Research Article

Determination of Location of Mandibular Foramen Across Age Groups and Genders Using Cone Beam Computed Tomography (CBCT): A Radio-Anatomical Study

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Abstract

Background: Accurately locating the mandibular foramen is crucial for oral and maxillofacial surgeons due to its variability and difficulty in conventional clinical palpation, necessitating advanced imaging techniques such as cone-beam computed tomography (CBCT).

Objective: This study aims to utilize CBCT to accurately ascertain the precise location of the mandibular foramen and investigate potential variations across different age groups and genders in our population. These insights can improve surgical precision and patient care in oral and maxillofacial procedures.

Methods: A retrospective comprehensive radio-anatomical investigation analyzed CBCT images of 103 patients collected over 21 months using convenient sampling. The distances between the mandibular foramen (MF) and key mandibular landmarks (anterior and posterior ramus borders, deepest sigmoid notch point, lowest mandibular notch point, and mandibular occlusal plane) were measured. Ratios for MF's horizontal and vertical locations were assessed. Statistical analysis was performed using Student's t-test and one-way ANOVA.

Results: The average distance between the MF and the occlusal plane was 5.38 mm. The MF was centrally positioned along the anteroposterior axis and shifted anteriorly and superiorly with age. No significant difference in MF location was found between the right and left sides, except for the distance to the posterior ramus border (13.89 ± 2 mm on the right vs. 14.46 ± 1.99 mm on the left, $p = 0.041$). Males had greater distances to landmarks compared to females, but the overall MF position was similar across genders.

Conclusion: Understanding MF variations, demonstrating that while gender differences exist in mandible dimensions, the MF's position remains consistent. These findings emphasize the need for tailored approaches in local anesthesia administration and surgical planning, particularly in the context of demographic-specific anatomical variations.

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Introduction

The mandibular foramen (MF) is an aperture located on the medial side of the mandible's ramus, serving as a gateway for the Inferior Alveolar Nerve (IAN) and blood vessels that provide sensory innervation to the lower teeth and surrounding structures. Locating the mandibular foramen is crucial for various dental and surgical procedures.[1] However pinpointing its exact position can be relatively challenging as it is not visible through clinical examination in the oral cavity. Instead the location is determined using specific landmarks and techniques which includes studying dried human mandibles or imaging radiographs like Orthopantogram (OPG) and Cone beam Computed Tomography (CBCT).[2] In comparison to 2D OPG or the conventional CT scans, CBCT offers several advantages, including its greater accuracy, higher image resolution and shorter exposure time which makes it more dependable for identifying anatomical structures with precision.[3,4]

Accurate knowledge of the mandibular foramen location is essential. Various procedures such as inferior alveolar nerve blocks, performing ramus osteotomies and planning dentoalveolar surgeries cannot be planned or performed without precise awareness of its location. On the contrary misjudging its position can not only result in failed anesthesia but also accidental injury to nerves and blood vessels during the surgical procedures.[5] Many scholarly articles detail the anatomy crucial for effective mandibular anesthesia, yet challenges persist, with estimates of nerve block failures ranging from 20-25%.[6-8]

Road traffic accidents have a major cause of injury to the orofacial region.[9] As Oral and Maxillofacial surgeons, the main focus is on creating a safe area for guiding mandibular osteotomies, including vertical subsigmoid osteotomy (VSS) and inverted L osteotomy (ILO).[10] These procedures are necessary for treating hypertrophic or dysplastic mandibles. The demarcation of this area aims to alleviate common difficulties that arise during inferior alveolar nerve anaesthesia and orthognathic surgeries such as bleeding control, irreversible injury to inferior alveolar nerve or unusual fractures of the mandibular ramus.[11]

In the subcontinent region, there is a notable absence of studies assessing the location of the mandibular foramen, making it imperative to investigate this aspect. Our study's main objective is to establish a precise 'target zone' for guiding the administration of the inferior alveolar nerve block. This research addresses the variability in the mandibular foramen's location across different demographics, including age and gender, comparing it with existing studies of diverse ethnicities. By exploring potential ethnic influences on the mandibular foramen's location, our study aims to bridge the existing gap in knowledge. This study's ultimate aim is to improve the efficacy of local anesthesia administration and other surgical procedures involving the mandible without any complications by considering the variations accounted by the demographical variations.

Methods

The retrospective, cross-sectional study utilized CBCT data from 103 cases obtained from the Department of Oral and Maxillofacial Surgery, University College of Dentistry, The University of Lahore, between January 2021 and September 2023. CBCT scans of individuals with fully developed mandibles and no history of trauma or surgery were included. Exclusion criteria involved patients under 12 years (due to incomplete mandibular growth), as well as scans with mandibular pathologies, syndromic conditions, or poor image quality caused by positioning errors or motion artifacts. After applying these criteria, the sample size calculated for the study was achieved

The CBCT scans were performed using Planmeca Promax, with parameters set at 5.6 mA, 90 kV, voxel size of 400 micrometers, a 12-second scan time and an image size of sigma 23.0×27.6cm (576x576x689). The scans were reconstructed and analyzed using Planmeca Romexis software under standardized conditions, including controlled lighting and opacity adjustments.

For the 3D panoramic reconstruction, the origin of the mandibular canal was located and marked on the axial plane, which was then replicated on the reconstructed panoramic view and labeled as the mandibular foramen (MF). The analysis of the MF location was performed using axial, cross-sectional, sagittal, and panoramic views. Nerve tracing in the panoramic reconstruction facilitated the identification of the nerve entering the MF (Figure 1), which was further confirmed using a 3D skeletal model. Distances from the MF to specific anatomical landmarks—including the anterior (A) and posterior (P) borders of the ramus, the mandibular notch (N), and the mandibular angle (I)—were measured based on previous studies. For vertical and horizontal position assessments, the shortest distances between MF and these landmarks were recorded, and ratios for these positions were subsequently calculated (Figure 2).

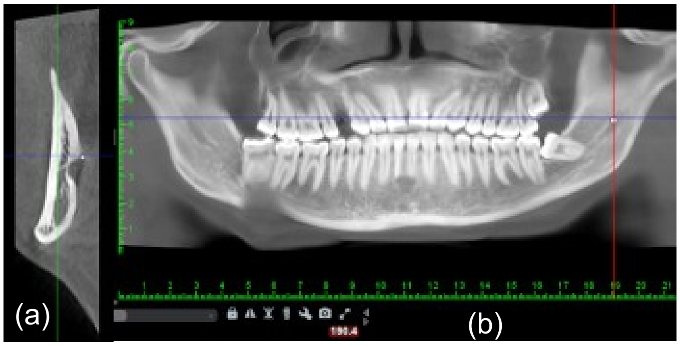

Figure 1: *a) Marking is done on the starting point of the mandibular canal in the sagittal view. b) Marking is replicated on the panoramic view.*

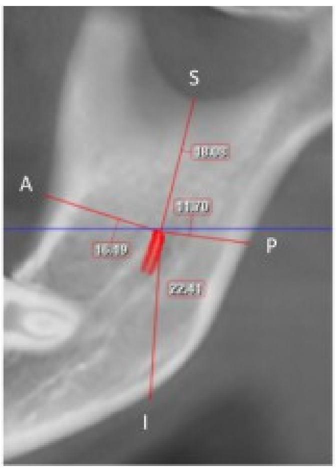

Figure 2: *The shortest distance between marked mandibular foramen (MF) to the landmarks A, P, S and I.*

The occlusal plane, connecting the mesiobuccal cusp of the first premolar and the distobuccal cusp of the first molar, served as a reference. The proceeding measurements were then taken as:

- MF-A: The shortest distance between MF and A
- MF-P: The shortest distance between MF and P
- MF-S: The shortest distance between MF and S
- MF-I: The shortest distance between MF and I
- AP: Distance from A to P
- SI: Distance from S to I

The use of these landmarks was justified by their reproducibility on other radiographs due to their specific anatomical locations, with the occlusal plane serving as an excellent reference for the intraoral IAN approach. Subjects were divided into four age groups to account for differences in mandibular growth: young adults (12-25 years), adults (26-40 years), middle-aged (41-60 years), and elderly (>60 years).

To ensure consistency and minimize intra-observer variability, the radiographs were analyzed by the same examiner twice, with a 2-month interval between analyses. An intra-examiner reliability test was conducted, and the results were validated by a senior consultant. It involved measuring the distance between the mandibular foramen (MF) and the shortest distance to the anatomical landmarks, as well as the anterior-posterior and superior-inferior dimensions of the mandible. The examiner was pre-calibrated to proficiently use the CBCT software and accurately identify the required landmarks. Standard radiographic evaluation conditions, such as light adjustment and opacity modifications, were consistently applied throughout the analysis.

Statistical analysis was performed using SPSS version 25. Descriptive statistics were computed for all variables, including means and standard deviations. To compare distances between the mandibular foramen and anatomical landmarks across different age groups and genders, Student's t-test was used for two-group comparisons, and one-way ANOVA was employed for comparisons among multiple groups. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 103 study participants were selected on which 206 mandibular foramina were analyzed, with an almost even split in gender distribution: 56 (54.37%) being male and 47 (45.63%) being female with a mean age of 28.87 ± 15.91 and 28.38 ± 14.18 respectively. Intra-observer reliability test showed perfect agreement (Table 1), confirming intra-observer consistency.

Table 1: *Intra-observer reliability*

Parameters	ICC	95% Confidence Interval		P value
		Lower Bound	Upper Bound	
MF-A	0.963	0.849	0.996	<0.001*
MF-P	0.983	0.930	0.998	<0.001*
MF-S	0.995	0.978	0.999	<0.001*
MF-I	0.991	0.963	0.999	<0.001*
MF-O	0.995	0.978	0.999	<0.001*
SI	0.998	0.992	0.992	<0.001*
AP	0.981	0.920	0.920	<0.001*

*Significant p-value

Upon comparing the location of the mandibular foramen (MF) with the studied landmarks, there was no significant difference between the distances measured on the right and left sides of the patients' mandibles, except for MF-P. On the right side, the mean distance was 13.89 ± 2 mm, while on the left side, it was 14.46 ± 1.99 mm. The corresponding p-value was 0.041, indicating a statistically significant difference for MF-P between the two sides.

Henceforth, when calculating the vertical and horizontal location of the foramen on the right and left sides, there was no significant difference (Table 2). As there was no difference found between the right and left sides therefore for further discussion only the left side was taken into consideration.

Table 2: *Comparison of the distances between the mandibular landmarks for the right and left sides.*

Parameters	Right side Mean±SD (mm)	Left side Mean±SD (mm)	P value
MF -A	13.79±2.46	13.73±2.46	0.873
MF -P	13.89±2	14.46 ± 1.99	0.041*
MF -S	15.65±3.24	15.56 ± 3.16	0.833
MF -I	28.47±4.63	27.89 ± 4.57	0.367
MF -O	5.51±3.42	5.26 ± 3.54	0.602
MF -A/AP	50.40±5.74	48.96 ± 5.81	0.075
MF -S/SI	37.16±10.81	36.80 ± 6.72	0.771

*Significant p-value

When comparing the distance between MF to the chosen landmarks between males and females, there was a statistically significant difference in the measurement of MF-P, MF-S, and MF-I with mean values being higher in males as compared to females (Table 3). There was no significant difference between the vertical and horizontal location of mandibular foramen between males and females.

Table 3: *Comparison of the distances between the mandibular landmarks for males and females*

Parameters	Male (Mean ± SD)	Female (Mean ± SD)	p-value
MF -A	14.19 ± 2.4	13.31 ± 2.46	0.068
MF -P	14.33 ± 2.09	13.37 ± 1.76	0.015*
MF -S	16.57 ± 3.25	14.57 ± 2.92	0.002*
MF -I	29.89 ± 5.3	26.77 ± 2.91	<0.001*
MF -O	5.23 ± 3.68	5.85 ± 3.08	0.365
MF -A/AP	50.57 ± 5.42	50.2 ± 6.15	0.746
MF -S/SI	36.49 ± 6.47	37.97 ± 14.42	0.491

*Significant p-value

With increasing age, the distance from the MF to the anterior border decreases, while MF-P, MF-I, and MF-O increase. MF-S also increases, peaking at 26-40 years before decreasing (Table 4)."

Horizontally, with an increasing age MF moves anteriorly. Vertically with an increasing age, MF moves superiorly (Table 5). The average distance between the mandibular foramen and occlusal plane in our population was 5.38 mm.

Table 4: *Comparison among age groups, a significant increase in MF-I with increasing age*

Parameters	Age groups	Mean(mm)	SD(±)	p-value
MF -A	12-25	13.88	2.32	0.267
	26-40	13.97	2.66	
	41-60	13.43	2.09	
	>60	11.91	3.32	
MF -P	12-25	14.05	1.9	0.148
	26-40	14.87	2.11	
	41-60	15.06	1.77	
	>60	15.08	2.33	
MF -S	12-25	15.42	3.15	0.665
	26-40	15.57	3.15	
	41-60	16.5	2.62	
	>60	14.8	4.67	
MF -I	12-25	26.75	4.09	0.035*
	26-40	29.46	5.13	
	41-60	28.35	4.4	
	>60	30.19	4.27	
MF -O	12-25	5.16	3.33	0.866
	26-40	5.55	4.44	
	41-60	5.51	2.78	
	>60	4.29	2.66	

*Significant p-value

Table 5: *Comparison of horizontal and vertical location of mandibular foramen among age groups.*

Parameters	Age groups	Mean	SD	p-value
MF -A/AP	12-25	50.06	5.46	0.036*
	26-40	48.54	5.74	
	41-60	47.69	5.52	
	>60	43.34	7.32	
MF -S/SI	12-25	37.46	5.88	0.429
	26-40	36.07	8.45	
	41-60	37.23	5.53	
	>60	33.05	7.57	

*Significant p-value

Discussion

The landmarks used to locate the position of the mandibular foramen are critical for surgical procedures, although they may pose challenges for some practitioners to locate accurately. These landmarks are essential for designing optimal inferior alveolar nerve blocks and ramus osteotomy lines, which can enhance the success rate of IAN blocks and minimize the risks of morbidity or nerve injury during ramus osteotomies.[12] This study is the first to investigate the location of the mandibular foramen in a Pakistani subpopulation, employing a design and methodology similar to that of previous studies.[3,8,13]

Our study revealed no significant difference in the location of the MF between the sides (right and left) aligning with findings from earlier studies conducted in Jordan and the USA.[13,14] Additionally we observed no significant variation in MF location across genders which was also consistent with results from other ethnic groups.[13,15] While the males exhibited significantly greater distances between certain anatomical landmarks and MF, these differences did not impact the overall position of the foramen.

Our study reveals that the distance between MF and anatomical landmarks varies as one ages. This change is attribute to growth and remodeling of ramus, the bony structure of the lower jaw, involving resorption on its anterior surface and deposition at the head of the condyle.[16,17] These developmental changes alter the position of the MF over time, a finding that is consistent with previous studies. The mandibular foramen moves anteriorly and superiorly with ongoing remodeling, resulting in an overall increase in distances between the MF and the landmarks MF-P, MF-I, and MF-O as a person ages. This finding was consistent across all previous studies.[13-15]

There has been a long-standing debate regarding the exact horizontal location of the mandibular foramen. Some studies indicate that the mandibular foramen is situated at the midpoint of the mandible's ramus,[18] which aligns with our findings. However, other studies suggest that it is located just behind the midline of the ramus which is different from what we observed in our population.[13,14]

The IAN block targets an area where the horizontal and vertical positions of MF intersect. This area is typically calculated as 50% of the anteroposterior dimension and a ratio of 35% to 65% in the superoinferior dimension. However, a study done in Jordan declared a 40% rule for the target area, which differs slightly from Trost's findings.[15]

The average distance between MF and the occlusal plane in our population was 5.38mm, indicating that our population falls on the lower end of Malamed's recommended distance of 6-10 mm for administering local anaesthesia. An Iranian and Indian study also had the average distance within the range given by Malamed.[14,6] The differences observed in the mandibular foramen's location between this study and others alike may stem from anatomical variations among different populations for which this study has given insight for our population which will help in providing them the best clinical services.

Our study provides valuable insights into the variability of mandibular foramen (MF) location across different ages and genders. The observed shifts in MF position have significant implications for surgical planning and anesthesia techniques. Particularly, the anterior and superior displacement of the MF with age suggests that surgical and anesthesia protocols should be adjusted accordingly. Future studies should be conducted. Large sample sizes are essential to establish a standardized understating of the MF's location in our population. The larger the dataset, the more it facilitate comprehensive statistical analyses. This would improve precision in identifying demographic specific variations and enhance the clinical significance of these findings.

Conclusion

MF location had minor changes in the mandibular dimensions across age groups and gender. It was observed that MF tend to shift anteriorly and superiorly with age with an average distance of 5.38mm above the occlusal plane. Although gender based differences in distances to anatomical landmarks were noted, they had no significant impact on the overall position of the MF. These findings of our demographics can help in better surgical planning resulting in improved precision and outcomes.

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Authors' Contribution:

TS: Conception & design, analysis & interpretation of data, drafting the article

AL: Analysis & interpretation of data, final approval of the version

HH: Acquisition of data, drafting the article

NN: Acquisition of data, analysis & interpretation of data

MAA: Analysis & interpretation of data, drafting the article, critically revision for important intellectual content

SA: Drafting the article

MAB: Critically revision for important intellectual content

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