutright *et al.*, 2003; Haghanifar & Rokouei 2009). Alternatively, the African based population groups (Zimbabwean, Malawian and Black American population); MF was found to reside below the apex of the second premolar (Mbajiorgu *et al.,* 1998; Cutright *et al.,* 2003; Igbigbi & Lebona 2005). Hence, a trend seems to suggest that the position of MF in the European based population groups is located on first and second premolar whilst the Indian, Chinese, and African community MF is inclined to reside on the second premolar. Overall, the associated implications of this trend could indicate an inherited genetic pattern of the position of MF in differing population groups based on ancestry.

Studies on MF have not only focused on the specific position on the mandible but also the shape and size of the foramen. As mentioned, differences in shape of MF have been identified and consolidated according to two major shapes namely round and oval (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005). However, in a few studies irregular shapes have been noted in panoramic studies (Al- Khateeb *et al.,* 2007; Al-Shayyab *et al.,* 2015). The Zimbabwean and Malawian study groups seem to share a similar trend toward a higher prevalence of oval shaped MF (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005). Conversely, an Indian sample tended toward predominance (94%) of a rounded MF shape on dry mandibular bones (Singh & Srivastava 2010). However, other studies conducted in various ethnic Indian populations tended towards an oval shape of MF which were observed in 92% of South Gujarat, 74% of North Indian, 66% of Sri Lankan, 83% of South Indian and 70% of Western Indian ethnic groups (Prabodha & Nanayakkara 2006**;** Agarwal & Gupta 2011 Siddique *et al.*, 2011; Udhaya *et al.,* 2013; Bhudhiraja *et al.,* 2013). The shape of MF tended to be inconsistent and highly variable between and within population groups, which could indicate environmental factors (e.g., mastication and diet) might have a greater role when compared to genetic predisposition with reference to shape of MF. Additionally, inconsistent methods employed to analyse the shape of MF could also contribute to discrepancies highlighted above. For instance, poor image quality when using panoramic and conventional radiography could lead to distortion of shape of MF (Al-Shayyab *et al.,* 2015).

When considering the size of MF, few studies have shown that dimensions of this foramen vary amongst population groups (Oguz & Bozkir 2002; Igbigbi & Lebona 2005; Gupta *et al.,* 2015). A vast number of modes of investigation have also been used to measure size of MF, including dry mandibular bone, periapical, panoramic, and CBCT radiographs. (Oguz & Bozkir 2002; Igbigbi & Lebona 2005; Gupta *et al.,* 2015 & Sheiki & Kheir 2016). While other researchers studied size of MF using variable measures such as, vertical dimension (VD) and horizontal dimension (HD) or even length and width, and others used diameters of MF on both sides (Oguz & Bozkir 2002; Igbigbi & Lebona 2005 & Gupta *et al.,*2015). Hence, MF size is challenging to analyse as different authors use different methods.

For instance, Voljevica *et al.,* (2015) measured MF size VD right: 1.7 mm; VD left:1.6 mm and HD right:2.56 mm; HD left:2.41 mm Bosnian population using dry mandibular bones. Meanwhile, in Malawian population utilizing dry mandibular bones, found MF on VD right: 2.43 mm; VD Left: 2.71 mm and HD right: 5.05 mm; HD left: 5 mm (Igbibi & Lebona 2005). Thus, dimensions illustrated the discrepancies of the dimensions on the two differing populations. Variations on the size of the MF are evident in different population groups, which could be influenced by shape and age. For example, in cases, where the horizontal measure was larger, we would expect the shape to be oval or ovoid (Mbajiorgu *et al.,* 1998). Overall, discrepancies in measurement of MF size, renders it difficult to compare and speculate on the differences and similarities across population groups. The different methods of investigation could also influence size of MF, for example in panoramic radiograph size would be larger due to magnification and distortion (Phillips *et al.,* 1992c) when compared to measurement on the dry mandibular bones. Overall, size of the MF has huge clinical implication as postulated by Rajkohilia *et al.,* (2018) indicating that a MF diameter exceeding 3 mm could present with surgical complications around the mental region of mandible especially for implant placements and other surgical interventions around the MF region. Hence, information garnered from these studies aids clinicians in conducting their clinical procedures more effectively especially in situations where resources might be limited. It is also clear from previous studies that population differences have an influence on position of mental foramen (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005; Singh & Srivastav 2010). Nevertheless, other biological variables should also be considered such as sexual dimorphism and ageing.

Few studies have assessed the differences in the dimensions of mandible between males and females (Fabian & Mpembeni 2002; Apinhasmit *et al.,* 2006; Haghanifar & Rokouei 2009; Sheiki & Kheir 2016). Studies that focused on differences of the position of MF between the biological sexes with the use of panoramic radiographs on a Korean and south Indian population found differences in position between males and females to be statistically insignificant (Kim *et al.,* 2006; Gupta *et al.,* 2015).In spite of the MF not being significant, studies on mandibular dimensions are not only clinically relevant but might also provide useful information for forensic application in the identification and estimation of biological sex (Gupta *et al.,* 2015).

Age-related studies are two-fold in the context of ontogenetic changes associated with biological development and effects of senescence or ageing in an adult sample (Gershenson *et* *al.*, 1986). Gershenson *et al.,* (1986) concluded that in children, position and size of MF varied according to sequence of tooth eruption while in adults it differed with age, tooth condition and degree of bone resorption. For instance, position of MF was reported to be in line with first deciduous molar in children, however, in adults it was found in between first and second premolar and positioned more posteriorly along the mandible in older edentulous individuals (Gershenson *et al.,* 1986). Al- Khateeb *et al.,* (2007) also suggested that, with increasing age MF position tends to move posteriorly and inferiorly on the mandible. Therefore, age related changes affect the topography of MF in adults whilst developmental changes affect the topography in children. However, the scope of this study was focused on adult age-related changes only.

1.3. Significance of the study

As depicted from previously mentioned multiple studies have addressed morphology and topography of MF in terms of position, size, shape, number, and associated changes in relation to demographic factors such as population affinity, biological sex, and age (Agarwal & Gupta 2011; Prabodha & Nanayakkara 2006**;** Siddique *et al.*, 2011; Udhaya *et al.,* 2013; Bhudhiraja *et al.,* 2013, Polakowska-Zmyslowska *et al.,* 2019). Earlier studies specifically focused on topography of MF in a black Southern African population with the use of multiple modes of inquiry (Mbajiorgu *et al.*, 1998; Igbigbi & Lebona 2005; Laher *et al.*, 2016). The application of data produced from this study, is of specific value particularly in under-resourced health care facilities where imaging modalities are not always readily available to confirm the topography of MF. The outcome of this investigation will contribute to the growing body of evidence already available in literature (Laher *et al.*, 2016). Overall, the results presented from the current study will provide dental clinicians and emergency physicians with predictable indicators that could assist in attaining successful clinical procedures such as mental nerve block especially in low resourced health facilities.

1.4. Aim of the study

The aim of this study was to assess associated anatomical and topographical variations of mental foramen in a black South African population from both human dry bone and cone beam computed tomography mandibular samples. Furthermore, the relevance of this study is to quantitatively analyse the MF dimensions using different modalities i.e dry mandibular bones and CBCT scans

1.5. Objectives

- To determine the frequency (prevalence) of position, shape, and metric dimensions of MF in a South African (SA) black population
- To determine the number of accessory MF in a SA black population.
- To determine if position, shape, and size of MF are significantly different between males and females in a SA black population.
- To determine if position, shape, and size of MF are affected by age within a SA black population group.
- To determine if position, shape, and size of MF is consistent between assessments on dry mandibular bones and CBCT scans in black SA population group.

2. CHAPTER TWO: METHOD AND MATERIALS

2.1. Study design

This was a retrospective cross-sectional study of dry mandibular bones and hospital records of CBCT scans of black South African.

2.2. Study site

The dry mandibular bone study was conducted at Raymond A. Dart Collection of Human Skeletons based in the School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand. Ethical approval was granted for the use of human skeletal material obtained from Raymond A. Dart collection of modern human skeletons from the School of Anatomical sciences, Faculty of Health Sciences, University of the Witwatersrand. Ethics waiver reference number: W-CJ-140604-1. An ethical clearance approval was also granted for the dry mandibular bone sample by Human Research and Ethics Committee of the University of the Witwatersrand. Ethics reference number: M170609.

The records of patients for CBCT scans from 2012 to 2017 radiographs was obtained from the Maxillo facial and Oral Radiology Department Wits Oral Health Centre, Charlotte Maxeke Academic Johannesburg Hospital, South Africa. Permission for the use patients CBCT records was obtained from the Wits Oral Health Centre Hospital research committee with a certificate number HRRC/AUG/03/20.

2.3. Eligibility criteria

2.3.1. Inclusion criteria for both dry bone and CBCT radiographs

- In cases where mandibular premolars and first molars were missing, the position of the MF was assessed based on preservation of associated alveolar socket.

- Fully dentate mandibles or partially dentate with presence of single or both mandibular premolars and first molar.
- Intact or preserved alveolar margin.
- CBCT scans of fully or partially dentate patients.

2.3.2. Exclusion criteria for both dry bone and CBCT radiographs

- Completely edentulous mandible.
- Mandible with obvious pathology and deformity.
- Mandibles that have undergone surgery or presented with trauma.
- Curatorial damaged mandibles.
- Radiographs of poor quality (unclear anatomical landmarks).
- Presence of crowding and spacing in the lower arch (Gross malocclusion).
- Presence of periodontal lesions.

2.4. Measuring instrument for the dry bone mandible.

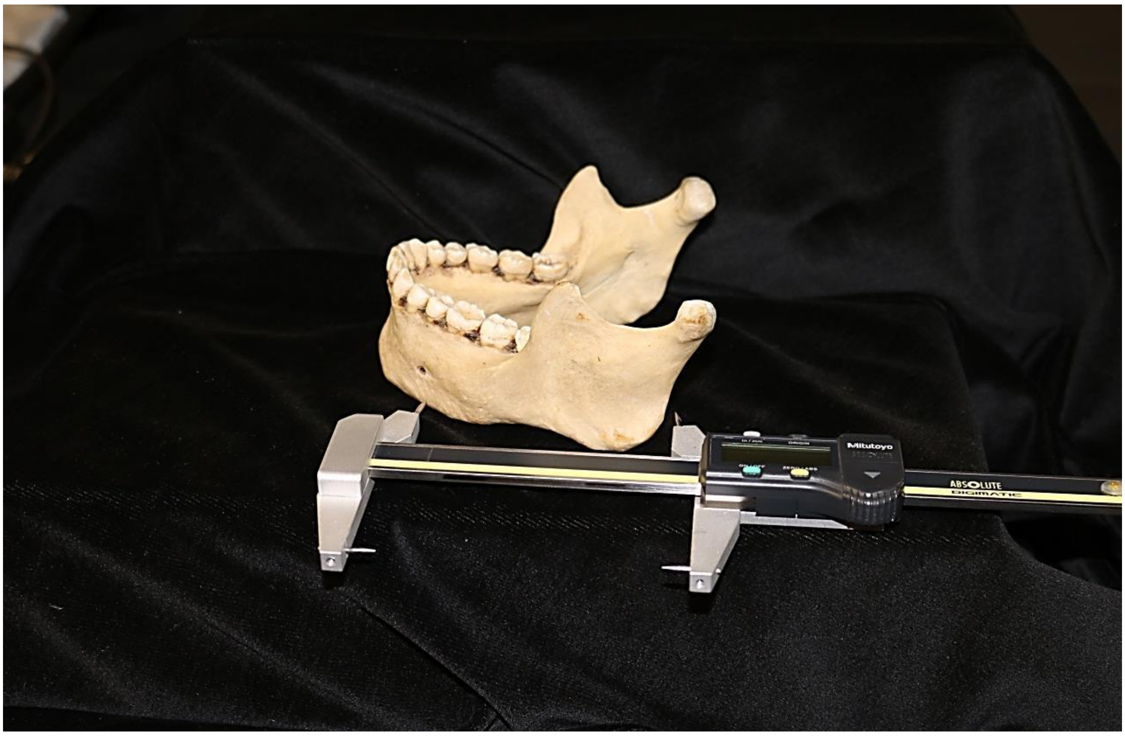


Figure 2:1: Dental calliper used to measure the size of MF

2.5. Size of Mental Foramen

The size of MF was measured using Digital Dental sliding calliper (Fig 2.1) (Mitutoyo Corporation, calibrated to 0.01 mm) to measure vertical and horizontal diameters in dry mandibular bones (Table 2.1) and (Fig 2.2).

2.5.1. Vertical and horizontal measurements.

All distances were measured in millimetres (mm) using landmarks such as including symphysis menti, alveolar crest, posterior border of ramus of mandible and lower border of mandible (Fig 2.2 & Table 2.1). The same landmarks were used in CBCT scans. The specific linear measurements were in accordance with Bhudhiraja *et al.*, (2013).

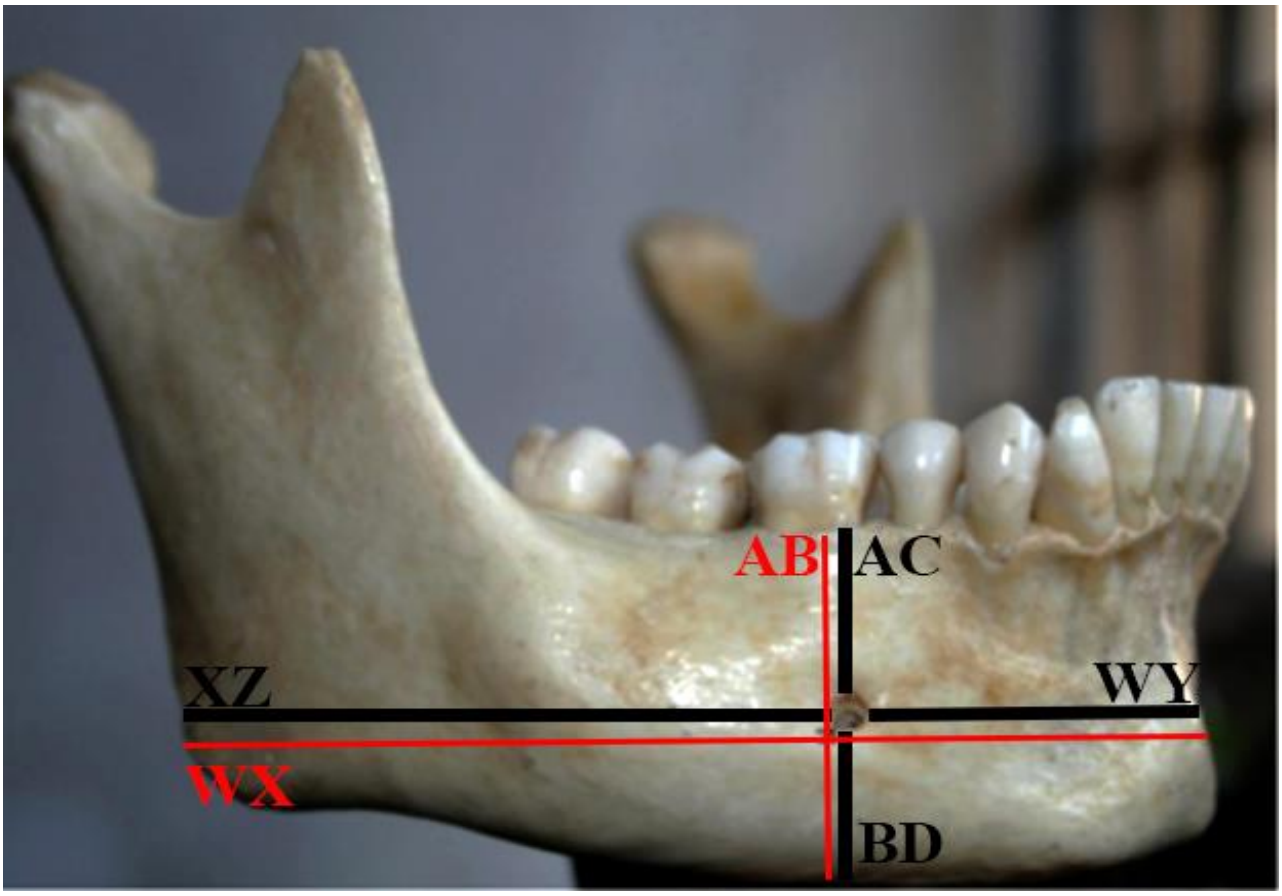


Figure 2:2. Vertical and horizontal measurements

Table 2:1. Illustration of vertical and horizontal measurements.

VERTICAL MEASURE	DESCRIPTION OF VERTICAL MEASURE
AC	Distance from most superior point of alveolar crest to the uppermost margin of mental foramen.
BD	Distance from the lowest border of mandible to lowest margin of mental foramen
AB	Distance from the most superior point of alveolar crest to lowest border of mandible.
VD	Vertical diameter of foramen =AB- (AC+BD).
HORIZONTAL MEASURE	**DESCRIPTION OF HORIZONTAL MEASURE**
WY	Distance from the most anterior part of symphysis menti to the most medial margin of mental foramen.
XZ	Distance from the most posterior border of ramus of mandible to the most lateral margin of mental foramen.
WX	Distance from most anterior part of symphysis menti to most posterior border of ramus of mandible
HD	Horizontal diameter of foramen = WX- (WY+XZ)

2.6. Shape of Mental Foramen

The shape of MF was visually observed qualitatively on both dry mandibular bones and CBCT scans for oval and round shapes only. A round-shaped foramen is when the foramen presented with an equidistant circular appearance, while oval-shaped presented with either the vertical or horizontal dimension which was larger in comparison to each other.

Figure 2:3: Diagrams showing oval and rounded shape MF respectively

2.7. Position of Mental Foramen

The positions of MF were determined based on the classification described by Tebo and Telford (1950). It is based on the relationship of MF with the teeth in dry mandibular bones and in CBCT scans.

Table: 2:2. Description of the MF position.

POSITION	DESCRIPTION OF THE POSITION
Position 1: (CP1)	Foramen positioned on a longitudinal axis passing between canine and first premolar
Position 2: (P1)	Foramen positioned on longitudinal axis of first premolar.
Position 3: (P1P2)	Foramen positioned on a longitudinal axis between first and second premolar.
Position 4: (P2)	Foramen positioned on longitudinal axis of second premolar
Position 5: (P2M1)	Foramen positioned on a longitudinal axis between second premolar and first molar.
Position 6: (M1)	Foramen positioned on longitudinal axis of first molar.

2.8. The number of mental foramina

In cases where accessory mental foramen (AMF) was observed, the largest foramen was considered the dominant or main foramen. Thereafter, the number of smaller accessory MF was recorded. It is important to note that position, size, and shape were exclusively recorded for the dominant foramen and not for the accessory foramina.

2.9. Radiographic assessment

Galexis Galileo software measuring ruler was used for all linear measurements of the mandible The height was calculated on the sagittal section and the length was calculated on the axial section. The shape, position and number of MF were identified using a 3D reconstructed view on the CBCT view. The records of the field of view of the mandible were also examined. All CBCT generated mandibular images were initially increased to a thickness of 300% to standardise the magnification factor before measurements were taken and a U-shaped mandible was maintained in all images. All CBCT radiographs measurements were attained from Sidexis software database on a 3D comfort by dental (SIRONA) Galileo GAX (Compact) 3351.

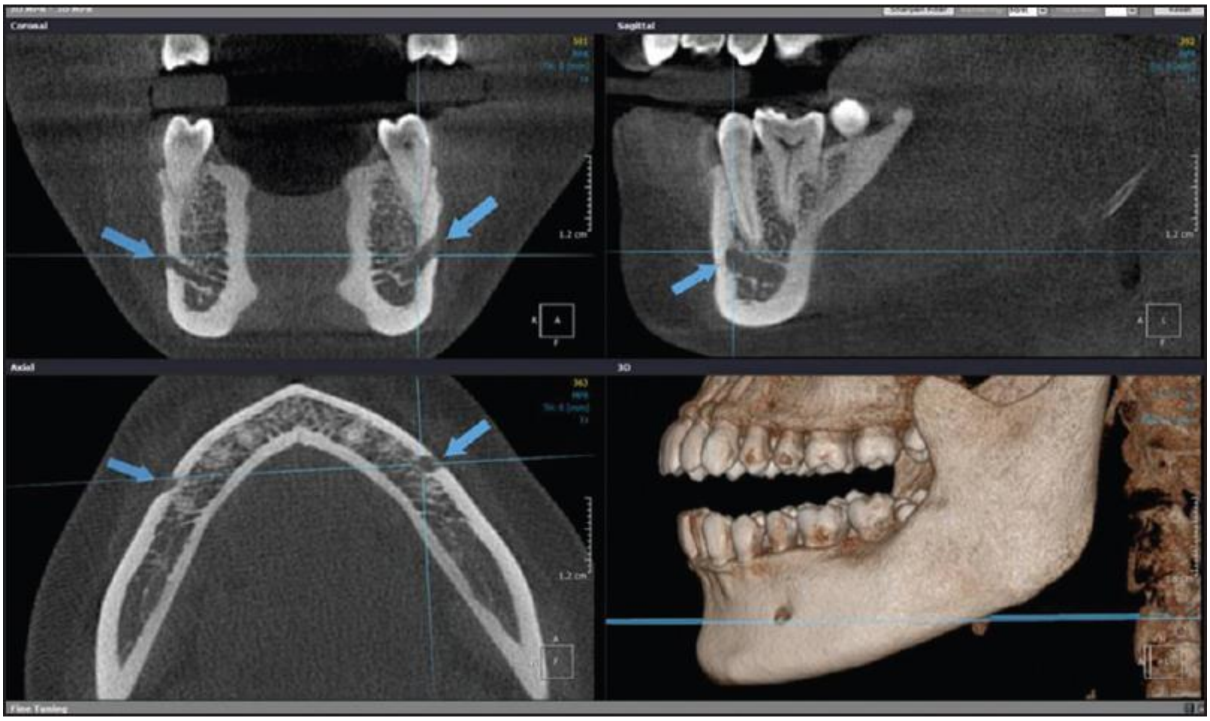


Figure 2:4: CBCT view of MF. Internet accessed, 15 August 2020.

https://witscloud
my.sharepoint.com/personal/a0038083_wits_ac_za/Documents/Pictures/cbct.png?Web=1

2.9.1. Data collection for dry mandibular bones.

A total sample size of 117 dry mandibular bones was assessed. The sample size included black South African males fifty-seven black South African males and 60 black South African females, all within ages 18 and 70 years. The sample was stratified into three age groups:18 - 30, 31 - 50 and 51 -70 years respectively.

2.9.2. Data collection for CBCT scans.

The second component of this study was based on assessing patient's CBCT scans which were retrieved from the Radiology department database of Wits Oral Health Centre. The total sample was 98 made up of 50 CBCT scans of (n=50) 48 CBCT scans of females (Table 2.3). The patient's radiographs were used to locate MF utilizing the same osteological landmarks used in the dry mandibular bone measurements. The Galexis Galileos software from the CBCT scans was utilized to determine the position, size, and shape of MF. MF was identified on axial, sagittal and coronal CBCT slices of 0.3 mm thickness. The degree of magnification and distortion was calculated.

Table 2:3. Stratification of the total sample according to sex and age.

	Dry mandibles (n=117)		CBCT (n=98)	
Sex	**n**	**Percentage**	**N**	**Percentage**
Female	60	51.28	48	48.98
Male	57	48.72	50	51.02
Age				
18-30	39	33.33	40	40.82
31-50	39	33.33	40	40.82
51-70	39	33.33	18	18.37

2.10. Statistical analysis

All data were captured in data collection sheet and transferred onto excel spreadsheet (Microsoft Excel 2010, Microsoft Corporation). Data were extrapolated from Microsoft Excel spreadsheet onto statistical analysis for the social sciences (SPSS 25 2017, IBM Corporation) which was used for analysis.

Descriptive statistics, such as means, and standard deviations were used to summarize data. Frequencies and percentages were also included to ascertain the prevalence of certain variables. Independent sample t-test was used to determine significant statistical differences between two groups and one way ANOVA was used to determine significant differences between the three groups. Chi-squared test was used to determine association between categorical variables. Level of significance was set at $p<0.05$.

2.11. Reproducibility test

A reproducibility test was conducted, namely an intra-observer test before commencement to ensure that measurements were reliable, accurate and reproducible. The calibration of the investigator was done by rescoring the same 10 samples of dry mandibular bones and 10 CBCT records on two separate occasions by the same observer. The reliability of the measurements was determined using confirmed by means of Lin’s correlation coefficient.

3. CHAPTER THREE: RESULTS

3.1. Data collection

The intra-observer agreement was equivalent to pc value range from 0.8 to 0.9 in 95% of the parameters measured on both dry mandibular bones and CBCT scans.

Table 3:1. Reproducibility data results.

				Dry mandible				
	AB	**AC**	**BD**	**AB-(AC+BD)**	**WX**	**WY**	**XZ**	**WX-(WY+XZ)**
R Side	0.94994	0.96575	0.93810	0.96640	0.89766	0.89967	0.95887	0.95723
L Side	0.95131	0.94632	0.92898	0.96747	0.98787	0.87767	0.98867	0.95774

				CBCT data				
	AB	**AC**	**BD**	**AB-(AC+BD)**	**WX**	**WY**	**XZ**	**WX-(WY+XZ)**
R Side	0.88780	0.95432	0.91541	0.81678	0.91892	0.97119	0.79123	0.94189
L Side	0.91761	0.93653	0.96982	0.96789	0.89871	0.87654	0.88645	0.91896

3.2. Distribution of MF according to its shapes on the right and left side of the dry mandibular bones.

The round and oval shapes were the only type of shapes seen in mandibular dry bone. Round shape was the commonest shape seen irrespective of the side of the mandible (Table 3:2 and Figure 3:1).

Table 3:2. Distribution of shape of MF right and left side of dry mandibular bone.

Dry mandible				
	Right		Left	
Shape	**n**	**%**	**n**	**%**
Round	90	76.9	82	70.1
Oval	27	23.1	35	29.9

3.3.Distribution of MF according to its location on dry mandibular bone.

MF were located between the apices of first premolar and first molar in the dry mandible. However, majority of MF were located specifically at apex of second premolar (P2) on the right (74.4%) and left (70.9 %) side (Table 3:3 and Figure 3:2). The apex of first molar was the least frequent location of MF on the dry mandibular bone on both the right and left side (0.9 % respectively) (Table 3.3 and Figure 3.2).

Table 3:3. Distribution of MF according to its location on the right and left sides dry mandibular bone.

Dry mandible				
	Right		Left	
Position	**n**	**%**	**n**	**%**
M1	1	0.9	1	0.9
P2	87	74.4	83	70.9
P1P2	12	10.3	20	17.1
P2M1	17	14.5	13	11.1

3.4. Frequency distribution of the number of MF on the right and left sides in dry mandibular bone.

A single dominant bilateral foramen was observed in 92.3% of dry mandibular bone on both sides respectively (Table 3:4 and Figure 3:3) followed by two accessory MF (6% and 7.7%) on the right and left sides respectively. The maximum number of foramina seen on the right side 4 (0.9%) while on the left side maximum was 2 (Table 3:4 and Figure 3:3).

Table 3:4. Frequency distribution of the number of MF foramina on right and left side of dry mandibular.

Dry mandibles				
	Right		Left	
Number of foramina	**n**	**%**	**n**	**%**
One	108	92.3	108	92.3
Two	7	6	9	7.7
Three	1	0.9	-	-
Four	1	0.9	-	-

3.5. The shapes of MF in association to CBCT scans on right and left sides the mandible.

The round shape was the commonest shape of the MF seen on both sides of mandibular CBCT scans (73.5% respectively) (Table 3:5 and Figure. 3:1).

Table 3:5. **Distribution of MF according to their shapes on the CBCT scans of the mandible.**

CBCT				
	Right		Left	
Shape	**n**	**%**	**n**	**%**
Round	72	73.5	72	73.5
Oval	26	26.5	26	26.5

3.6. Distribution of MF according to its location on the mandible using CBCT scans.

The commonest site MF on the mandible at apices of P2 (79.6 %: right and 82.7%: left) (Table 3:6 and Figure 3:2). Followed by location between P1 and P2 bilaterally. The least site for MF was the apex of M1(Table 3:6 and Figure 3:2).

Table 3:6. Site distribution of MF on both sides of the mandible using CBCT scans.

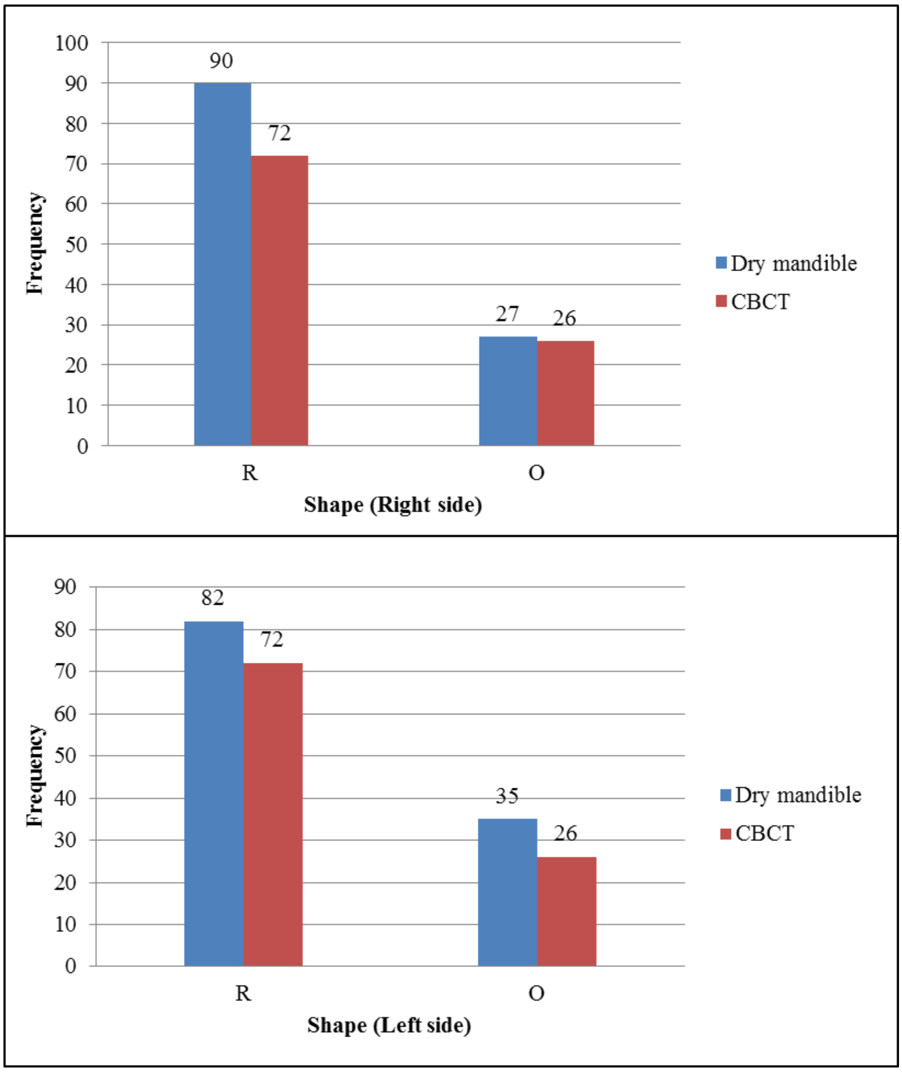
CBCT				
	Right		Left	
Position	**n**	**%**	**n**	**%**
M1	2	2	2	2
P2	78	79.6	81	82.7
P1P2	13	13.3	13	13.3
P2M1	5	5.1	2	2

3.7. The number of MF on both sides of the mandible using CBCT scans.

A single foramen was the commonest number seen on the right (96.9% and left (93.9%) respectively (Table 3:7 and Figure 3:3). The maximum number of MF seen was 5 on the left side of the mandible. (Table 3:7 and Figure 3:3).

Table 3:7. Percentage distribution of the number of mental foramina on right and left side of CBCT.

CBCT				
	Right		Left	
Number of foramina	**n**	**%**	**n**	**%**
One	95	96.9	92	93.9
Two	3	3	5	5.1
Three	-	-	1	1
Four	-	-	-	-



R= denotes round shape and O= denotes oval shape of the mental foramen.

Figure 3:1: Frequency distribution of the shapes of MF of dry mandibles and CBCT

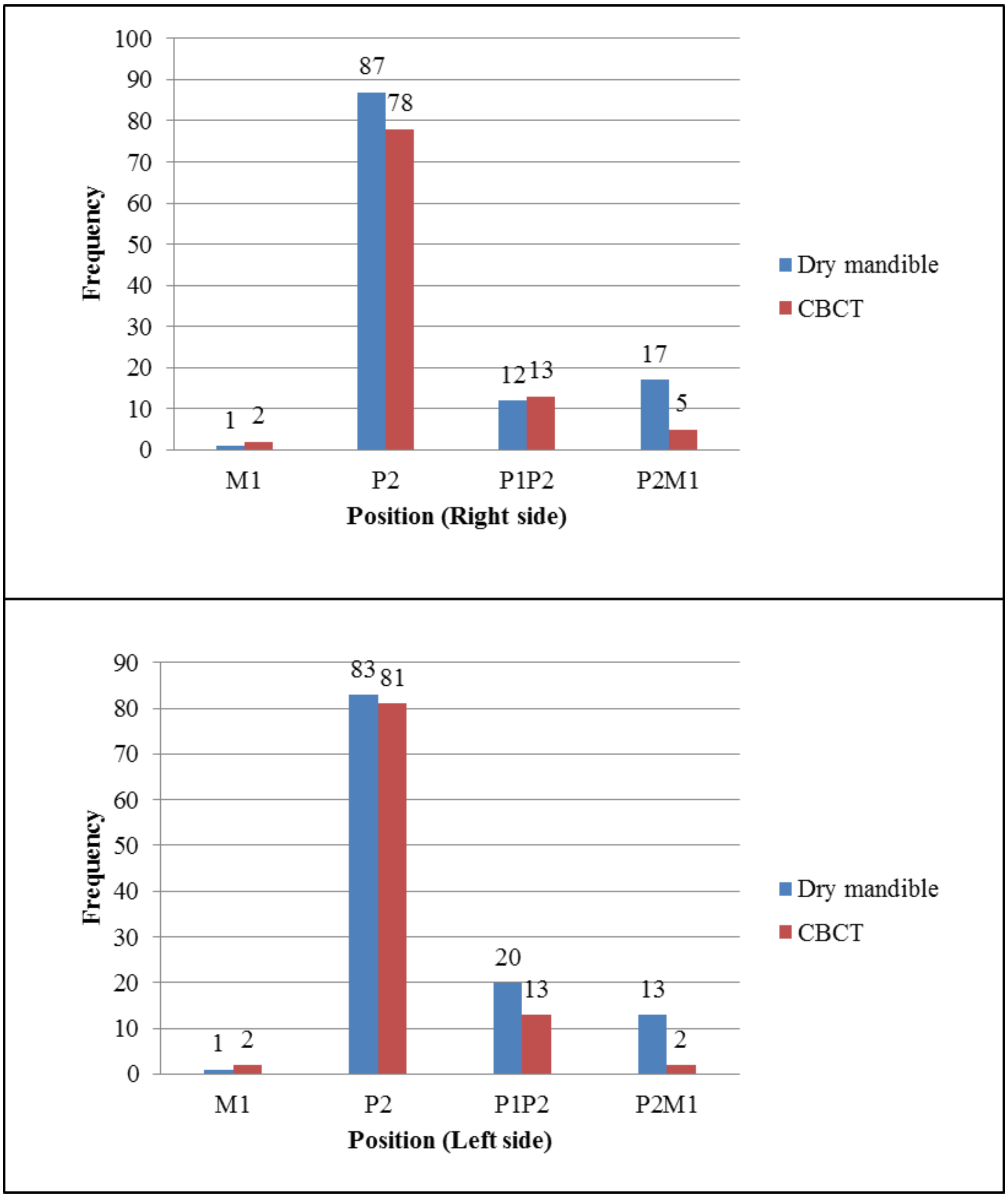


Figure 3:2: Frequency distribution of different positions of MF in association to dry mandible and CBCT

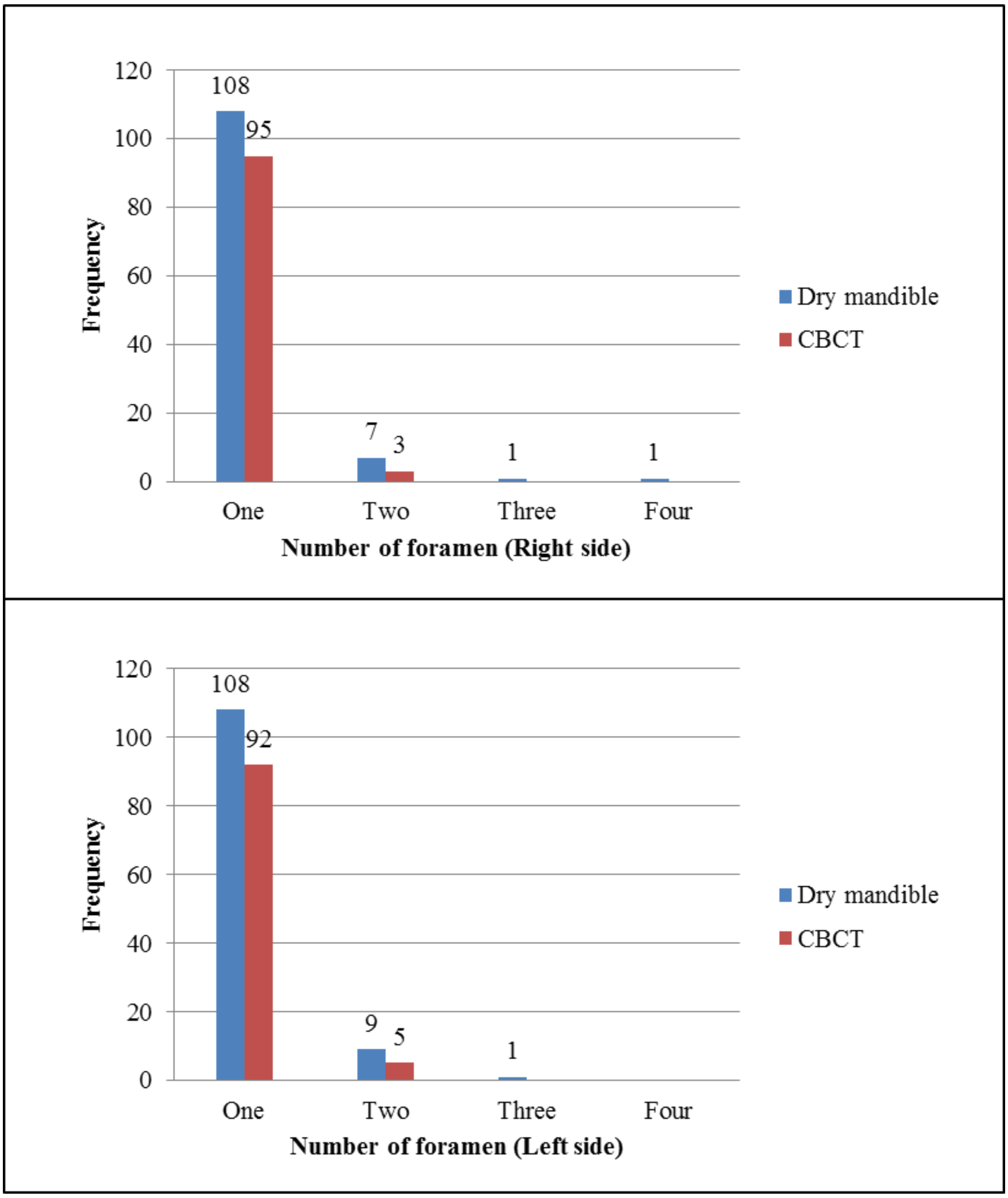


Figure 3:3: Frequency distribution of the number of MF

3.8. Comparison of the MF dimensions in dry mandibular bone and CBCT scans.

Table 3.8 Vertical dimension (VD) and horizontal dimensions (HD) of MF were measured on both dry mandibular bone and CBCT samples bilaterally.

The results demonstrate statistically significant differences in the mean VD and HD values of MF between dry mandibular bone and CBCT scans ($p<0.05$) respectively.

Table 3:8. Comparison of the mean dimension between dry mandibular bone and CBCT scans.

	Dry bone mandibles		CBCT		Independent Sample T-Test		
Right	**Mean**	**SD**	**Mean**	**SD**	**t**	**Mean difference**	**P**
Vertical	2.59	0.65	2.9	0.84	-3.09	-0.31	0.003*
Horizontal	2.81	0.73	3.4	0.88	-5.36	-0.31	0.000*
Left							
Vertical	2.48	0.6	2.77	0.7	-3.28	-0.29	0.001*
Horizontal	2.72	0.62	3.45	0.91	-6.68	-0.73	0.000*

3.9. Comparison of the mean MF dimension sex.

There were no sex differences in the MF dimension in both dry mandibular bone and CBCT scan ($p>0.05$ respectively).

Table 3:9. Sex distribution between dry mandibular bones and CBCT scans in terms of size.

	Dry mandibles			CBCT		
Right	**Male**	**Female**	**p-value**	**Male**	**Female**	**p-value**
Vertical	2.69(0.64)	2.50(0.65)	0.11	2.93(0.96)	2.87(0.70)	0.72
Horizontal	2.94(0.82)	2.69(0.60)	0.06	3.35(0.85)	3.45(0.85)	0.59
Left	**Male**	**Female**	**p-value**	**Male**	**Female**	**p-value**
Vertical	2.49(0.62)	2.47(0.58)	0.86	2.75(0.70)	2.79(0.71)	0.77
Horizontal	2.71(0.65)	2.74(0.59)	0.79	3.36(0.82)	3.54(1.01)	0.35

3.10. Parameters of size in terms of age distribution

There were no significant age differences in the mean values of MF dimension by age in both dry mandibular and CBCT scans (p>0.05 respectively).

Table 3:10. Age distribution between dry mandibular bones and CBCT scans in terms of size.

	Dry mandibles				CBCT			
Right	**18-30**	**31-50**	**51-70**	**p-value**	**18-30**	**31-50**	**51-70**	**p-value**
Vertical	2.67(0.68)	2.58(0.67)	2.52(0.58)	0.58	2.91(0.87)	2.89(0.80)	2.92(0.91)	0.99
Horizontal	2.88(0.87)	2.89(0.69)	2.67(0.60)	0.34	3.23(0.72)	3.61(1.01	3.30(0.85)	0.14
Left	**18-30**	**31-50**	**51-70**	**p-value**	**18-30**	**31-50**	**51-70**	**p-value**
Vertical	2.55(0.63)	2.43(0.54)	2.45(0.63)	0.65	2.59(0.59)	2.91(0.78)	2.87(0.67)	0.1
Horizontal	2.67(0.56)	2.85(0.74)	2.65(0.52)	0.32	3.30(0.96)	3.57(0.91)	3.52(0.82)	0.39

3.11 Intra gender comparison of the mean MF dimensions in dry mandibular bones and CBCT scans.

Significant differences were noted in all the mean MF dimensions in both males and females (p,0.005 respectively) except the vertical dimension in males. (p>0.05).

Table 3:11. Intra gender comparison of mean dimensions.

Male	Right		Left	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**
	Mean(SD)	**Mean(SD)**	**Mean(SD)**	**Mean(SD)**
Dry mandible	2.69(0.64)	2.94(0.83)	2.49(0.62)	2.71(0.65)
CBCT	2.93(0.96)	3.35(0.85)	2.75(0.70)	3.36(0.82)
p-value	0.117	0.012*	0.046*	0.000*
Female	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**
	Mean(SD)	**Mean(SD)**	**Mean(SD)**	**Mean(SD)**
Dry mandible	2.50(0.65)	2.69(0.61)	2.47(0.58)	2.74(0.59)
CBCT	2.87(0.70)	3.45(0.92)	2.79(0.71)	3.54(1.01)
p-value	0.005*	0.000*	0.011*	0.000*

4. CHAPTER FOUR: DISCUSSION

The study was aimed at assessing shape, size, and position of MF, including the number of foramina in a black South African population by utilizing dry mandibular bones and CBCT radiographs. The general finding in this study demonstrated a high level of congruency between dry mandibular bones and CBCT scans in terms of morphological, topographical, and number of MF that were investigated. Moreover, the location of MF in the mandible in this study is similar to the location found in previous African population-based studies thus, highlighting population specific location or position of MF (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005; Fabian 2007; Ukoha *et al.,* 2013; Laher *et al.,* 2016; Bello *et al.,* 2018).

Furthermore, no statistically significant age and sex variations were observed on morphological attributes of MF (i.e., shape and size) as well as topographical (e.g., position) and number of MF, bilaterally in both sample groups. There were statistically significant differences in the dimensions of MF between dry mandibular bone and CBCT scan.

Previous studies reported that (Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005; Ukoha *et al.,* 2013), round and oval shapes were the predominant were shape of MF. In addition to the round and oval shapes commonly reported, irregular shape was observed on panoramic radiographs by (Al- Khateeb *et al.,* 2007 & Al-Shayyab *et al.,* 2015). Irregularly shaped MF refers to any shape that does not conform to round and oval shaped MF (Al- Khateeb *et al.,* 2007 & Al-Shayyab *et al.,* 2015). The present study found no irregular shaped MF. In the present study, round shaped MF was the predominant shape in both direct observation of dry mandibular bone and CBCT scans. Although some studies found a similar high prevalence for rounded-shaped MF within African populations, for example, 75.5% in South-eastern Nigerians (Ukoha *et al.,* 2013), others found the shape MF to be more variable among interpopulation and intra population groups. For example, other African population groups present with a higher expression of oval shape such as Central Nigeria (55.2%), Tanzania (54%) Malawi (74%) and Zimbabwe (56%) (Bello *et al.,* 2018; Fabian 2007; Igbibi & Lebona 2005 and Mbajiorgu *et al.,* 1998). This variation in shape of MF is not confined to African populations, it was also observed in studies on Indian population groups. While some studies reported high percentage 94%: for round MF in a North Indian population (Singh & Srivastav 2010), while others observed high percentage of the oval typed shape in their different populations. (Agarwal & Gupta 2011; Siddique *et al.,* 2011; Udhaya *et al.,* 2013; Bhudhiraja *et al.,*2013).

This study did not find sex variations in the shape of the MF shape. Furthermore, age variation was observed in the shape of MF. Many of the previous study did not studies assess age and sex variations in the MF shape (e.g Mbajiorgu *et al.,* 1998; Igbigbi & Lebona 2005; Prabodha & Nanayakkara 2006; Udhaya *et al.,* 2013), however the few that observed them found insignificant sex variation in the shape of MF. (Fabian 2007; Singh & Srivastav 2010; Siddique *et al.,* 2011; Ukoha *et al.,* 2013; Budhiraja *et al.,* 2013). This is also in agreement with the findings of the current study. The inconsistency in presentation of the two shapes of MF described above could be related to multiple factors such as environmental factors (i.e., feeding patterns and mastication) in particular (Budhiraja *et al.,* 2013).Furthermore, this changes in environmental factors consequently affect the development of the mandible in time (Yesilyurt *et al.,* 2008).Other aspects concerning variation in expression of shape of MF could also be related to observer-bias based on a qualitative approach, which is generally subjective in nature, especially when defining shape utilising multiple methods of interpretation. Magnification and positioning errors could possibly be implicated as source of inconsistencies in panoramic radiographs (Al-Shayyab *et al.,* 2015). Additionally, factors such as superimposition of tissues, changes in angles and movement of patient during exposure might result in hidden detail regarding the anatomy in the hands of an inexperienced clinician (Alrahabi & Zafar 2018). If other studies included quantification of the MF it might have assisted better in their definition or observation of the disparity between the two shapes. Hence, CBCT scans were utilized instead of panoramic radiographs in the current study. From the foregoings, it is probable that the shape of MF is more likely to be defined by environmental factors rather than a strong genetic predisposition (i.e., population affinity), or sexual dimorphic traits. More research is needed to determine the reasons for the variations associated to the shape of MF.

Table 4.1: Shapes of Mental Foramen in different populations.

Author & Year	Population	Round	Oval
Rajkohila *et al.,* 2018	India	**74%**	26%
Prabodha & Nanayakkara 2006	Sri Lanka	**66.70%**	33.00%
Udhaya *et al* .,2013	South Indian	16.70%	**83.30%**
Agarwal & Gupta 2011	South Gujarat	8%	**92%**
Bhudhiraja *et al* .,2013	North Indian	25%	**74%**
Siddique *et al* .,2011	Western Indian	30%	**70%**
Singh & Srivatav 2010	North Indian	**94%**	6%
Igbibi & Lebona 2005	Malawi	26%	**74%**
Mbajiorgu *et al.,* 1998	Zimbabwe	**56.30%**	14.40%
Fabian *et al* .,2007	Tanzanian	46%	**56%**
Ukoha *et al* .,2013	South Eastern Nigeria	**75.76%**	25.24%
Bello *et al* .,2018	Central Nigeria	32.80%	**55.20%**
Al-Shayyab *et al* .,2015	Iraqi	**51%**	41%
Alrahabi & Zafar 2018	Saudi Arabia	**40%**	35.7%
Present study CBCT 2021	**Black South African**	**73.5%**	26.5%
Present study dry mandible 2021	**Black South African**	**R:76.9% L:70.1%**	R:23.1% L:29.9%

4.1. Position of Mental Foramen

In the present study, the predominant position or location of MF was at the apex of second premolar (P2), (74.4%; 70.9%) for dry mandibular bones and CBCT scans (76.6%; 82.7%) right and left sides, respectively. The second most common position was in between the apices of mandibular premolars (P1/P2). The findings of this study agree with other studies from African countries. (Mbajiorgu *et al.,* 1998; Fabian 2007; Igbigbi & Lebona 2005; Ukoha *et al.,* 2013; Laher *et al.,* 2016; and Bello *et al.,* 2018).

Furthermore, the findings from this study are also in agreement with research observations from five different sub-populations within the Indian community (Argawal & Gupta 2011; Bhudhiraja *et al.,* 2013; Siddique *et al.,* 2011; Singh & Srivastav 2011 and Udhaya *et al.,* 2013). Therefore, it could be concluded that the apex of P2 is the predominant location of MF in most populations. However, there are few contrary findings for example, (Santini & Alayan 2012) in their study, observed MF to be located between the apices P1/P2 in an Indian population, however, sample size is very small (n=33) to warrant generalization.

Also, the findings from studies conducted among show that the most common position of MF is in between the apices of P1/P2 (Moisewitch 1998; Cutright *et al.,* 2003; Kqiku *et al.,* 2011 & Santini & Alayan 2012). This finding contrasts with the results of the present study. No reason can be adduced for the observed differences however, genetic, and environmental factors might be responsible. Also, the location of MF the Middle Eastern population groups such as Iraqi and Jordanian populations is similar to the Europeans (Al-Shayyab *et al.*, 2015 and Al-Khateeb *et al.*, 2007). The reason may be due to the common ancestry in both populations, but further studies are needed to prove this assertion. Another reason could be because even though these populations are geographically separated they may be share same genetics. It should be pointed out that the findings from the middle east are not all homogenous. In studies conducted in Iran where similar populations were studied independently. Some of the studies show that MF were commonly located on the apices of P2 while and others observed MF to be located to be predominantly identified between apices of P1/P2 (Haghanifar & Rokouie 2009; Afkhami *et al.*, 2013). No reason can be adduced for this intra population differences.

In summary it could be inferred that MF is usually located on the apex of P2 in African and Indian derived populations (Igbibi & Lebona 2005; Fabian 2007; Argawal & Gupta 2011; Siddique *et al.*, 2011; Bhudhiraja *et al.*, 2013 and Bello *et al.*, 2018). Whereas the European and North American populations seem to follow a different pattern in the location of MF which is usually P1/P2 (Moisewitch 1998; Cutright *et al.*, 2003; Kqiku *et al.*, 2011 & Santini & Alayan 2012). It appears like the position of the MF on mandibles is population specific and perhaps more genetically driven than environmentally influenced.

In terms of comparative differences, position of MF with specific reference to biological sex, there was no significant differences between males and females in this study. This is in agreement with other studies conducted among different population groups (Apinhasmit *et al.*, 2006 and Amorim *et al.*, 2008) including a black South African population (Laher *et al.*, 2016). This lack ability to discriminate between sex is nonetheless an important finding, as the mandible has been shown to be sexually dimorphic, have application within forensic anthropology for determination of sex (Malik *et al.*, 2016 & Thakur *et al.*, 2014). No reason could be adduced in particular for this observation. Further studies on the pattern of growth of the mandible, the influence of muscle activities and other environmental factors as regards to the location of MF are needed. Previous researchers have also concluded that position of MF should be excluded from the set of traits to be used for determination of sex in the mandible (Apinhasmit *et al.*, 2006; Amorim *et al.*, 2008). In contrast to the school of thought above some authors have identified differences in the lateralisation and symmetry of position of MF with regards to sex. For example, MF is frequently located on the apices of P2 (42%) on the right side for males, whereas in females is frequently located in between on P1/P2 (44%) on the left side (Bello *et al.,* 2018). Lateralisation as a trait of sexual dimorphism should be explored further in future research.

In the current study, there was no age-related difference in the location of MF both dry mandibular bone and CBCT scans on both sides of the mandible. A limitation of the current study was the low sample size in the oldest age cohort (50 to 71 years). This could possibly have affected the findings in the current study. Several studies have demonstrated variations in the location of MF and ageing (Gershenson *et al.,* 1986; Laher *et al.,* 2016). A study conducted in Jordan population demonstrated that the position of MF changes MF position with a tendency to shift posteriorly and inferiorly on the mandible as age advances (Al-Khateeb *et al.,* 2007).

This could be due to tissue degeneration and alveolar bone resorption because of ageing. Relative MF position may be affected by age due to edentulism and interproximal caries, Green (1998), suggested tooth that interproximal attrition of tooth may cause mesial drifting of the teeth thus leading to an apparent change in the position of MF in relation to teeth present. This may support the assertion that the variation seen in location of MF may be due to environmental factors and not population or sex differences.

Table 4.2: Position of MF in different population

Author and Year	Population group	Predominant position	2nd most frequent
Agarwal & Gupta 2011	South Gujarat	P2	M1
Bhudhiraja *et al.*, 2013	North Indian	P2	P1/P2
Siddique *et al.*, 2011	Western India	P2	P1/P2
Singh & Srivastav 2011	India	P2	P1/P2
Udhaya *et al* .,2011	South India	P2	P1/P2
Cutright *et al.*, 2003	American	P1/P2	P2
Kqiku *et al.*, 2011	Austria	P1/P2	P2
Moisewitch 1998	North American	P1/P2	P2
Phillips *et al.*, 1992	American	P2	P1/P2
Santini & Alayan 2012	Indian	P1/P2	P2
Santini & Alayan 2012	Chinese	P2	P1/P2
Santini & Alayan 2012	British	P1/P2	P2
Haghanifar & Rokouei 2009	Iran	P1/P2	P2
Al-Khateeb *et al.*,2015	Jordanian	P1/P2	P2
Al-Shayyab *et al.*,2015	Iraqi	P1/P2	P2
Afkhami *et al.*, 2013	Iran	P2	P1/P2
Al Jasser & AL Nwoku 1998	Saudi Arabia	P2	P1/P2
Yesiyurt *et al.*, 2008	Turkey	P2	P1/P2
Fabian 2007	Tanzania	P2	P1/P2
Igbibi & Lebona 2005	Malawian	P2	P1/P2
Mbajiorgu *et al.*, 1998	Zimbabwean	P2	P1/P2
Ukoha *et al.*, 2004	Central Nigerian	P2	P1/P2
Laher *et al.*,2016	**South African Blacks**	**P2**	**P1/P2**
Present study 2021	**Black South Africans**	**P2**	**P1/P2**

4.2. Number of Mental Foramina

In terms of the number of MF expressed on the mandible, one dominant MF on the right and left hemispheres of the mandible was the most prevalent for dry mandibles (92.3%; 92.3%) and CBCT (96.9%; 93.9%) in the present study. In dry mandibular bones, 6% of the sample presented with two foramina on the right and 7.7% on the left side. In the CBCT scans, 3% and 5.1% presented with two foramina on right and left sides respectively. Furthermore, the current study agrees with previous reports whereby the incidence of AMF fell within the collective range of approximately 1% to 13% of the total sample (Mbajiorgu *et al.*, 1998; Igbibi & Lebona 2005; Singh & Srivastava 2010; Khojastepour *et al.*, 2015 and Laher *et al.*, 2016). Hence, from earlier findings and the current study a single foramen is the most prevalent and AMF seems to be a rare occurrence in various populations across the world. The underlying reasons for the occurrence of these AMF have been debated, but the consensus is that it is a consequence of changes in the development of mandible (Toh *et al.,* (1992; Naitoh *et al.,* 2009). Naitoh *et al.,* (2009), postulated that AMF development may be due to branching of mental nerve into several nerve bundles before the actual development of MF which occurs around the 12th gestational week. However, Toh *et al.,* (1992), deducted that during embryonic stages if mental nerve separation precedes the formation of MF, then AMF would still emerge. Nonetheless, inconsequential of the exact underlying factors that induce the formation of these accessory foramina, the clinician should be cautious of the associated consequences of ignoring the possibility of their existence during clinical practice. Toh *et al.,* (1992) also suggested that regions innervated by the mental nerve could also be anaesthetised by local infiltration due to accessory mental nerve communicating with branches of facial and buccal nerve. Hence, an infiltration could result in injury if the needle is injected directly through the mucous membrane. Therefore, clinicians are advised to conduct proper preoperative planning even when dealing with populations exhibiting low incidence of AMF to preclude iatrogenic injury.

In clinical practice, misdiagnosis of periapical radiolucencies may be encountered with conventional radiography with the presence of one or even multiple MF (Borghesi *et al.,* 2018). In cases of treatment of trigeminal neuralgia, failure to do peripheral neurectomy of accessory mental nerve has ensued in the relapse of neuralgic pain (Thakur *et al.,* 2011). In addition, AMF could be useful in analysing anatomical landmarks in forensic odontology, such as the suggestion that non-white individuals may have a high incidence of AMF than white individuals (Khojastepour *et al.,* 2015).

4.3.The size of the mental foramen

In the current study, size of MF in terms of VD and HD were measured on both dry mandibular bones and CBCT scans, bilaterally. The mean VD on right side was 2.59 mm and 2.48 mm on left side, whereas the mean HD on the right side was 2.81mm and 2.72 mm on the left side for dry mandibles. For CBCT, mean VD on the right side was 2.9 mm and 2.77 mm on the left side. The mean HD on the right side was 3.4 mm and 3.45 mm on the left side. Both the vertical and horizontal dimensions in the current study are similar to the other population group. Extreme horizontal dimensions were noted for specific population groups such as Malawian (5.05 mm: R and 5 mm: L) and North Indians (5.19 mm: R and 5.1 mm: L). These large horizontal dimensions could be as a result of the oval shaped MF as in Malawian and North Indian population. (Igbigbi & Lebona 2005 & Bhudhiraja *et al.,* 2013). However, the largest dimensions noted in current study was 3.4 mm on the right and 3.45 mm on the left (CBCT) and 2.81 mm on right and 2.72 mm on left (dry bone mandible). Generally, right MF showed slightly larger right sided dimension when compared to the left MF. Contrary to our findings, Gupta *et al.*, (2013) and Phillips *et al.,* (1990) identified the left side to be larger than the right in South Indians and White Americans. However, this study and others, did not show any significant differences between the MF dimension on both sides of the jaw.

No statistically significant differences were identified between males and females with reference to size of the MF in the current study (Table 3:11). However, average dimensions for both vertical and horizontal measures are larger in males when compared to females. The findings in this study were corroborated by other studies as well (Kalendar *et al.,* 2011; von Arx *et al.,* 2013 & Oliveira *et al.,* 2018). Apinhasmit *et al.,* (2006). The reason for the difference in dimensions of MF between males and females might be related to the overall larger size of the mandible in males compared to females. Size of MF might therefore be a more noteworthy deduction for forensic application.

There was no significant age variation in the dimensions of the MF in the current study in both dry mandibular bone and CBCT scans. This is in agreement with the findings of Oliveira *et al.,* (2018) but, in direct contrast with Bello. Bello *et al.,* (2018) that discovered that young adults present with larger MF dimensions than the middle-aged adults. However, no consensus has been reached to date on the effects of ageing on the size of MF. The best method in the author's opinion of addressing the relationship between age and the size of MF would include a longitudinal study that tracks these changes in the same individuals over time. Additionally, the standardisation of the methods employed to measure the dimensions of MF should be re-visited. von Arx et al., (2013) further corroborates this idea by stipulating those differences outlined in the dimensions of MF amongst studies could be related to the differing methodologies.

Table 4:3. Size of Mental Foramen in different populations.

Author and year	Population	Mode of investigation	Vertical D		Horizontal D	
			Right	**Left**	**Right**	**Left**
Bello *et al* ., 2018	Nigeria	Panoramic X-ray	2.88mm	2.73mm	3.6mm	3.52mm
Gupta *et al.*, 2015	South Indian	Panoramic X-ray	2.44mm	2.29mm	2.61mm	2.81mm
Udhaya *et al.*, 2013	South Indian	Dry mandible	2.86mm	2.52mm	2.28mm	2.9mm
Bhudhiraja *et al.*, 2013	North Indian	Dry mandible	2.61mm	2.53mm	5.19mm	5.1mm
Voljevica *et al.*, 2015	Bosnian	Dry mandible	1.71mm	1.6mm	2.56mm	2.41mm
Oguz & Bozkir 2002	Turkish	Dry mandible	2.32mm	2.64mm	2.93mm	3.14mm
Igbibi & Lebona 2005	Malawian	Dry mandible	2.43mm	2.71mm	5.05mm	5mm
Agarwal & Gupta 2011	South Gujarat	Dry mandible	2.15mm	2.13mm	3.33mm	3.26mm
Present study	**South African Black**	**Dry mandible**	**2.59mm**	**2.48mm**	**2.81mm**	**2.72mm**
Present study	**South African Black**	**CBCT**	**2.9mm**	**2.77mm**	**3.4mm**	**3.45mm**

4.4. CBCT vs dry bone

The comparison of the MF dimensions between CBCT and dry mandibular bone shows statistically significant differences in the horizontal and vertical dimensions bilaterally. Literature research yielded no result on such comparison between dry mandibular bone measurement and CBCT scans. Therefore, more studies are required to validate our findings. A reason for the differences in the dimensions of MF in the dry mandibular bone and CBCT could be due to secular trend. The dry mandibular bones are from skeletal material of Black South Africans from 19^{th} and 20^{th} century curated in the Raymond A. Dart Museum (Dayal *et al.,* 2009) while the CBCT scans are from the 21^{st} Black South Africans. Hence it is probable that the contemporary Black South African population differ significantly from an older Black South African population in terms of the size dimensions of the MF. This could also refer to a secular trend between the 19^{th} and 20^{th} century. The reason (e.g., diet and genetic admixture). Further studies are necessary to prove our assertion.

Table 4: 4. Size of Mental Foramen in different populations using CBCT.

Author and year	Population	Mode of investigation	VD	HD
von Arx *et al.*,2013	Switzerland	CBCT	3.0mm	3.2mm
Oliveira *et al* .,2018	Brazil	CBCT	3.11mm	3.2mm
Kalendar *et al* .,2012	Turkish	CBCT	3.7mm	3.4mm
Carruth *et al.*,2015	Americans	CBCT	3.7mm	3.4mm

5. CHAPTER FIVE: CONCLUSION

Overall, a round shape was the most prevalent in Black South African population. No significant gender and age differences were found in the shape of the MF. Also, a single MF was found on each side of mandible. The incidence of AMF only occurred in less than 8% of both samples on the Black South African population. The size of MF ranged from 2.4 mm to 2.81mm in dry mandibular bones, while in CBCT it ranged from 2.7 mm to 3.45 mm. These measures are within the confines of what has been described by other populations studied previously.

A significant difference was noted in both vertical and horizontal measurements between the direct visual measurements of MF on dry mandibular bone and the measurements of MF on CBCT scans. These discrepancies should be further investigated in future studies.

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APPENDIX A: ETHICAL APPROVAL

UNIVERSITY OF THE WITWATERSRAND
OFFICE OF THE DEPUTY VICE CHANCELLOR RESEARCH
12 SEP 2017
RESEARCH OFFICE
HREC (Medical)
JOHANNESBURG

R14/49 Dr Ivonne Osekeng Stemmer

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M170609

NAME: (Principal Investigator)	Dr Ivonne Osekeng Stemmer
DEPARTMENT:	Oral Health Sciences/ General Dental Practice School of Oral Health Sciences and School of Anatomical Sciences
PROJECT TITLE:	Variations Associated to the Topography of the Mental Foramen in a Black South African Population from Both Human Dry Bone and Cone Beam Computed Tomography (CBCT) Mandibular Samples
DATE CONSIDERED:	30/06/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Mr. B.K Billings and ~~Dr. H.~~ Tasseva
APPROVED BY:	Professor C. Penny ~~Co-Chairperson~~, HREC (Medical)
DATE OF APPROVAL:	28/08/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004,10th floor, Senate House/3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially review June and will therefore be due in the month of June each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date 30/08/2017

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B: PERMISSION TO CONDUCT STUDY

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

WITS ORAL HEALTH CENTRE

Private Bag X15 Braamfontein, Johannesburg, 2017
Enquiries: Ms Tumelo Marule
Tel: (011)488-4893, Fax 086 406 3196
E-mail: Tumelo.Marule@wits.ac.za

7 August 2017

Dr I O .Stemmer
General Dental Practice
Faculty of Health Sciences
University of the Witwatersrand
Johannesburg

REGARDING: PERMISSION TO CONDUCT RESEARCH BY COLLECTING DATA FROM THE RECORDS AT THE DEPARTMENT OF ORAL PATHOLOGY..

REFERENCE :HRRC/AUG/03/2017

It is my pleasure to grant final approval to utilize resources at Wits Oral Health Centre in order to conduct your research.
The Hospital Research and Risk Committee allocated a unique reference number to this application – Kindly quote this reference number in all future correspondence regarding this research.

Please note that the Hospital Research and Risk Committee should be informed of the estimated date the research will commence, as well as regular status reports until the research has been concluded. Within a month after conclusion of the research project, a written report must be submitted to the Head of School/CEO, summarizing the final result/outcome as well as the recommendations made based on the research concluded.

Regards,

(Acting HOS)
Prof MS Nemutandani
CEO/Head of School

APPENDIX C: DATA COLLECTION SHEET

Specimen/File no:	Shape	Position	No of foramen	AB	AC	BD	AB-(AC+BD)	WX	WY	XZ	WX-(WY+XZ)	Ethnicity	Age

APPENDIX D: ADDITIONAL TABLES

Table 1: sex mean difference on size associated with dry mandibles and CBCT.

	Dry mandibles			CBCT		
Right	**Male**	**Female**	**p-value**	**Male**	**Female**	**p-value**
Vertical	2.69(0.64)	2.50(0.65)	0.11	2.93(0.96)	2.87(0.70)	0.72
Horizontal	2.94(0.82)	2.69(0.60)	0.06	3.35(0.85)	3.45(0.85)	0.59
Left	**Male**	**Female**	**p-value**	**Male**	**Female**	**p-value**
Vertical	2.49(0.62)	2.47(0.58)	0.86	2.75(0.70)	2.79(0.71)	0.77
Horizontal	2.71(0.65)	2.74(0.59)	0.79	3.36(0.82)	3.54(1.01)	0.35

Table 2: Association between dry mandibles and CBCT properties

	Dry bone mandibles		CBCT	
Sex, p-value	**Right**	**Left**	**Right**	**Left**
Shape	1	1	0.26	1
Position	0.47	0.65	0.07	0.52
Number of foramen	0.35	1	0.24	0.84
Age, p-value	**Right**	**Left**	**Right**	**Left**
Shape	0.68	0.91	0.39	0.79
Position	0.4	0.1	0.99	1
Number of foramen	0.58	0.91	0.09	1