# THREE-DIMENSIONAL MORPHOMETRIC ANALYSIS OF MANDIBULAR FORAMINA: A CONE BEAM COMPUTED TOMOGRAPHY STUDY COMPARING MAHAJIR AND PUKHTOON ETHNICS IN PAKISTAN

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**UNIVERSITI SAINS MALAYSIA**

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# THREE-DIMENSIONAL MORPHOMETRIC ANALYSIS OF MANDIBULAR FORAMINA: A CONE BEAM COMPUTED TOMOGRAPHY COMPARING MAHAJIR AND PUKHTOON ETHNICS IN PAKISTAN

**by**

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| | |
|---|---|
| 1M | 1st molar |
| 2D | Two-dimensional |
| 3D | Three dimenisonal |
| 3M | Third molar |
| A to B | From point A to B |
| AC | Alveolar crest |
| AMdF | Accessory Mandibular Foramen |
| AMtF | Accessory Mental Foramen |
| AM | Angle of mandible |
| MM | Menton of mandible |
| AntM | Anterior border of mandible |
| AY | Asilah Yusof |
| BFA | Beenish Fatima Alam |
| CM | Condyle of mandible |
| CoM | Coronoid process of Mandible |
| CT | Computed Tomography |
| CBCT | Cone beam-computed tomography |
| FoV | Field of View |
| GT | Genial Tubercle |
| InfM | Inferior border of mandible |
| IAN | Inferior Alveolar Nerve |
| IIT/CCD | Image intensifier tube/charge-coupled device |
| IVRO | intraoral vertical ramus osteotomy |
| LAMdF | Left accessory mandibular foramen |
| LF | Lingual foramen |
| LLF | Lateral lingual foramen |
| LN | Lingual nerve |
| LM | Lingual border of mandible |
| LMdF | Left mandibular foramen |
| LMtF | Left mental foramen |
| MdF | Mandibular Foramen |
| MtF | Mental Foramen |
| MLF | Midline lingual foramen |
| MM | Menton of mandible |
| MN | Mandibular notch of mandible |
| OPG | Orthopantomographs |
| ParaMLF | Paramedian lingual foramen |
| ParaMLLF | Paramedian left lingual foramen |
| ParaMRLF | Paramedian right lingual foramen |
| PM1 | 1ST mandibular premolar, |
| PM2 | 2nd Mandibular premolar |
| PostLF | Posterior lingual foramen |

| | |
|---|---|
| PostLLF | Posterior left lingual foramen |
| PostM | Posterior border of mandible |
| PostRLF | Posterior right lingual foramen |
| RAMdF | Right accessory mandibular foramen |
| RAMtF | Right accessory mental foramen |
| RMdF | Right mandibular foramen |
| RMtF | Right mental foramen |
| SSRO | sagittal split ramus osteotomy |
| SPSS | IBM Statistical Package for the Social Sciences |
| 1M | $1^{st}$ molar |
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| RMtF | Right mental foramen |
| SSRO | Sagittal split ramus osteotomy |
| SPSS | IBM Statistical Package for the Social Sciences |

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# ANALISIS MORFOMETRIK TIGA DIMENSI FORAMINA MANDIBULAR: KAJIAN PERBANDINGAN ANTARA ETNIK MAHAJIR DAN PUKHTOON DI PAKISTAN MENGGUNAKAN TOMOGRAFI BERKOMPUTER ALUR KON

## ABSTRAK

Untuk mengurangkan risiko kecederaan saraf alveolar inferior, pemahaman menyeluruh tentang mercu tanda antropometri pada mandibel dan aplikasi klinikalnya adalah perlu, sebelum melakukan sebarang prosedur pembedahan. Tomografi berkomputer alur kon (CBCT) ialah alat diagnostik yang diiktiraf secara meluas yang menghasilkan imej berkualiti tinggi, tepat, dan membantu dalam mengenal pasti lokasi tepat komponen anatomi mandibel. Ia telah digunakan sebagai instrumen untuk memudahkan perancangan praoperasi prosedur pembedahan. Kajian ini bertujuan untuk mengenal pasti foramina yang terletak pada permukaan mandibel, dan untuk menentukan bilangan, bentuk, klasifikasi, dimensi, kedudukan, dan jarak ke pelbagai mercu tanda anatomi. Objektif lain adalah untuk menentukan perkaitan lokasi foramina mandibel dengan badan mandibel dan ketinggian dan lebar ramus antara jantina, antara sisi kanan dan kiri, dan antara kumpulan etnik Mahajir dan Pukhtoon di Pakistan. Bahan dan Kaedah: Empat ratus CBCT daripada populasi Pakistan Mahajir dan Pukhtoon telah dikumpulkan dari Institut Pergigian Khans, Karachi dari 2016 hingga 2021. Pengimejan CBCT telah dijalankan menggunakan mesin New Tom VGi (NewTom Co., Ltd., Shawnee, Itali). Pemprosesan imej dan analisis morfometrik foramina mandibel telah dijalankan menggunakan perisian MIMICS (Materialise, Belgium). Analisis statistik dilakukan menggunakan Pakej Statistik untuk Sains Sosial (SPSS), versi 28.0 (IBM SPSS Statistics, Armonk, NY, USA). Keputusan penyiasatan menunjukkan bahawa foramen lingual garis tengah adalah bentuk yang paling biasa.

Etnik Pukhtoon mempunyai dimensi foramen lingual yang lebih besar secara keseluruhan, manakala lelaki mempamerkan ukuran yang lebih besar dari segi saiz. Kumpulan etnik Pukhtoon mempamerkan jarak yang lebih jauh dari mercu tanda ke foramen lingual. Bentuk foramen mental yang paling lazim adalah bulat. Dari segi saiz dan jarak ke mercu tanda, etnik Pukhtoon menunjukkan ukuran yang lebih panjang daripada foramen mental. Lokasi mendatar yang paling tipikal adalah di sebelah premolar kedua, dan kedudukan menegak yang paling kerap diperhatikan adalah apikal ke hujung akar gigi. Bentuk bulat adalah yang paling biasa untuk foramen mental aksesori manakala bentuk tidak sekata dan bujur lebih lazim pada kedua-dua belah foramen mandibular aksesori. Selain itu, bentuk bujur diperhatikan lebih lazim di sebelah kanan dan kiri foramen mandibular. Begitu juga, dimensi foramen mandibular dan foramen mandibular aksesori dan jarak ke mercu tanda diperhatikan lebih besar dalam etnik Pukhtoon. Korelasi yang lemah tetapi positif telah dikesan antara foramen mandibular dengan lebar ramus, ketinggian ramus dan panjang badan mandibel. Kajian ini memberikan pandangan yang berharga dan nilai rujukan klinikal mengenai dimensi dan jarak ke mercu tanda anatomi untuk semua foramina mandibular untuk etnik Mahajir dan Pukhtoon di Pakistan serta mengikut jantina dan sisi yang berbeza, yang berpotensi berguna semasa penilaian pra-pembedahan mandibel.

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## ABSTRACT

A thorough understanding of the anthropometric landmarks on the mandible and their clinical application is necessary, before performing any surgical procedure to reduce the risk of inferior alveolar nerve injury. Cone bean computed tomography (CBCT) is a widely recognised diagnostic tool that generates high-quality, accurate images and assists in identifying the precise location of anatomical components. It has been utilised as instruments for facilitating preoperative planning of surgical procedures. This study aimed to identify the foramen located on the surface of mandible, and to determine their number, shape, classification, dimensions, position, and their distance to various anatomical landmarks. Another objective is to determine the association of mandibular foramen location with mandibular body and ramus height and length between sexes, between right and left sides, and between Mahajir and Pukhtoon ethnic groups of Pakistan. Four hundred CBCT from Mahajir and Pukhtoon Pakistani populations were collected from Khans Dental Institute, Karachi from 2016 to 2021. CBCT imaging was carried out using the New Tom VGi machine (NewTom Co., Ltd., Shawnee, Italy). Image processing and morphometric analysis of the mandibular foramina was conducted using MIMICS software (Materialise, Belgium). Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 28.0 (IBM SPSS Statistics, Armonk, NY, USA). The results of this investigation showed that midline lingual foramen was the most common form. Pukhtoon ethnicity had larger lingual foramen dimensions overall, while males exhibited larger measurements in terms of size. The Pukhtoon ethnic group exhibited a greater distance from landmarks to lingual foramen. The most prevalent shape of mental foramen was round. In terms of size and distance to landmarks, Pukhtoon showed longer measurements from mental foramen. The most typical horizontal location was next to the second premolar, and the most frequently observed vertical position was apical to the tooth's root apex. The round shape was the common for accessory mental foramen while irregular and oval shapes were more prevalent on both sides of accessory mandibular foramen. Additionally, oval shapes were observed to be more prevalent on the right and left side of mandibular foramen. Similarly, the mandibular foramen and accessory mandibular foramen dimensions and distance to landmarks were observed to be greater in Pukhtoon ethnicity. A weak but positive correlation was detected between mandibular foramen with ramus width, height, and length of the mandibular body. This study provided valuable insight and clinical reference values regarding dimensions and distances to anatomical landmarks of all foramina of the mandible for the Mahajir and Pukhtoon ethnicity in Pakistan as well as according to different sexes and sides, which potentially be useful during pre-surgical evaluation of the mandible.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

The mandible functions as a complicated three-dimensional (3D) landmark with a distinctive U-shape structure that characterises the facial contour of an individual and dynamically influences the external projection and symmetry of the lower face (Schrag et al., 2006; Heffelfinger et al., 2008). Additionally, it is crucial for chewing, swallowing, speech articulation, and preserving the competence of the upper airway (Alalawy & Abdulnabi, 2022). Therefore, surgical procedures involving the mandible present considerable complexity, creating challenging situations for the treating surgeon.

Orthognathic surgical procedures address patients with severe skeletal discrepancies with the aim to enhance their skeletal and aesthetic relationship (Von Arx et al., 2013). Understanding of anatomical structures is paramount in these procedures as it enables surgeons to navigate complex facial anatomy, minimising potential risks and complications, and promotes long-term positive outcomes. Similarly, this knowledge is also important for implant procedures. Often a variety of augmentation procedures are required to regenerate adequate bone volume for the placement of endosseous implants. This is usually associated with severe loss of the alveolar ridge following tooth loss. Accurate and comprehensive evaluation of the mandible will assist surgeons to determine the type of implant, as well as the surgical approach to be employed (Kawai et al., 2006).

Due to sufficient bone density and lack of important neurovascular structures, the anterior mandible has been regarded as a safe position for performing surgical procedures (Kawai et al., 2006; Rosano et al., 2009). One of these is the mandibular symphysis, which serves as an appropriate choice for autologous donor grafts and for placing overdentures or fixed partial dentures (Dreiseidler et al., 2009). Recent studies have shown that, despite being regarded as a safe area for implants and other surgical procedures, perforation of the lingual cortex during surgical placement of implants and other surgical procedures could result in life-threatening hemorrhage and hematoma formation on the floor of mouth due to injury to the blood vessels of the mandibular lingual foramen (Niamtu III, 2001; Nuri Mraiwa et al., 2003).

Additionally, identifying the surgical difficulty associated with third molar extraction is an important step in developing a treatment strategy which balances the benefits and drawbacks of the surgical treatments. Assessment of mandibular foramen (MdF) and canal is important for third molar extraction to plan the appropriate surgical intervention and minimize the likelihood of postoperative pain and bleeding (Rosano et al., 2009). Moreover, accessory canals, if they are not identified preoperatively, could result in iatrogenic surgical damage to the neurovascular bundles and could lead to failure of delivering local anesthesia. Unexpected intraoperative hemorrhage or postoperative paraesthesia in the innervated area may further complicate the procedure (Zeltner et al., 2016).

Considering the reasons listed above, it is essential to understand the mandibular architecture, including the position, course, and origin of the neurovascular bundle, as well as any deviations present. Digital imaging technology has recently made it easier for surgeons to visualise the area of interest (Logan et al., 2013). Concentrating on thorough understanding the mandibular foramina's position as well as its anatomical variations, such as the major and accessory foramina, could help with surgery and protects the patient against unforeseen circumstances (Von Arx et al., 2013). These include the lingual foramen, mental foramen and its accessory as well as the mandibular accessory foramen and its accessory.

**The lingual foramen (LF)** is characterised as tiny openings in the mandibular lingual area, positioned either above or below the mental spines, near the middle aspect of the mandible (Sheikhi et al., 2012). They may be visible on orthopantomograph (OPG) as minute radiolucent openings, present 10 mm below the apices of the mandibular incisors. It could be quite challenging to detect the LF with conventional imaging owing to its variable size. LF typically has a diameter of 1-2 mm but may vary with respect to location, number, and length (Choi et al., 2013; von Arx & Lozanoff, 2017; Sanchez-Perez et al., 2018; Barbosa et al., 2022). The branches of the sublingual and submental arteries passes through the LF. Clinically, imaging investigations involving LF should be properly investigated, primarily due to surgical complications associated with procedures carried out in the regions adjacent to LF, that can lead to perforation of the lingual cortex and damage to the sublingual and submental arteries, causing extensive hemorrhage (Barbosa et al., 2022).

**Mental foramen (MtF)** is a funnel-shaped opening located on the mandible's lateral surface, either in close approximation to the second premolar or in between the two premolars. MtF is an important anatomical landmark which needs to be taken into consideration during various procedures such as administering local anaesthesia, creating incisions, positioning of the implants, performing periapical operations, and helps execute osteotomies on the lateral surface of the mandible ( Phillips et al., 1990; Apostolakis & Brown, 2012). Injury to the mental nerves can cause sensory dysfunction in the skin of chin, labial mucosa, and lower lip (Iyengar et al., 2013; Von

Arx et al., 2013). Studies have shown that placement of implants in the premolar region could lead to both short-term and long-term sensory disruptions in the perioral soft tissue (Wismeijer et al., 1997; Ritter et al., 2012). Hence, it is of the utmost significance to locate MtF accurately to prevent damage to the mental nerve.

**Accessory mental foramen (AMtF)** is present in the close vicinity to MtF, but its location and morphology has not been clearly demarcated (Katakami et al., 2008; Naitoh, Nakahara, et al., 2009; Chen et al., 2013). AMtF is quite smaller than MtF in dimensions and is connected with the mental nerve, which is assumed to be the branch of the mental nerve which emerges from the MtF (Fuakami et al., 2011). This additional branch of mental nerve which arises from the AMtF innervates the skin at the corner of lips, mucous membrane of cheeks, and lower lip (Kaufman et al., 2000). The existence of this extra branch could also explain why pain still persists following neurectomy of the mental nerve, which acts as one of the trigger points for trigeminal neuralgia (Gumusok et al., 2017). Furthermore, an anterior location of AMtF relative to MtF could also be re-entry point of mental nerve into the mandible, which then innervates the incisors (crossed innervation) (Khan et al., 2014; Gumusok et al., 2017). Prior to commencing any surgical procedures, AMtF identification may help reduce the possibility of problems which includes bleeding, discomfort after surgery (Aytugar et al., 2019).

**Mandibular foramen (MdF)** is an anatomical landmark situated at the mandibular canal's opening, located on the lingual aspect of the mandible. The inferior alveolar nerve (IAN) and its blood vessels passes from the mandibular canal innervating and supplying the mandibular teeth. This neurovascular bundle later divides into incisive and mental branches, and sometimes involved in the formation of the anterior loop

(Juodzbalys et al., 2010; Rodella et al., 2012). Moreover, the most common anesthetic procedure of the mandible is IAN block. It has been reported that this anaesthetic technique could fail as often as 20 –25%. The most prevalent cause of failure being inaccurate localisation of MdF (Yu et al., 2015). Additionally, hemorrhage, injury to the neural component, bony fractures, and mandibular ramus destruction are the main risks factors associated with surgical procedures in this region (Oguz & Bozkir, 2002; Shah et al., 2013).

**Accessory Mandibular Foramen (AMdF),** in this context denotes an additional foramen located in close proximity to the MdF (Gunduz et al., 2019). It was reported to differ in size and number, and frequently identified to occur bilaterally. Lack of knowledge regarding these anatomical variations may have detrimental effects and may contribute towards anaesthetic failure during surgical procedures (Przystańska & Bruska, 2012).

**Human sexual dimorphism**

In the field of forensics, determining gender using fragmented skeletal remains is of utmost importance. It serves as vital step in forensic anthropology for developing biological profiles and artistically recreating facial characteristics from an unidentified skeleton to determine its identity (Kieser & Groeneveld, 1986; Saini et al., 2022). Due to its size, strength, dimorphism, and likelihood of retrieval in forensic and archaeological investigations, the mandible is regarded as the most significant bone in the skull. Numerous studies have been conducted on mandible to analyse population variance among different races. Studies showed that both sexes experience distinct levels of stress over time, which could result in intra- and interpopulation variation with respect to mandibular morphological characteristics (Saini et al., 2022).

Sexual dimorphism of the mandible is particularly significant in a clinical context, as it plays a crucial role in influencing diagnoses and treatment planning. Understanding these distinctions is essential for orthodontists, oral surgeons, and other dental professionals in providing tailored and effective care, particularly in orthognathic procedures or prosthodontic interventions. This observation could also extend to the assessment of size, shape, and spatial positioning of the mandibular foramina (Koju et al., 2021).

**Right and left side differences**

The mandible typically exhibits bilateral symmetry, meaning that the right and left sides are similar. However, subtle differences between the right and left sides could occur, especially due to factors like tooth eruption patterns, injuries, or developmental issues (Srivastava et al., 2018) These differences are often small and may not significantly impact overall function. For instance, slight differences in the length and height of the ramus between the two sides were observed (Saini et al., 2022) These differences can be relevant in dental and orthodontic assessments, as well as in surgical procedures such as orthognathic surgery. Indeed, assessment of the mandibular foramina may reveal side differences in terms of their size, shape, and position, and can have implications for dental procedures.

**Pakistan** is a highly diverse country in terms of its ethnic and linguistic composition. The estimated population of Pakistan is approximately 204.65 million (Abid et al., 2020). Pakistan's population is composed of five main ethnic groups: Mahajir, Pukhtoon, Sindhi, Baluchi, and Punjabi (Kukreja, 2020). Following the 1947 partition, millions of people moved from India to Pakistan resulting in Karachi's population to increase considerably. The vast majority of Muslims from India relocated to Sindh, while many Mahajir Muslims moved west to reside in Punjab, Pakistan. Due to this, Karachi became a distinct city, different from the rest of Pakistan with respect to its demographic, racial, and cultural context. The term Mahajir in Pakistan specifically referred to individuals who migrated from various cities in India to settle in Sindh. (Shah & Sareen, 2019).

The Pukhtoon are ethnic group that resides in both Afghanistan and Pakistan. They are the second biggest ethnic group in Pakistan, accounting for 15% of the population and primarily concentrated in the province of Khyber Pakhtoon Khuwa (Yousaf, 2019). This study will concentrate on the Mahajir ethnic group, which mostly resides in the province of Sindh, and the Pukhtoon ethnic group, which are largely located in the province of Khyber Pukhtoon Khuwa.

Prior investigations have identified anatomical variations in numerous ethnic populations with respect to the differences identified in the position of the various foramina present in the mandible. Henceforth failure to identify them correctly during surgical procedures could lead to many complications (Neves et al., 2014). Similarly, adequate comprehension of the anatomical positions of mandibular foramina such as MtF is critical in evaluating morphometric analysis of the mental triangle, along with the morphological concepts and maturity of human mandible, remodelling of bone activity, and paleoanthropological characteristics of the facial skeleton among various populations (Ngeow & Yuzawati, 2003).

Badshah et al. (2016) assessed dried mandibles at a number of medical institutions in Khyber Pukhtoon Khuwa, region. These mandibles which had been examination were Caucasian in origin. Authors used digital caliper to determine their size, location, and position of MtF and AMtF (Badshah et al., 2016). Another study by Shah et al. (2017)

had analysed 200 CBCT images and measured their number, location, and distance from MtF to various landmarks. The ethnic background of the research participants was not specified in this study (Shah et al., 2017). Moreover, no prior research investigations conducted in Pakistan have examined the lingual, mandibular, and accessory mandibular foramen, and similarly, the ethnic background of the participants has not been documented.

Numerous investigations made use of dried human skulls, conventional radiography, conventional CT scans, as well as cephalometric radiography to investigate the morphology of the foramina of the mandible (Ghandourah et al., 2023). Radiography is a widely used non-invasive technique in detecting and planning major mandibular surgical procedures. Panoramic radiographs are one of the common tools for diagnosis, screening, and determining the most appropriate surgical strategy. Compared to intraoral radiography, panoramic radiographs have several benefits. They can view adjacent regions and encompass a wider range of hard and soft tissue, making it feasible to identify the MtF and MdF in the vertical and horizontal dimensions with greater accuracy (Izzetti et al., 2021). Periapical images on the other hand, are unable to identify the exact location of the mental foramen due to their limited field of view (Aminoshariae et al., 2014).

More currently, CBCT has become widely recognized diagnostic tool that not only generates high-quality, accurate images yet also assists in identifying the precise location of anatomical components (Jacobs et al., 2018). It creates high-resolution 3D images with minimum radiation exposure. CBCT offers multi-plane dynamic navigation, data enhancement through contrast and brightness adjustments, and volume parameter modifications that include the thickness of slices and sliced interval.

This diagnostic approach may be applied in a variety of clinical purposes as well as research considering its improved specificity and sensitivity in relation to hard tissue as opposed to 2D scanning. Endodontics, surgery, implantology, orthodontics, periodontics, temporomandibular disorders, and imaging for diagnostic purposes have all reaped multiple clinical advantages of CBCT (Bueno et al., 2018). Furthermore, the significant reduction in overlapping anatomy obtained through imaging across multiple planes (coronal, axial, sagittal, and oblique) alongside its superior resolution and higher contrast distinguishes this imaging technique from others. Finally, using a map-reading method with CBCT images could minimise the issues related to complicated assessment situations, such as ambiguous situations which require special attention during diagnosis Several studies have found great accuracy with CBCT for assessing several anatomical features, with no statistically significant disparities between CBCT and real measurements (Estrela et al., 2017).

Numerous CBCT equipment has been created by various manufacturers, each equipped with unique software. Companies such as CDT software (Bauru, SP, Brazil) developed the e-Vol DX software which catered to the growing need for high-quality images, visualization of complex anatomical components, precise identification of occult lesions (potentially undiagnosed), and artefact elimination (Bueno et al., 2018). Care stream Dental created CS 3D Imaging Software (Assari et al., 2017), whereas Planmeca in Helsinki, Finland created Romexis® digital imaging software (Salemi et al., 2021).

These CBCT software were able to import and handle DICOM files. DICOM is an acronym that stands for Digital Imaging and Communications in Medicine. Requirements for messaging and communications all imaging devices could be merged and visualized in a single digital file system that can be accessed through a specific software program (Mamdouh et al., 2020). This file may be utilized for holding technical acquisition data, dates, and patient clinical information, and it may be converted to an STL format for creating 3D models.

Several researchers used Romexis® digital imaging tools to assess the CBCT images. Mirhosseini et al. (2019) employed CBCT to assess the morphology of lower incisors using Romexis® software (Mirhosseini et al., 2019). Similarly, Kuzekanani et al. (2020) Baltacıoĝlu et al. (2016) and Kalender et al. (2012) also used Romexis® software to analyze CBCT datasets (Kalender et al., 2012; Baltacıoĝlu et al., 2016; Kuzekanani et al., 2020). For the current study, Materialise Interactive Medical Image Control System/MIMICS software (Materialise, Belgium) was chosen to create and analyse 3D images from CBCT. Several previously conducted studies have used MIMICS software for detection of dental age, foreign body, and root reconstruction (Asif et al., 2018; Wang et al., 2018; Asif et al., 2019).

Therefore, the aim of this research was to evaluate the various anatomical foramens present in the mandible with the help of CBCT and MIMICS software prior to various pre-surgical procedures within the Mahajir and Pukhtoon ethnicities of Pakistan and to assess their differences between genders and between the right and left sides.

### 1.2 Problem Statement

Based on the literature search, none of the previously conducted research in Pakistan has focused on evaluating the various foramina present on the mandible within different ethnic groups of Pakistan namely the Mahajir and Pukhtoon ethnicities prior to surgical procedures. So far, Ahmed et al. (2019) had examined the location of MtF with mandibular teeth and the development of the foramen, along with the prevalence of AMtF, although the ethnic origin of the study participants was not stated (Ahmed et al., 2019). Similarly, Shah et al. (2017) investigated the prevalence of MtF and its position on the mandible whereas Rehman et al, (2015) investigated the size, shape, and incidence of MtF and the number of AMtF utilising dry mandible.(Rehman et al., 2015; Shah et al., 2017) None of these prior studies have recorded the ethnicities of the study subjects.

### 1.3 Justification of the research

The lack of prior research focusing on the evaluation of foramina present in the mandible within distinct ethnic groups in Pakistan, such as the Mahajir and Pukhtoon ethnicities, emphasises the need for targeted investigations. Recognising potential ethnic variations in the anatomy of the foramina present in mandible is crucial for improving surgical precision and minimising adverse effects, as anatomical differences can impact the surgical outcomes and patient care. This knowledge is valuable in the evaluation and therapeutic planning of patients undergoing orthodontic treatment, maxillofacial, orthognathic, plastic, and reconstructive procedures, implantology, local anaesthesia administrations as well as forensic sciences.

This research also emphasised on assessing the presence and characteristics of the LF, AMtF and AMdF. Previously, these structures have received limited attention. Understanding the variations in the occurrence and morphology of these accessory foramina is crucial for clinicians, especially in oral surgery and dental implantology, as these structures can impact the distribution of nerves and blood vessels. By incorporating an investigation of accessory foramina alongside ethnic considerations, the research aimed to offer a more comprehensive understanding of mandibular anatomy, providing valuable information for pre-surgical assessments and enhancing the safety and efficacy of clinical procedures.

## 1.4 Objectives of the study

### 1.4.1 General objective

To study the number, size, shape, positions, and distances of different foramina present on mandible to various landmarks and to compare their differences between Mahajir and Pukhtoon ethnic groups of Pakistan, between sexes and between the right and left sides.

### 1.4.2 Specific Objectives

1. To determine and compare the number, classification, dimensions, distances to landmarks, direction of travel, and type of LF canal between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

2. To determine and compare the shape, dimensions, distances to landmarks, vertical and horizontal position of MtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

3. To determine and compare the shape, dimensions, and distances to landmarks of AMtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

4. To determine and compare the shape of MdF and its lingula, dimensions, and distances to landmarks between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

5. To determine and compare the shape, dimensions, and distances to landmarks of AMdF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

6. To determine the association of MdF with ramus width, ramus height, and body of mandible.

### 1.4.3 Research Questions

1. Is there any difference in the number, classification, dimensions, distances to landmarks, direction of travel, and type of canal of LF between Mahajir and Pukhtoon ethnicities, between sexes and between the left and right sides?

2. Is there any difference in the shape, dimensions, and distances to landmarks, vertical and horizontal position of MtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides?

3. Is there any difference in the shape, dimensions, and distances to landmarks of AMtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides?

4. Is there any difference in the shape of MdF and its lingula, dimensions, and distances to landmarks between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides?

5. Is there any difference in the number, shape, dimensions, and distances to landmarks of AMdF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides?

6. Is there any association of MdF with ramus width, ramus height, and body of mandible?

### 1.4.4 Research Hypotheses

1. There is no difference in the number, classification, dimensions, and distances to landmarks, direction of travel, and type of LF canal between Mahajir and Pukhtoon ethnicities, between sexes and between the left and right sides.

2. There is no difference in the shape, dimensions, and distances to landmarks, vertical and horizontal position of MtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

3. There is no difference in the shape, dimensions, and distances to landmarks of AMtF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

4. There is no difference in the shape of MdF and lingula, dimensions, and distances to landmarks between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

5. There is no difference in the number, shape, dimensions, and distances to landmarks of AMdF between Mahajir and Pukhtoon ethnicities, between sexes, and between the left and right sides.

6. There is no association of MdF with ramus width, ramus height, and body of mandible.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The mandible is a symmetrical, unpaired bone which is situated in the lowermost aspect of the face. It has a horseshoe-shaped body and two rami which extend from the posterior aspect of the body towards the cranium (Alves & Deana, 2016). During the sixth week of the intrauterine period, the first branchial arch begins to develop around Meckel's cartilage, marking the exact position of the future bone. The mandible forms through intramembranous ossification around the Meckel's cartilage which act as a template. During the first year of life, the mandible fuses in the region of the mandibular symphysis, and symphysis normally disappears by the age of 18 years (Lipski et al., 2013).

The foramina of the mandible forms as a part of intricate developmental process of the mandible. As the mandible undergoes intramembranous ossification, specific foramina begin to take shape as well. These foramina serve as passageways for nerves and blood vessels and contribute towards the vascularisation and innervation of the mandible. The foramina present within the mandibular bone comprise of LF, MtF, AMtF, MdF, and AMdF. Anatomical variations of these foramina have clinical implications, and if not recognized beforehand, could complicate clinical dental practice (Claeys & Wackens, 2005).

Meticulous clinical and radiological investigation of the mandible and its foramina must be assessed pre-operatively when surgical procedures are planned which includes implant placement, periodontal surgery, and orthognathic surgery. Additionally, the presence and variability of these foramina have been associated with challenges in anesthesia administration, particularly contributing to failures during IAN blocks (Sawyer & Kiely, 1991). Awareness of the location and morphology of these foramina is crucial and must be taken into consideration, as it would enhance the accuracy and efficacy of nerve blocks and other procedures involving the mandible, ultimately ensuring patient safety and optimal clinical outcomes.

## 2.2 Surgical procedures requiring anatomical knowledge in dentistry.

A thorough understanding of anatomical structures is necessary for a variety of surgical procedures used in dentistry to ensure the optimal outcomes. Some examples of these procedures are as follows:

**Dental Implants**

Dental implants have become tremendously common over the years for replacing missing teeth. The anterior mandible is of special relevance in implant therapy because it replaces the mandibular incisors, which are gets lost due to periodontal disease (Padhye et al., 2023; Tanner et al., 2005). The mandibular anterior bone is considered as the most appropriate region for placing implants to support overdentures (Meijer et al., 2009). The blocks from the mandibular symphysial area are frequently removed for autogenous grafts to be used for ridge augmentation surgeries (Safi et al., 2021). Given the significance of the mandibular anterior area, surgical difficulties could be avoided by having a thorough understanding of the anatomical landmarks (Padhye et al., 2023). In the same context, inadequate alveolar bone height in the mandible is a common problem faced during placement of  dental implants (Kim et al., 2023). This insufficiency has led to development of several therapeutic techniques, which includes guided bone regeneration, block bone grafting, and the use of implants with short lengths (Lemos et al., 2016). These methods aim to improve the alveolar ridge and create an environment that is conducive for implantation. However, the aforementioned techniques may not be feasible in situations where the IAN is positioned superiorly, when dental crowns cannot be placed at a sufficient height, or when the mental nerve and neighboring teeth prevent vertical augmentation (Terheyden et al., 2021).

Knowing the anatomy of the region where the implants are to be placed is crucial. The planning and placement of the implant needs a thorough analysis of the regional neurovascular supply. It is important to comprehend the various consequences that may occur in case of damage to the neurovascular bundles. One such consequence is uncontrollable bleeding due to damage to the artery. If the situation is not well managed, this complication could get lethal (Vyas & Tadinada, 2023).

**Orthognathic Surgery**

This surgical procedure involves repositioning the maxilla and mandible to correct functional and aesthetic issues associated with bite discrepancies and facial harmony which requires detailed anatomical knowledge of the facial skeleton (Verhelst et al., 2020). The pretreatment approach entails using both manual model surgery and conventional two-dimensional (2D) imaging. However, this method has its limitations because 2D images are unable to accurately depict the three dimensional (3D) structures, particularly in the case of patients with significant facial asymmetry or deformity (Alkhayer et al., 2020). Unexpected complications may include bony collision in the ramus of the mandible, variations in movements, midline disparities, and incorrect chin positioning which could happen when conventional radiography has been used (Xia et al., 2009). In comparison to Lateral cephalometry, CBCT has been observed to be more reliable, accurate and generates images without overlapping anatomy (Cattaneo et al., 2008). Recently, CBCT has become essential for monitoring and evaluating orthognathic surgery. Preoperative information can be used to plan 3D simulated surgeries and postoperatively to examine stability, remodeling, and accuracy (Xia et al., 2009).

Although several different methods have been proposed, sagittal split ramus osteotomy (SSRO) is the most common form of mandibular osteotomy. Other treatments used to improve the stability and postoperative function of the mandibular bone included reverse L osteotomy, horizontal osteotomy, and minor modified techniques. Among these, intraoral vertical ramus osteotomy (IVRO) is considered as an important surgical procedure. IVRO is a well-known uncomplicated treatment that assists in reducing the incidence of IAN injury following surgery and, according to earlier findings, has reduced detrimental impacts on condylar function after surgery (Goda et al., 2015).

**Maxillofacial trauma procedures**

Surgical interventions for facial fractures and trauma require surgeons to navigate complex structures to restore facial function and aesthetics, addressing fractures in the mandible, maxilla, and surrounding bones with precision. It has been thought that the region located in the floor of mouth and its surroundings are considered to be safe for carrying out surgical treatments, despite the presence of complicated vascularisation (Taschieri et al., 2022). Evidently, this misconception is supported by the numerous reports of major bleeding episodes which have occurred in this area following placement of implants (Kalpidis & Setayesh, 2004; Del Castillo-Pardo de Vera et al., 2008; Blanc et al., 2021). These situations could pose a major risk to individuals, even though they're relatively rare given the overall number of implants inserted and other surgical procedures executed. An accurate anatomical understanding of the vascularisation of the interforaminal region and an extensive pre-operative radiological assessment of the variation of the landmarks are consequently essential to prevent potentially fatal complications from arising (Taschieri et al., 2022).

**Third molar surgical extractions**

The most frequent procedure carried out by oral surgeons is the surgical extraction of the third molars. Initial preoperative assessments must critically assess the third molar's form and its relationships with surrounding tissues, especially the distance from the mandibular canal, which should be evaluated to determine the appropriate surgical methods (Nakamori et al., 2014). Patients may experience severe neurosensory impairments following the extraction of the mandibular third molar, particularly when the lingual nerve (LN) and IAN are injured. If the third molar is either entirely or partially impacted in the alveolar bone, bone removal and tooth sectioning will be required. These medically invasive treatments may result in oedema, postoperative discomfort, and restricted mouth opening or movement due to muscular spasms (Leung & Cheung, 2011).  The age of the patient increases the risk of damage due to higher prevalence of dental hypercementosis, decreased bone flexibility, and technical problems during surgery. Furthermore, aging could attribute towards decreased capacity to repair damaged nerve fibres. The chance of developing pathological osteomyelitis surrounding the impacted tooth is significantly increased in older individuals who exhibits signs of sclerotic changes (Miyamoto et al., 2013). According to Nakagawa et al. (2007) female patients had reduced buccolingual mandibular thickness, which places them at a higher risk of IAN injuries. A narrower mandible has a greater likelihood of injury as there is less room between the third molar and mandibular canal. Tooth angulation, the presence of distal overhang, and the degree of impaction are additional anatomical risk factors for surgical-related injuries (Nakagawa et al., 2007).

The damage to the IAN is one of the most serious side effects of intraoral surgical operations (Juodzbalys et al., 2013). Anaesthesia, paresthesias and dysesthesias are some of the common symptoms of damage to the nerve. It could be further characterised as reversible or permanent based on how long the damage to the nerve lasts (Xu et al., 2013). Consequently, it is crucial to do a comprehensive evaluation, including a careful radiographical inspection of the mandibular canal, before undergoing surgical treatments in the surrounding area of the IAN. Panoramic radiography could be helpful; however it noted to be insufficient to determine the position of MdF accurately (Velasco-Torres et al., 2017). CBCT is one of the most widely used imaging modality as it provides 3D assessment, minimises magnification, and eliminates image overlapping (Angelopoulos et al., 2008). Notably, compared to CT scans, CBCT has lower radiation doses (Loubele et al., 2008).

## 2.3 Lingual Foramen

The LF is situated on the internal surface of the mandible which provides a channel for the sublingual and mylohyoid nerves and vessels to pass (Nuri Mraiwa et al., 2003; Liang et al., 2007). It is generally located superior or inferior to the genial tubercles (GT) in the middle of the mandibular symphysis (Prado et al., 2010; Pires et al., 2012).

### 2.3.1 Classification

The mandible's anterior region contains the LF and its intra-osseous canal, both of which serve as significant landmarks (Gahleitner et al., 2001). An individual may have one or more LF. Previously conducted studies have referred to this anatomical feature as the lingual vascular foramen or auxiliary lingual foramen because there was no agreement on its designation (Moshfeghi et al., 2021). According to its location, LF has been divided into two categories by several researchers: either within or close to the midline, it is referred as median lingual foramen (MLF) (Figure 2.1) and when occurred laterally, lateral lingual foramen (LLF) (Tagaya et al., 2009; Sahman et al., 2014). Other authors had classified LF as midline (MLF) (when present in the middle of symphysis), paramedian (ParaMLF) (located at distal aspect of the canines and the mesial aspects of the central incisors) and posterior (PostLF) (seen between the mesial aspects of the first premolar and the distal part of the third tooth) (Von Arx et al., 2011; Sekerci et al., 2014; Demiralp et al., 2018).

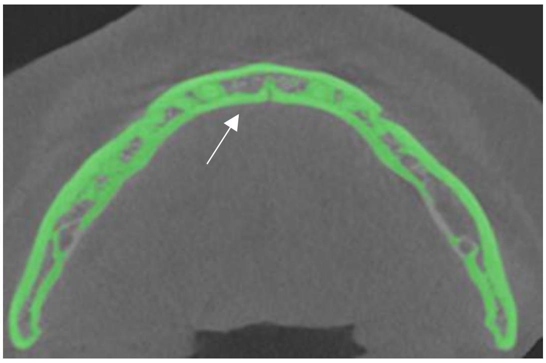

Figure 2.1 Axial view of CBCT showing MLF.

### 2.3.2 Number

Numerous studies have noted the significant diversity in the number and regional geographical distribution of MLF, ParaMLF and PostLF. A study conducted by Demiralp et al. (2018) and Sekerci et al. (2014) reported absence of LF in a small percentage of participants (1.8% and 3.4%), which was relatively uncommon but possible occurrence (Sekerci et al., 2014; Demiralp et al., 2018).

Researchers have detected up to seven LF in a study conducted on 300 individuals whilst another study identified eight LF in a patient, which was the highest number of LF observed in an individual (Sheikhi et al., 2012). Moreover, prior research have shown that a significant percentage of LF could be uncommonly found (Taschieri et al., 2022). Additionally, the study by Patil et al. (2015) analyzed CT scan of 300 patients revealed the presence of 11 LF in certain cases (Patil et al., 2015). Yet, the average number of LF per individual was substantially quite low. In study by Taschieri et al. (2022) three LF, two LF, four LF and one LF were found in 32.3%, 27%, and 17.7% and 10% of patients, respectively (Taschieri et al., 2022). Lastly findings from study performed on Chinese Han population revealed that most of the individuals had LF ranging from 0-8, with three (24.50%) or four (23.50%) being the most common number (He et al., 2016).

Previous research on MLF showed a 3-8% chance of having no LF in the central region of the symphysis of mandible. Study by Taschieri et al. (2022) discovered five LF in one patient, two LF in 57.3%, while four LF in 1.3% had been observed (Taschieri et al., 2022). Whereas other studies had reported similar findings, describing four LF in 2.9% and 2% of cases, respectively (Sheikhi et al., 2012; Wang et al., 2015).

The frequency of LF in the paramedian and posterior aspect of mandible documented in the literature varies widely. The prevalence of a single ParaMLF varied between studies conducted by Tagaya et al. (2009) and He et al. (2016) with the former reported higher prevalence than the latter (Tagaya et al., 2009; He et al., 2016). Findings by Taschieri et al. (2022) identified ParaMLF in more than 60% of patients (Taschieri et al., 2022). Moreover, ParaMLF was observed in 53% of the individuals in a study led by Tepper et al. (2001) (Tepper et al., 2001). Past studies have shown that ParaMLF are usually bilateral and symmetrical (Przystańska & Bruska, 2012).

### 2.3.3 Dimensions

LF has sizes which ranges from 0.64 to 0.84 mm (Scaravilli et al., 2010; Sahman et al., 2014) and these dimensions varied with respect to location. The diameter of LF had been categorized to be "≤1 mm and >1 mm" to estimate the possibility of serious hemorrhage. He et al. (2016) performed a study using 200 CBCT scans, it was observed that from a total of 683 LF, 79% had diameter less than 1 mm while remaining 21% had diameter more than one millimeter (He et al., 2016). In study led by Yildirim et al. (2014) it was revealed that the dimension of MLF were greater in comparison to the size reported for ParaMLF and PostLF (Yildirim et al., 2014). Moreover studies have identified greater diameter in males in comparison to females (Yildirim et al., 2014).

### 2.3.4 Location

Distance from LF to various landmarks was measured. According to Kumar et al. (2017), distance from LF to alveolar crest was observed to be 12.52 mm in females, whilst in males it was detected to be 17.15 mm, highlighting higher dimensions in males (Kumar et al., 2017). A research conducted in Lebanon, reported that the distance between the LF and alveolar crest was found to be 16.24 ± 2.82 mm (Aoun et al., 2017). These results corroborate findings reported by Sheikhi et al. (2012) and Babiuc et al. (2011) where the mean distance was stated to be 18 ± 5.63 mm and 14.2 ± 4.34 mm, respectively (Liang et al., 2007; Babiuc et al., 2011; Sheikhi et al., 2012). The distance of LF to alveolar crest was clinically significant whilst performing surgical placement of dental implant as it could restrict the placement of total length of the implant (Kilic et al., 2014). Clinically speaking, this prompts careful implant length selection, particularly in cases of atrophied mandibles.