

**THREE-DIMENSIONAL MORPHOMETRIC  
ANALYSIS OF MANDIBULAR CANAL AND  
FORAMINA: A CONE BEAM COMPUTED  
TOMOGRAPHY STUDY COMPARING ARABIC  
AND KURDISH ETHNICITIES IN IRAQ**

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**UNIVERSITI SAINS MALAYSIA**

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by

**OMAR BASHEER TAHA**

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## **LIST OF SYMBOLS**

|   |                       |
|---|-----------------------|
| R | Right side            |
| L | Left side             |
| D | Distal                |
| M | Mesial                |
| 5 | Lower second premolar |
| 6 | Lower first molar     |
| 7 | Lower second molar    |
| 8 | Lower third molar     |

## LIST OF ABBREVIATIONS

|                  |                                                                                                                                                                                                                                                                                      |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMandF</b>    | Accessory mandibular foramen                                                                                                                                                                                                                                                         |
| <b>AMentF</b>    | Accessory mental foramen                                                                                                                                                                                                                                                             |
| <b>LIG</b>       | Lingula                                                                                                                                                                                                                                                                              |
| <b>MandF</b>     | Mandibular foramen                                                                                                                                                                                                                                                                   |
| <b>MC</b>        | Mandibular canal                                                                                                                                                                                                                                                                     |
| <b>MentF</b>     | Mental foramen                                                                                                                                                                                                                                                                       |
| <b>LIG-Inf</b>   | Distance from the most superior tip of the lingula (LIG) to the most inferior border of mandible (INF).                                                                                                                                                                              |
| <b>LIG-Cd</b>    | Distance from the most superior tip of the lingula (LIG) to the most superior aspect of condylar process of mandible (Cd).                                                                                                                                                           |
| <b>LIG-Cr</b>    | Distance from the most superior tip of the lingula (LIG) to the tip of coronoid process of mandible (Cr).                                                                                                                                                                            |
| <b>LIG-Mn</b>    | Distance from the centre of mandibular foramen (LIG) to the most inferior aspect of mandibular notch of mandible (Mn).                                                                                                                                                               |
| <b>LIG-Occ</b>   | Distance from the most superior tip of the lingula (LIG) to the occlusal table of mandible (Occ). Occlusal table is measured The occlusal table is the surface of a tooth that comes into contact with the opposite tooth.                                                           |
| <b>LIG-Post</b>  | Distance from the most superior tip of the lingula (LIG) to the posterior border of ramus (PostR). Point PostR is recorded on posterior border of ramus at intersection of a line extending from the centre of mandibular foramen with the posterior border of ramus at right angle. |
| <b>LIG-Ant</b>   | Distance from the most superior tip of the lingula (LIG) to the anterior border of ramus (AntR). Point AntR is recorded on anterior border of ramus at intersection of a line extending from the centre of mandibular foramen with the anterior border of ramus at right angle.      |
| <b>LIG-Go</b>    | Distance from the most superior tip of the lingula (LIG) to the angle of mandible. Angle of mandible is recorded at point gonion (Go). Gonion is the <u>most</u> inferior, posterior, and lateral point on the angle of the mandible                                                 |
| <b>LIG-Gn</b>    | Distance from the most superior tip of the lingula (LIG) to the anterior part of body of mandible. Anterior part of body of mandible is recorded at point gnathion (Gn). Gnathion is The most inferior point of the mandible in the midline.                                         |
| <b>LIG-MentF</b> | Distance from the most superior tip of the lingula (LIG) to the centre of mental foramen (MtF).                                                                                                                                                                                      |
| <b>MC-D</b>      | Distance from the maximum length of the section of mandibular canal(MC) to the apex of the distal root of third molar(R).                                                                                                                                                            |
| <b>MC-BC</b>     | Distance from the maximum length of the section of mandibular canal (MC) to the most superior aspect of the crest of the buccal ridge(BC) below the distal root of third molar.                                                                                                      |
| <b>MC-LC</b>     | Distance from the maximum superior length of the section of mandibular canal (MC) to the most superior aspect of the crest of the lingual ridge(LC) below the distal root of third molar.                                                                                            |
| <b>MC-BB</b>     | Distance from the most width of the mandibular canal(MC) to the buccal cortical bone(BB).Point BB is recorded on the buccal wall at intersection of line extending from the most width of MC with the buccal wall of alveolar ridge below the distal root of third molar.            |

|                    |                                                                                                                                                                                                                                                                              |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>MC-LB</b>       | Distance from the most width of the mandibular canal(MC) to the lingual cortical bone(LB).Point LB is recorded on the lingual wall at intersection of line extending from the most width of MC with the lingual wall of alveolar ridge below the distal root of third molar. |
| <b>MC-IB</b>       | Distance from the maximum inferior length of the section of mandibular canal (MC) to the inferior border of the alveolar bone (IB) below the distal root of third molar.                                                                                                     |
| <b>MentF-5R</b>    | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the apex of the root of the second premolar(5R).                                                                                                                                                    |
| <b>MentF-4R</b>    | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the apex of the root of the first premolar(4R).                                                                                                                                                     |
| <b>MentF-6R</b>    | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the apex of the root of the first molar(6R).                                                                                                                                                        |
| <b>MentF-Go</b>    | Distance from the centre of mental foramen ( <b>MentF</b> ) to the angle of mandible. Angle of mandible is recorded at point gonion (Go). Gonion is the <u>most</u> inferior, posterior, and lateral point on the angle of the mandible                                      |
| <b>MentF-Gn</b>    | Distance from the centre of mental foramen ( <b>MentF</b> ) to the anterior part of body of mandible. Anterior part of body of mandible is recorded at point gnathion (Gn). Gnathion is The most inferior point of the mandible in the midline.                              |
| <b>MentF-Cd</b>    | Distance from the centre of mental foramen ( <b>MentF</b> ) to the most superior aspect of condylar process of mandible (Cd).                                                                                                                                                |
| <b>MentF-Cr</b>    | Distance from the centre of mandibular foramen ( <b>MentF</b> ) to the tip of coronoid process of mandible (Cr).                                                                                                                                                             |
| <b>MentF-Inf</b>   | distance from most inferior border of the mental foramen to the inferior border of the mandible                                                                                                                                                                              |
| <b>MentF-4RE</b>   | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the crest of residual ridge of the first premolar area.                                                                                                                                             |
| <b>MentF-5RE</b>   | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the crest of residual ridge of the second premolar area.                                                                                                                                            |
| <b>MentF-6RE</b>   | Distance from the nearest wall of the mental foramen ( <b>MentF</b> ) to the crest of residual ridge of the first molar area.                                                                                                                                                |
| <b>Angle-MentF</b> | The value of the angle measured in the opening of the ( <b>MentF</b> )                                                                                                                                                                                                       |
| <b>BMC</b>         | Bifid mandibular canal                                                                                                                                                                                                                                                       |
| <b>TMC</b>         | Trifid Mandibular canal                                                                                                                                                                                                                                                      |
| <b>MPR</b>         | Multi planar reconstruction                                                                                                                                                                                                                                                  |

|             |                                  |
|-------------|----------------------------------|
| <b>IQR</b>  | Interquartile range              |
| <b>BMCL</b> | Length of bifid mandibular canal |
| <b>BMCw</b> | width of bifid mandibular canal  |
| <b>CBCT</b> | Cone Beam Computed Tomography    |

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**ANALISIS MORFOMETRI TIGA DIMENSI SALURAN DAN FORAMINA  
MANDIBULAR: KAJIAN TOMOGRAFI BERKOMPUTER ALUR KON  
MEMBANDINGKAN ETNIK ARAB DAN KURDISH DI IRAQ**

**ABSTRAK**

Untuk mengelak komplikasi neurologi selepas pembedahan, adalah amat disyorkan supaya penilaian tepat dibuat terhadap morfologi saluran mandibel (MC) dan foramina serta variasi mereka sebelum menjalankan sebarang prosedur pembedahan yang melibatkan rahang bawah. Matlamat utama kajian ini adalah untuk mengkaji bagaimana saraf inferior alveolar (IAN) bergerak melalui MC dan berakhir pada foramen mental (MentF) serta menentukan variasinya dan dimorfisme seksualnya di kalangan masyarakat Arab dan Kurdi di Iraq. Kajian ini, yang menggunakan 400 imej CBCT dan melibatkan 200 orang Arab dan 200 orang Kurdi, terdiri daripada 100 lelaki dan 100 perempuan daripada setiap kumpulan etnik, dijalankan untuk mengukur morfologi foramen mandibel (MandF), MC, dan MentF serta variasi mereka, dan membandingkan ukuran antara jantina untuk setiap kumpulan etnik dan antara populasi Arab dan Kurdi untuk menguji sama ada ukuran saiz dan lokasi MandF dan MentF boleh meramalkan jenis jantina, dan jika mungkin, untuk meramalkan kedudukan MandF berdasarkan ukuran kedudukan MentF. Keputusan kajian ini menunjukkan bahawa terdapat perbezaan ketara dalam ukuran saiz dan kedudukan MC dan foraminanya antara jantina dan antara kedua-dua kumpulan etnik; variasi MC dan foraminanya ditemui dalam kedua-dua populasi Arab dan Kurdi; ujian regresi binari bagi ukuran MandF dan MentF dapat meramalkan jenis jantina; dan akhir sekali, ujian regresi linear mudah menunjukkan bahawa ramalan kedudukan MandF berdasarkan pengukuran kedudukan MentF

adalah mungkin. Dalam kajian semasa, butiran lanjut mengenai saiz, bentuk, dan kedudukan MC dan foraminanya dan variasi mereka pada orang Kurdi dan Arab di Iraq telah dikemukakan kepada kesusasteraan. Penemuan kajian ini akan menawarkan data morfometrik penting yang diperlukan untuk menjalankan blok IAM dengan jayanya dan mengelakkan kesukaran semasa pembedahan mandibel.

**THREE-DIMENSIONAL MORPHOMETRIC ANALYSIS OF  
MANDIBULAR CANAL AND FORAMINA: A CONE BEAM COMPUTED  
TOMOGRAPHY STUDY COMPARING ARABIC AND KURDISH  
ETHNICITIES IN IRAQ**

**ABSTRACT**

Precise evaluation of the morphology of mandibular canal (MC) and foramina and their variations is highly recommended before any surgical procedures involve the mandible to avoid neurological complications after surgery. The primary goal of this study is to examine how inferior alveolar nerve (IAN) moves through the MC and terminates at the mental foramen (MentF), as well as to determine its variations and sexual dimorphism among the Arabic and Kurdish communities in Iraq. The study done on 400 CBCT images, 200 Arabs and 200 Kurds, for each ethnic group 100 males and 100 females, to measure the morphology of mandibular foramen (MandF), MC, and MentF and their variations, and compare the measurements between the genders of each ethnic group and between the Arabs and Kurds populations, to test whether the measurements of the size and location of MandF and MentF can predict the type of genders, and if possible, to predict the position of the MandF depending on the measurements of the position of the MentF. The results have shown that there were significant differences in the measurements of the size and position of the MC and its foramina between the genders and between the two ethnic groups; the variations of MC and its foramina were found in both Arabs and Kurds populations; a binary regression test of the measurements of MandF and MentF can predict the type of gender; and finally, a simple linear regression test showed that the prediction of the position of MandF depending on the measurements of the position of MentF is possible. In the current study, more details about the size,

shape, and location of the MC and its foramina and their variations in the Kurdish and Arabic people of Iraq were presented to the literature. The findings of this study will offer crucial morphometric data needed to carry out an IAN block successfully and avoid difficulties during mandibular surgery.

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Thorough understanding of crucial anatomical structures is essential for ensuring the efficacy and safety of surgical procedures of the mandible. There is a spectrum of surgical procedures of the mandible, ranging from the placement of dental implants to the surgical extraction of impacted mandibular third molars, orthognathic surgeries, and bilateral sagittal split osteotomy (Ylikontiola et al., 2002; Yamamoto et al., 2002; Yoshioka et al., 2012,2010; Cheung et al., 2010; Gerlach et al., 2010; Huang et al., 2013; Taha AL-Tekreeti & Irhayyim, 2020). The critical structures under scrutiny are the mandibular foramen (MandF), the mandibular canal (MC), the mental foramen (MentF), the accessory mandibular foramen (AMandF), and the accessory mental foramen (AMentF).

The MandF is an aperture on the medial aspect of the mandibular ramus. The inferior alveolar nerve (IAN) and vessels pass through the MandF to enter the MC, where they innervate and supply the mandibular teeth, gingiva, and lower lip. The neurovascular bundle later divides into incisive and mental branches and is sometimes involved in the formation of the anterior loop at the MentF (Standring, 2015).

Variations of the location and dimensions of the MandF have been reported. The location of MandF has been described as midway between the anterior and posterior aspects of the mandibular ramus (Ferris, 1929; Basmajian & Grant, 1972). In the vertical plane, it was observed to be above the occlusal plane or at the same level as the occlusal plane of the mandibular dentition (Feuerstein et al., 2020).

According to Fabian (2005), the MandF is situated above the middle of the mandible on the medial surface of the ramus. Several studies have measured the location of the MandF from the lingual due to its prominence and proximity to the MandF (Hayward et al., 1977; Hetson et al., 1988; Ahn et al., 2020b). The Lingula (LIG), which resembles the shape of the tongue, is a bony prominence situated near the posterior border of the MandF on the medial surface of the mandibular ramus (Freny & Jaypee, 2009).

Studies by Jansisyanont et al. (2009) and Ahn et al. (2020) have observed variations in diameters. Ahn et al. (2020) reported anteroposterior and mediolateral diameters of the MandF as 3.2 mm and 2.7 mm, respectively, while Jansisyanont et al. (2009) found a mean anteroposterior diameter of 4.7 mm. Additionally, the shape of the MandF's orifice has been reported as circular or even V-shaped in different individuals (Friedrich et al., 2019; Nguyen & Duong, 2022).

The MC is a hollow space within the mandibular body that extends from the MandF posteriorly to the MentF anteriorly, via which the IAN and vessels nourish the mandibular teeth and surrounding structures (Sanchis et al., 2003). Given the extensive surgical interventions conducted on the mandible, precise localisation of the MC holds paramount importance. Variations in the vertical distances of MC to the inferior border of the mandible and to the mandibular root apices have been reported in different populations (Razumova et al., 2022). Its diameter also demonstrates variability. For instance, Koivisto et al. (2016) reported average diameters of 3.03 mm and 2.91 mm for the left and right MC, respectively. Another study revealed that about 75% of cases exhibited MC diameters ranging from 2.1 mm to 4.0 mm (de Oliveira-Santos et al., 2012a). In terms of shape, oval and

irregular shapes were frequently observed (Friedrich et al., 2019; Nguyen & Duong, 2022).

The MentF is typically a bilateral opening on the lateral aspect of the mandibular body through which the mental nerve and artery leave the MC to supply the surrounding soft tissues. Under the depressor anguli oris muscle, the mental nerve splits into three sensory branches, two of which innervate the skin and mucous membrane of the lower lip and one innervates the chin (Clemente, 1985; Alantar et al., 2000; Greenstein & Tarnow, 2006a). The MentF position in the vertical and horizontal planes has been observed to exhibit significant anatomical variation. Most investigations have found the MentF below the root of the mandibular second premolar or in between the roots of the mandibular first and second premolar. Chkoura & El Wady (2013) reported that the MentF was situated precisely below the apex of the second premolar in 62.7% of patients and between the first and second premolars in 30% of patients. However, its location may range from under the canine to below the first molar (Alantar et al., 2000). The MentF may move closer to the bony crest after teeth are extracted due to alveolar ridge resorption, making the mental nerve more vulnerable to damage during surgical treatments. Surgical interventions in this region may injure the mental nerve, resulting in paraesthesia of the chin and lower lip.

The MC has typically been thought of as a single structure; however, since 1973, variants like bifid (BMC) and trifid canals (TMC) have been found (Kiersch & Jordan, 1973; Patterson & Funke, 1973). Each of these bifid or trifid canals comprises their own neurovascular bundles and typically emerges from one MandF (Langlais et al., 1985). The presence of these branching canals and their neurovascular bundles implies their potential significance in providing blood supply

and innervation to the mandible (Kaufman et al., 2000). Another study reported that 60% of the MC consists of the full IAN, while the remaining 40% of the branches may be distributed within canals that are not clearly defined (Carter & Keen, 1971).

AMandF is an uncommon anatomical feature adjacent to the MandF. It leads to a distinct structure through which a bifid MC passes through, either connecting to the primary MC or terminating at the level of the mandibular molar region (Narayana et al., 2003; Das & Suri, 2004; Manikandhan et al., 2010). The presence of AMandF can vary in numbers. Studies have estimated its occurrence to range from 0.06% to 35%. Immunohistochemical analysis revealed that the contents of these foramina comprise a neurovascular bundle, emphasising their clinical significance (Przystańska & Bruska, 2010).

Researchers have classified AMentF as any foramen in the lateral body of the mandible in addition to the MentF (Mraiwa et al., 2003; Çağırankaya & Kansu, 2008; Prabodha & Nanayakkara, 2009; Singh & Srivastav, 2010; Thakur et al., 2011; Jha & Kumar, 2012; Gupta & Soni, 2012; Rai et al., 2014; Paraskevas et al., 2015; Ahmed et al., 2015), while others described it as a minor foramen in the vicinity of the MentF (Riesenfeld, 1956; Sutton, 1974). It was described as a foramen that is continuous with the MC but smaller when compared to the MentF on each side of the mandible (Naitoh et al., 2011,2009; Sisman et al., 2012). Other definitions include AMentF as being continuous with MC as well as IAN (Pancer et al., 2014), and it should be less than or equal to half of the size of ipsilateral MentF. In contrast, a term double MentF is when the additional foramen is more than or equal to half of the size of ipsilateral MentF (Oliveira Santos, 2011; Von Arx et al., 2014). The prevalence and location of AMentF also vary in different populations (Haghanifar et al., 2017).

The past two decades have witnessed dental implants (DI) becoming prevalent owing to successful outcomes. Osseo integrated DIs are being used annually for 450,000 cases due to their significant (95%) success and few complications (Sullivan, 2001). A suitable amount of alveolar bone must be present to allow the attachment of a DI. Tooth removal is followed by wound recovery in the socket, modeling, and re-modelling, causing structural changes on the residual ridge (del Canto-Díaz et al., 2019). Such dimensional alterations might reduce bone width and height, leading to constraints concerning DI insertion in terms of the required dimensions (Eufinger et al., 1998,1999). Moreover, like other surgical interventions, complications are observed for DI procedures too (Kim, 2011; Moslehifard et al., 2012).

The most common anaesthetic procedure of the mandible is inferior alveolar nerve block. It has been reported that this anaesthetic procedure could fail as often as 20% to 25%, with the most prevalent cause of failure being inaccurate localisation of MandF (Standring, 2015). However, there are other factors of not achieving proper anaesthesia, such as anatomical variations, improper needle placement, insufficient anaesthesia delivery, patient anxiety, and pain perception thresholds (Kamel et al., 2022).

Surgical procedures of the mandible may be associated with risks of haemorrhage, injury to the neural component, bony fractures, and mandibular ramus destruction (Oguz & Bozkir, 2002; AlAli et al., 2023). During surgical procedures on the mandible, the IAN is the nerve that is harmed most frequently (64.4%), followed by the lingual nerve (28.8%) (Tay & Zuniga, 2007). Oral surgery comprises interventions like implant attachment, third molar surgery, mandibular osteotomies, and mandibular fracture fixes necessitate comprehensive anatomical information

concerning the MC to reduce the likelihood of injury to the inferior alveolar neurovascular bundle (Mavili et al., 2009; Suomalainen et al., 2010). Damage to the IAN can cause paraesthesia and neuropathic pain (Alves et al., 2014). Given the significant variability of the MandF, MC, and MentF, understanding their precise location and trajectory in the mandible, as well as the anatomical differences, is crucial to avoid clinical issues with these procedures.

Identification of BMC, TMC, AMandF, and AMentF is frequently overlooked during surgical treatments due to a lack of comprehensive understanding of their anatomical structures, frequency, and variations. The presence of these variations may potentially pose additional challenges during clinical procedures of the mandible (Auluck & Pai, 2005; Auluck et al., 2007; Wadhwani et al., 2008a; Mizbah et al., 2012; Rashsuren et al., 2014). Failure to identify them, clinically as well as radiographically, could lead to iatrogenic harm. Traumatic neuroma and bleeding may arise from damage to any of these branches (Kieser et al., 2005). Furthermore, any bifurcation type may result in insufficient anesthesia, particularly if the variant contains two mandibular foramina that render normal injection procedures useless in some patients. Other anesthetic injection strategies may need to be considered to compensate for these aberrant canals and foramina.

Genetic factors play important roles in how different races and groups differ in the size, form, and location of anatomical landmarks (Ahmed et al., 2021). Moreover, population-oriented data is crucial, as using standards that were developed for other groups and described in books or journals might not be appropriate for other incidents, which could lead to grave injuries and/or diminish the effectiveness of treatments (Kochhar et al., 2020).

Iraq is a country in the Middle East with a population of 42.8 million consisting of various ethnicities such as Arabs, Kurdish, Turkmen, Assyrians, and Yazidis, with Arabs comprising the largest ethnic community (<https://www.worldometers.info/world-population/iraq-population>). Retrieved on June 15, 2023. Each of these ethnic groups contributes to the cultural diversity of the country. This study will focus on the Arab and Kurdish populations and their distinct cultural, social, and genetic characteristics. Notably, facial features between Arabs and Kurds differ, with Arabs typically having more prominent noses and fuller lips, while Kurds often exhibit higher cheekbones and broader foreheads (Ali & Ahmed, 2019). Understanding these differences, particularly in context with the current subject, is essential for a successful treatment outcome.

Reliable gender identification is one of the many issues of morphological characteristics of human skeletal remains in forensic medicine. The pelvis and mandible are two bones that have been used to determine distinctions in genetically sex-linked growth and development, and they best reflect the differences between the male and female skeleton. Much research has analysed different mandibular features and determined if they were reliable sex indicators. Morphometric measurements on dry mandibles (Ongkana & Sudwan, 2009; Vinay et al., 2013; Datta et al., 2015), orthopantomographs (OPG) (Indira et al., 2012), and cone-beam computed tomography (CBCT) (Alves & Haiter-Neto, 2015) exhibited considerable differences between males and females.

Male parameters were substantially larger than female ones. It was hypothesised that the manifestation of mandibular dimorphism could potentially be explained by differences in the forces exerted during mastication between sexes. These variations could be due to differences in strength, size, and angulation of the

masticatory muscles. On the other hand, no significant gender differences were found in MentF locations in a Moroccan population (Chkoura & El Wady, 2013). Previous studies indicate that the relative position of MC and its MentF and MandF in adults presents sexual dimorphism (Ribeiro et al., 2021). These differences may have forensic value in determining the identity of human remains (Krishan et al., 2016).

The most significant development in dentistry has been the development of the CBCT technology, which enables three-dimensional diagnosis. The literature has demonstrated numerous applications of CBCT in dental implant treatment planning, especially in terms of linear measurements, visualisation of critical anatomical components, three-dimensional assessments of alveolar ridge topography, and creation of surgical guides (Scarfe et al., 2006a; Benavides et al., 2012). The lack of superimposition and picture magnification, faster scanning times, and lower radiation exposure than multi-slice computed tomography (CT) are some of the benefits of CBCT over traditional imaging (Benavides et al., 2012).

The integration of advanced computer software with CBCT technology enhances visualisation and measurement accuracy, especially in reconstructing two-dimensional (2D) images into three dimensions (3D). Moreover, some software enables the automation of measurements and the creation of virtual surgical guides, thereby streamlining the planning process and improving surgical predictability and outcomes. In this study, RadiAnt DICOM Viewer (Medixant, Poland) was utilised. This software package provides precise manipulation of 3D images, facilitating detailed examination of anatomical structures and aiding in the assessment process. By incorporating algorithms for image segmentation and reconstruction, accurate linear and volumetric measurements of bone quality and quantity can also be performed.

The use of mathematical equations in human anatomy and physiology proved to be beneficial, such as in the structure of bone lamellae and the distribution of forces on the hip joint, the structure of the femoral condyles, which distribute weight to the lower part of the leg, and the role of ligaments on the movements of the femur in comparison with the hip and its mathematical examination (Habbal & Al-Baali, 2006).

Given the considerable variability of the MandF, MC, and MentF, it is imperative to have a precise understanding of their precise location and dimensions in the mandible. Additionally, it is important to gather information about BMC, TMC, AMandF, and AMentF. It is essential to consider these anatomical variations specific to the Arab and Kurdish ethnicities in our study. This knowledge is essential in the preoperative assessment of mandibular procedures to mitigate any potential clinical complications that may arise during the procedures. The investigations were performed using CBCT with the integration of advanced computer software.

## **1.2 Problem statement**

There was a scarcity of information regarding comprehensive comparative studies of the mandibular foramina and the MC location, size, and form between Arabic and Kurdish ethnicities in Iraq, as well as between sexes. There is insufficient investigation regarding the BMC, TMC, AMandF, and AMentF, not only in Iraq but also in other parts of the world.

### **1.3 Justification and Novelty of Study**

Before surgery, the surgeons or clinicians must have a thorough grasp of the precise location, size, and quantity of the mandibular foramina, the MC, and their variations to prevent injury to the neurovascular bundles and to achieve local anaesthesia. Addressing this issue is crucial for improving clinical outcomes and surgical precision in dental and craniofacial procedures.

As previously stated, the standards suggested for other populations are not appropriate for use with other populations. This study produces data particular to the Arabic and Kurdish Iraqi ethnicities of Iraq and in different sexes. The data can contribute to the development of population- and gender-specific guidelines and treatment protocols, enhancing healthcare delivery and patient outcomes. This study proposes a comprehensive comparative analysis of mandibular foramina and MC characteristics between Arabic and Kurdish ethnicities, shedding light on previously unexplored anatomical variations in these populations. By investigating BMC, TMC, AMandF, and AMentF characteristics, this study also incorporated novel insights into craniofacial anatomy, potentially uncovering unique features that could inform future research and clinical practice globally. To add more novelty to the research, we applied the mathematical calculation-based statistical analysis to the study's measurements to test the predictive power of gender and MandF location.

## **1.4 Objectives of the study**

### **1.4.1 General objective**

The aim of this study is to compare the mandibular foramina and the MC variations between the Arabic and Kurdish ethnicities of Iraq and between the sexes.

### **1.4.2 Specific objectives**

Particularly, the study will address the following objectives:

1. To compare the location, size, and form of MandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
2. To compare the position of MC in relation to the roots of adjacent mandibular teeth between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
3. To compare the location, size, and form of MentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
4. To compare the prevalence, location, size, and form of BMC and TMC between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
5. To compare the prevalence, location, size, and form of AMandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
6. To compare the prevalence, location, size, and form of AMentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
7. To compare the location of MC between the dentate and edentulous ridges and between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.

8. To determine sex using a mathematical calculation based on statistical analysis to from the location of the MandF and MentF.
9. To determine the location of MandF using a mathematical calculation based on statistical analysis of the location of MentF.

### **1.5 Research Questions**

1. Are there any differences in the location, size, and form of MandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
2. Are there any differences in the position of MC in relation to the roots of adjacent mandibular teeth between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
3. Are there any differences in the location, size, and form of MentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
4. Are there any differences in the prevalence, location, size, and form of BMC and TMC between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
5. Are there any differences in the prevalence, location, size, and form of AMandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
6. Are there any differences in the prevalence, location, size, and form of AMentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?
7. Are there any differences in the location of MC between the dentate and edentulous ridges and between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes?

8. Can sex be determined using a mathematical calculation based on statistical analysis of location of the MandF and MentF?
9. Can the location of MandF be determined using a mathematical calculation based on statistical analysis of the location of MentF?

## **1.6 Research Hypotheses**

1. There are differences in the location, size, and form of MandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
2. There are differences in the position of MC in relation to the roots of adjacent mandibular teeth between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
3. There are differences in the location, size, and form of MentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
4. There are differences in the prevalence, location, size, and form of BMC and TMC between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
5. There are differences in the prevalence, location, size, and form of AMandF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
6. There are differences in the prevalence, location, size, and form of AMentF between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.
7. There are differences in the location of MC between the dentate and edentulous ridges and between the Arabic and Kurdish Iraqi ethnicities, as well as between the sexes.

8. Sex can be determined using a mathematical calculation based on statistical analysis of location of the MandF and MentF.
9. The location of MandF can be determined using a mathematical calculation based on statistical analysis of the location of MentF.

## **CHAPTER 2**

### **LITERATURE REVIEW**

A comprehensive understanding of key anatomical structures is mandatory for ensuring the success and safety of surgical procedures involving the mandible. The range of mandibular surgical procedures is diverse, including dental implant placement, impacted mandibular third molar extraction, orthognathic surgeries, and bilateral sagittal split osteotomy (Yamamoto et al., 2002; Ylikontiola et al., 2002; Cheung et al., 2010; Gerlach et al., 2010; Yoshioka et al., 2010, 2012; Huang et al., 2013; Taha AL-Tekreeti & Irhayyim, 2020). Fundamental to these procedures are critical anatomical landmarks, including the MandF, MC, MentF, AMandF, and AMentF, which are the focus of the current study.

#### **2.1 Mandibular Foramen**

The MandF is an aperture located in the medial aspect of the mandibular ramus. The IAN and vessels pass through the MandF to enter the MC, where they innervate and supply the mandibular teeth, gingiva, and lower lip. The neurovascular bundle subsequently divides into incisive and mental branches and is sometimes involved in the formation of the anterior loop prior to exiting through the MentF (Standring, 2015) (Figure 2.1).

Radiographically, MandF appears as a circular or oval radiolucency located within the ramus of the mandible when viewed with panoramic or CT technology but is not visible on periapical radiographs (Freny & Jaypee, 2009). There is no

discernible difference between the right and left MandF according to several studies on bilateral symmetry (Kilarkaje et al., 2005; Varma et al., 2011; LIMA et al., 2011).

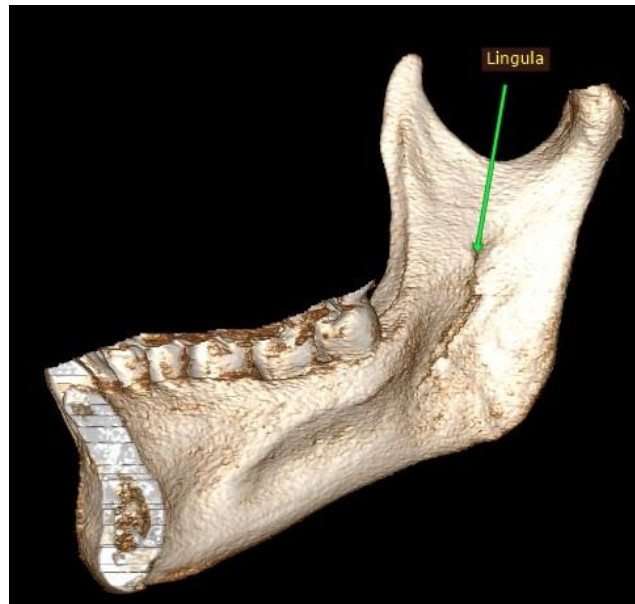


Figure 2.1: CBCT 3D rendering of the mandible, the lingula as pointed by the green arrow.

### **2.1.1 Location of Mandibular Foramen**

The location of the MandF has been ardently debated by several authors, including those who have written anatomy textbooks and academic papers. Several authors defined its location as being midway between the anterior and posterior border of the mandibular ramus (Ferris, 1929; Basmajian & Grant, 1972). In their well-known book of Gray's Anatomy, Williams and Warwick (1980) stated that the

MandF is located a little above the center of the ramus. Fabian (2005) found that the MandF is situated above the middle of the mandible on the medial surface of the ramus (upper half).

There are also a lack of consistency in determining the MandF location related to the mandibular occlusal plane. Some researchers noted MandF to be above the occlusal plane (Basmajian, 1980), while others found it to be at the same level as the occlusal plane (Rj, 1978a; Zhou et al., 2017). In an investigation on adult black Tanzanians, it was observed that the horizontal location of MandF was 20 mm and 12 mm from the anterior and posterior border of the ramus, respectively, and in the vertical location above the occlusal plane (Russa & Fabian, 2014).

A study of the Zimbabwean population revealed that MandF was at the same level as the occlusal plane in 47% of the study population, above the occlusal plane in 29% of the population, and below the occlusal plane in 24% of the population, all without bilateral differences (Mbajjorgu, 2000). The MandF was found to be below the occlusal plane in 64.6% of adult Kenyan Africans and at the level of the occlusal plane in 31.1% (Mwaniki & Hassanali, 1992). These observations showed that among African black populations, the MandF varied greatly.

### **2.1.2 Shape of Mandibular Foramen**

The MandF's shape might differ based on its contents. The shape of the MandF's orifice could be circular or even V-shaped in some persons (Friedrich et al., 2019; Nguyen & Duong, 2022).

The ossification of the mandibular canal, and consequently of the MandF, takes place around the inferior alveolar nerve, considering that this nerve penetrates in the MF anteriorly to the inferior alveolar artery and vein. In this order, the oval foramens will present their contents with a larger space between them in the horizontal plane. The opposite will occur in circular foramens, where its contents will be closer to each other (Lima et al., 2016).

### **2.1.3 Size of Mandibular Foramen**

The size of MandF, which includes measurements of width, length, and height, varies among individuals. Typically, the width ranges from 2 to 4 mm (Yu and Wong, 2008), while the length can vary between 4 and 8 mm (Jansisyanont et al., 2009; Scomparin et al., 2017). The height of the foramen usually falls within 6 to 10 mm (Noletto et al., 2010; Huang and Liao, 2016). Furthermore, the area of the mandibular foramen, which is important for surgical considerations, generally spans from 12 to 40 mm<sup>2</sup> (Sekerci, Sahman, 2014; Al-Shayyab et al., 2019). reflecting its variability among populations and individuals.

Ahn et al. (2020) documented the anteroposterior and mediolateral diameters of the MandF as 3.2 mm and 2.7 mm, respectively, while Jansisyanont et al. (2009) observed a mean anteroposterior diameter of 4.7 mm. Al-Shayyab et al., 2019; and Scomparin et al. demonstrated that there was a significant difference in the length of MandF measurements between males and females.

#### **2.1.4 Lingula**

For many MandF location measurements, the lingula was used as a reference point due to its prominent and consistent anatomical position near the MandF. The lingula is a bony protrusion in the shape of a tongue located near the posterior edge of the MandF on the medial surface of the mandibular ramus (Devi et al., 2003). (Figure 2.2). On panoramic images, the lingula appeared as an indistinct radiopacity but cannot be observed on periapical images (Freny & Jaypee, 2009; Iannucci & Howerton, 2016). In this study, the lingula was utilized to measure the position of MandF; variations in its shape and dimensions were not taken into consideration.

The lingula serves as the attachment site for the sphenomandibular ligament, which assists in protecting the passing of inferior alveolar neurovascular bundles through the MandF (Tomaszewska et al., 2019). Due to its close relation to the neurovascular bundles, the lingula offers important information during oral and maxillofacial surgical procedures, including the vertical ramus osteotomy, sagittal split ramus osteotomy, orthognathic surgery, inverted-L osteotomy, mandibular trauma management, removal of malignant and benign lesions, and pre-prosthetic surgery (Smith et al., 1991). Intraoperative complications such as nerve damage, hemorrhage, and fracture may occur if the lingula was not accurately detected (Acebal-Bianco et al., 2000). The lingula and the MandF were not directly visible during surgical procedures such as intraoral vertical ramus osteotomy, which may pose additional challenges to the procedure (Jansisyanont et al., 2009).

Many researchers have examined the location of the lingula and found that its location varies, which would explain why the IAN was not blocked following local anesthesia administration (Nicholson, 1985a). Table 2.1 summarized the location of

lingula with relation to the mandibular occlusal plane, and Table 2.2 summarized the distances of lingula to mandibular structures in different populations.

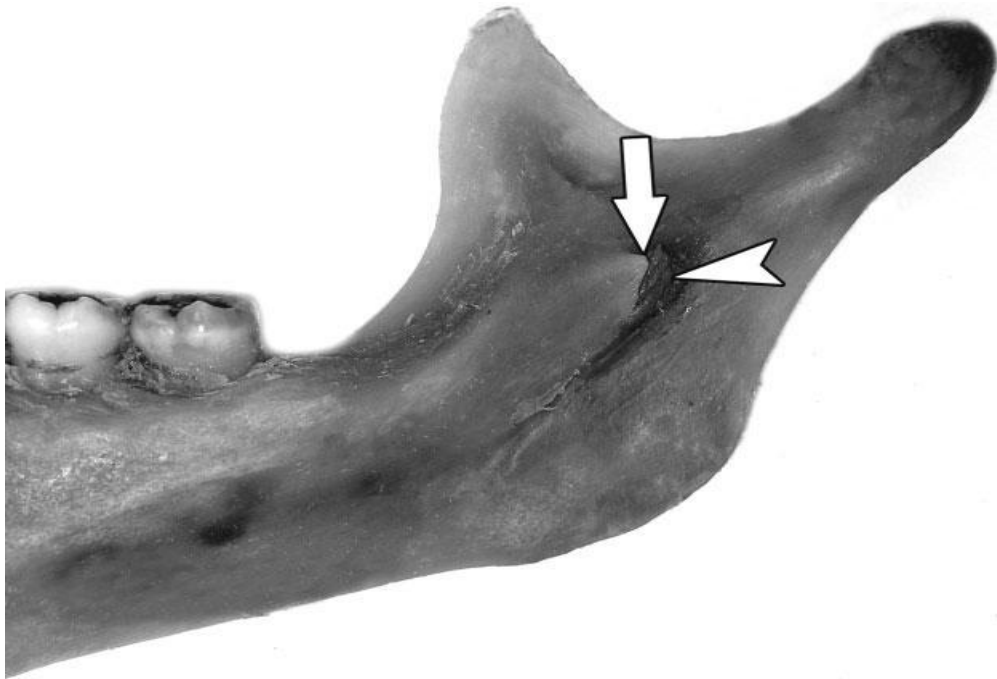


Figure 2.2 A dry mandible showing the lingula and the MandF on the medial surface of mandibular ramus (Jansisyanont et al., 2009).

Table 2.1: Percentage of the LIG at or below the occlusal plane

| <b>Author(year)<br/>reference</b> | <b>Ages<br/>(years)</b>       | <b>Study<br/>design</b> | <b>At or below the<br/>occlusal plane<br/>(%)</b> | <b>Sample<br/>size</b> |
|-----------------------------------|-------------------------------|-------------------------|---------------------------------------------------|------------------------|
| Jansisyanont<br>et al. (2009)     | 18–83                         | Dry<br>mandible         | 19.9%                                             | 92                     |
| Zhou et al.<br>(2017)             | 18–36                         | CBCT                    | 1.6%                                              | 121                    |
| Aps et al.<br>(2018)              | 6–18<br>6–9<br>10-13<br>14-18 | CBCT                    | 8.9%<br>6.1%<br>2.5%<br>0.4%                      | 280                    |

Table 2.2: Distance of lingula to mandibular structures in different populations (mm).

| Author (year) [Reference]  | Population | Gender | ML-AM |       |       | ML-PM |       |       | ML-IM |       |       | ML-MN |       |      |
|----------------------------|------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
|                            |            | Right  | Left  | Total | Right | Left  | Total | Right | Left  | Total | Right | Left  | Total |      |
| Woo et al. (2002)          | Korean     | Total  |       |       |       | 18.6  |       |       |       |       |       |       |       | 19.8 |
| Jansisyanont et al. (2009) | Thai       | Male   | 20.9  | 20.6  | 20.6  | 18.2  | 18.4  | 18.0  |       |       |       | 16.9  | 16.8  | 16.6 |
|                            |            | Female | 20.2  | 20.1  |       | 17.4  | 17.3  |       |       |       |       | 16.0  | 15.9  |      |
| Samanta and Kharb (2012)   | Indian     | Total  | 20.0  | 20.2  | 20.0  | 14.9  | 15.2  | 15.0  |       |       |       | 15.3  | 15.6  |      |
| *Monnazzi et al. (2012)    |            | Total  |       |       | 16.5  |       |       | 14.6  |       |       | 27.1  |       |       | 16.4 |
| *Sekerci and Sisman (2014) | Turkish    | Male   | 18.2  | 17.3  | 16.6  | 13.6  | 14.0  |       | 35.5  | 36.3  |       | 17.2  | 15.9  |      |
|                            |            | Female | 16.0  | 15.6  | 8     | 12.4  | 12.0  | 13.0  | 30.9  | 30.9  | 33.4  | 14.0  | 14.2  | 15.3 |
| Senel et al. (2015)        |            | Total  | 18.4  | 18.7  | 18.5  | 16.7  | 17.1  | 16.9  | 37.6  | 39.1  | 38.3  | 18.1  | 18.1  | 18.1 |
| Lima et al. (2016)         |            | Total  | 18.7  | 20.0  |       | 15.8  | 15.8  |       | 33.5  | 33.9  |       | 16.6  | 16.3  |      |
| *Zhou et al. (2017)        |            | Male   |       |       |       |       |       | 18.2  |       |       | 35.3  |       |       | 15.7 |
|                            |            | Female |       |       |       |       |       | 17.0  |       |       | 30.5  |       |       | 15.5 |
| *Aps et al. (2018)         |            | Total  | 18.0  | 18.1  |       | 14.9  | 15.0  |       | 27.2  | 27.4  |       | 15.9  | 15.5  |      |

ML-AM — mean distance between the mandibular lingula and the anterior border of the mandible; ML-PM — mean distance between the mandibular lingula and the posterior border of the mandible; ML-IM — mean distance between the mandibular lingula and the inferior border of the mandible; ML-MN — mean distance between the mandibular lingula and the mandibular notch;  
\*significance difference

### **2.1.5 Methods of studying the Mandibular Foramen**

#### **2.1.5(a) Dry mandible**

To prevent the complication of damage to the inferior alveolar neurovascular bundle during surgery, many studies have attempted to develop novel techniques to avoid damage during osteotomy of the lateral side of the ramus by using a dry mandible (Akçay et al., 2019). Many studies have also been conducted to locate the anatomical placement of the inferior alveolar neurovascular bundle in the lateral side of the ramus in order to establish the theoretical underpinnings of these surgical procedures (Akçay et al., 2019; Hsu et al., 2020; Ahn et al., 2020).

#### **2.1.5(b) Panoramic radiographs**

Panoramic radiographs may help clinicians in administering the inferior alveolar nerve block by providing information about the location of the MandF, as the anesthetic solution should be deposited around the inferior alveolar nerve (IAN) prior to entrance in the foramen. Accurate knowledge of the location of the foramen may reduce the possibility of an unsuccessful injection (Tuli et al., 2000; Acebal-Bianco et al., 2000).

#### **2.1.5(c) Computed Tomography and Cone Beam Computed Tomography**

Advancements in imaging methods have prompted scientists to perform anatomical research based on cone beam computed tomography (CBCT) reconstructions. Considering the three-dimensional aspects of the image, CBCT offers better data compared to two-dimensional orthopantomography (Dalili et al., 2011; Kapila et al., 2014; Peker et al., 2014). The radiation exposure is comparatively less than multi-slice computed tomography (Dalili et al., 2011; Patel et al., 2014; Scarfe, 2019).

The rise in diagnostic imaging for oral implant assessment explains the high interest in morphometrical assessments of several imaging procedures. CT software allows for the assessment of dental implant candidates, offering radiologists a straightforward approach to evaluating pathological and anatomical aspects concerning the mandible. Computer-based reformatting software uses CT imaging to provide accurate cross-sectional images of the mandible and maxilla for oral implant and surgery candidates for maxillary or mandibular arches (Bodard et al., 2008). CT imaging provides a better assessment of the osseous mandible and maxilla, allowing better outcomes concerning numerous neck and head surgeries (Boeddinghaus & Whyte, 2008). Dental CT reformatting software is the current state-of-the-art for assessing jaw lesions and patients with oral implants (Friedland et al., 2008).