Cone Beam CT to Map Mandibular Foramen Variations for Improving Dental and Surgical Accuracy

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Abstract

Background: The mandibular foramen (MF) is a key anatomical feature of the mandible, critical for dental and surgical procedures due to its role in housing the inferior alveolar nerve, artery, and vein. Accurate localization of the MF is challenging, often necessitating the use of anatomical landmarks during procedures to prevent complications, such as nerve damage. Methods: This study analyzed the position of the MF using panoramic images reconstructed from cone beam computed tomography (CBCT). The sample included 56 dentate patients, comprising 22 males and 34 females aged 20-55 years. Linear measurements from the MF to various anatomical landmarks were taken, and statistical analysis was conducted using the T-test and ANOVA to assess the impact of gender, age, and side of the mandible on MF positioning. Results: The study found no significant gender differences in the distances from the MF to the mandibular notch (N-MF), the anterior border of the ramus (A-MF), and the inferior border of the mandible (I-MF). However, significant gender differences were observed in the distance from the MF to the posterior border of the ramus (P-MF). Age also significantly affected the P-MF distance, while side comparisons showed no significant differences in MF positioning between the right and left mandibles. Conclusion: The findings indicate that while most MF measurements are consistent across genders and ages, the P-MF distance varies significantly, necessitating personalized approaches in dental and surgical procedures to ensure precision and minimize complications. These insights into MF positioning enhance the effectiveness of clinical practices involving the mandibular foramen.

Keywords: Mandibular foramen, Inferior alveolar nerve block, CBCT imaging, Anatomical landmarks, Gender and age differences.

Significance | This study enhanced precision in dental and surgical procedures by detailing mandibular foramen variations influenced by gender and age, reducing complications.

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Editor Aman Shah Bin Abdul Majid, And accepted by the Editorial Board Jun 06, 2024 (received for review Apr 09, 2024)

Introduction

The mandibular foramen (MF) is a crucial anatomical feature of the mandible, functioning as a passage for essential neurovascular structures. It is an opening on the inner surface of the mandibular ramus through which the inferior alveolar nerve, artery, and vein pass. Notably, the inferior alveolar artery supplies blood to the mandible, gums, teeth, and associated lower jaw nerves (Toth & Lappin, 2022). Clinically, locating the MF is challenging due to its non-palpable nature; hence, dentists and surgeons rely on specific anatomical landmarks to identify its position. Key landmarks include the occlusal plane, the anterior border of the ramus, and both the external and internal oblique ridges (Afsar et al., 1998). Accurate knowledge of the MF's location is vital in dental and jaw surgeries to avoid damaging the inferior alveolar nerve, a significant risk during procedures like third molar extractions or dental implantations (Shen et al., 2019).

Administering anesthesia in the mandible poses unique challenges compared to the maxilla. Inferior alveolar nerve block anesthesia, in particular, is prone to failure, often due to inaccurate needle

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Please cite this article.
Ryaheen Ghazi Rashid, Rand Mohammed Abdul-Jabbar et al. (2024). Cone Beam CT to Map Mandibular Foramen Variations for Improving Dental and Surgical Accuracy, Journal of Angiotherapy, 8(6), 1-8, 9729

placement resulting from incorrect identification of the MF (Altunsoy et al., 2014). The anesthetic typically delivered just above the MF; however, its effectiveness diminishes if the foramen's anatomical location is misjudged or if it has shifted (Park & Lee, 2015). Therefore, practitioners must locate the MF accurately using reliable anatomical references such as the pterygomandibular raphe and the coronoid notch (Thangavelu et al., 2012). Successfully blocking the inferior alveolar nerve, commonly performed during various dental procedures, requires precise administration of local anesthetic between these landmarks to numb the sensory region effectively (Hwang et al., 1990).

This study utilized panoramic images reconstructed from cone beam computed tomography (CBCT) to determine the MF's position accurately. The research aimed to assess how variables such as gender, age, and side of the mandible influence the location of the MF. Understanding these variations is crucial for improving the precision of dental procedures involving the mandibular foramen, reducing the risk of complications, and enhancing patient outcomes. By analyzing CBCT images, this study sought to provide more detailed and reliable data on the anatomical positioning of the MF, contributing to the refinement of clinical techniques and the overall effectiveness of dental and surgical interventions.

2. Materials and methods

2.1 Study design

This study was conducted in compliance with ethical guidelines and standards for research involving human subjects. The sample comprised 56 dentate patients (22 males and 34 females) aged between 20 and 55 years, who attended the specialist dental center in Diyala for cone beam computed tomography (CBCT) investigations for various diagnostic purposes. Prior to participation, all patients were provided with detailed information about the study and were required to give written informed consent. The study protocol was reviewed and approved by the ethical review board, ensuring adherence to the principles of the Declaration of Helsinki. Patient confidentiality was maintained throughout the study, with all data anonymized to protect personal information. Participation was voluntary, and patients were assured that their decision to participate or not would not affect their treatment.

2.2InclusionCriteria

To ensure pathological conditions did not alter the anatomical landmarks, the images selected for this study were from patients with normal occlusion and no history of trauma, facial asymmetry, fractures, or cystic lesions.

2.3CBCTImaging

The CBCT images were acquired using the New Tom Giano CBCT machine. The imaging parameters included a field of view measuring 16 cm × 14 cm, a voltage of 110 kV, an exposure time of 24 seconds, and an electrical current range of 5-7 mA. The mandibular foramen (MF) was assessed in the region where the mandibular canal ended. All CBCT images were reconstructed into panoramic views to ensure consistent evaluation.

2.4.Measurements

The study involved linear measurements on both sides of the mandible to accurately locate the MF. The specific measurements included: (1) AMF (Line 1) measuring the distance from the anterior border of the ramus (A) to the MF; (2) PMF (Line 2) measuring the distance from the posterior border of the ramus (P) to the MF; (3) IMF (Line 3) determining the distance from the most inferior border of the ramus (I) to the MF; and (4) NMF (Line 4) measuring the distance from the mandibular notch (N) to the MF. These measurements were meticulously taken to ensure accuracy and illustrated in Figure 1.

2.5Data Collection and Analysis Procedures

Data were systematically collected from the CBCT images, with each measurement recorded twice to ensure reliability. Any discrepancies between the measurements were resolved by re-evaluating the images.

2.6 Statistical Analysis

The Statistical Analysis System (SAS) software, version 2018, was used to determine the impact of various factors on the study parameters. T-tests and the Least Significant Difference (LSD) test within an Analysis of Variance (ANOVA) framework were employed to make meaningful comparisons between means. This approach allowed for a robust analysis of how variables such as gender, age, and side of the mandible affected the position of the MF. The statistical analysis aimed to highlight significant differences and trends in the anatomical positioning of the MF, providing insights that could enhance clinical practices in dental and surgical procedures.

3. Results

The study's findings revealed several key points regarding the distances from the mandibular foramen (MF) to various anatomical landmarks, with a particular focus on gender and age differences. Regarding gender differences, the distance from the mandibular notch (N) to the MF (N-MF) showed no significant variation between genders, with p-values of 0.110 for the right side and 0.102 for the left side. Similarly, the distance from the MF to the anterior border of the ramus (A-MF) did not differ significantly between males and females, as indicated by p-values of 0.654 for the right side and 0.882 for the left side. Additionally, the distance from the MF to the inferior border of the mandible (I-MF) exhibited no significant gender differences, with p-values of 0.187 for the right side and 0.107 for the left side. However, a significant gender difference was observed for the distance from the MF to the posterior border of the ramus (P-MF), with highly significant p-values of 0.0001 for both the right and left sides. This indicated that while most distances did not vary by gender, the P-MF distance was significantly different between males and females.

In terms of age-related differences, the distance from the MF to the mandibular notch (N-MF) showed no significant variation with age, with p-values of 0.941 for the right side and 0.707 for the left side. Similarly, the distance from the MF to the inferior border of the mandible (I-MF) did not differ significantly with age, with p-values of 0.250 for the right side and 0.327 for the left side. The distance from the MF to the anterior border of the ramus (A-MF) also showed no significant age-related differences, with p-values of 0.198 for the right side and 0.148 for the left side. In contrast, the distance from the MF to the posterior border of the ramus (P-MF) exhibited significant age-related differences, with p-values of 0.0008 for the right side and 0.0013 for the left side. This suggested that, like gender, age significantly influenced the P-MF distance.

Comparisons of the selected measurements between the right and left sides revealed no significant differences between the two sides for both males and females. This consistency indicated that the MF's anatomical positioning relative to these landmarks was symmetrical, regardless of the side.

The study demonstrated that while most linear measurements from the MF to various anatomical landmarks showed no significant differences concerning gender and age, the P-MF distance was an exception. This measurement exhibited significant variation between genders and across different age groups. Understanding these differences is crucial for improving the precision of dental procedures, as it highlights the need for tailored approaches based on individual anatomical variations. The findings provided valuable insights into the anatomical positioning of the MF, contributing to the refinement of clinical techniques and enhancing the overall effectiveness of dental and surgical interventions.

4. Discussion

Inferior alveolar nerve block anesthesia (IANBA) is a primary method for administering local anesthetic to teeth (Pogrel et al., 2018). Despite its widespread use, the success of IANBA can be influenced by several factors, including improper anesthetic technique and anatomical variations of the mandibular foramen (MF) (Shahid et al., 2020). The anatomical location of the MF is crucial in IANBA, as well as in procedures such as ramus osteotomy and surgeries involving the posterior angle of the mandibular ramus (Saber et al., 2019). This study aimed to investigate the anatomical variation of the MF position according to gender, age, and side.Park and Lee (2015) examined the location of the MF in patients with different types of malocclusion and found no significant gender-related differences in patients with normal occlusion. This finding aligns with our study, which also showed no significant gender differences in the distances from the MF to the mandibular notch, the anterior border of the ramus, and the inferior border of the mandible (Alqahtani et al., 2022). However, our study did find a significant gender difference in the distance from the MF to the posterior border of the ramus, with the mean value being higher in females than in males (Gupta et al., 2017). This result can be explained by noting that adult men tend to have a posterior ramus bent at the level of the molars' occlusal surfaces, while females often have a straight juvenile form or a bend above the occlusal level near the neck of the condyle (Rogers & Fuentes, 2016).Correa et al. (2019) examined the location of the MF concerning different facial shapes and found no significant differences according to sex, supporting our results. In contrast, Hayagreev et al. (2021) and Movahhed et al. (2011) reported different MF locations according to sex, particularly in individuals under 20 years of age. These studies suggest that mandibular growth rates differ between sexes, with females showing faster growth rates than males at this age (Meyer et al., 2019). Our study, however, focused on individuals older than 20 years, which may account for the differing findings (Zhang et al., 2021).Regarding age-related differences, our study found no significant differences in the distances between the MF and the mandibular notch, the mandible's inferior border, or the ramus's anterior border. This is consistent with the findings of Shokri et al. (2015), who evaluated the position of the MF using CBCT and found no appreciable changes in the MF's position with age (Pogrel et al., 2018). Feuerstein et al. (2020) also concluded that the MF position was similar across all patients, reinforcing that the MF maintains a consistent anatomical location (Fornasier et al., 2018).However, our study did find that age significantly affected the distance from the MF to the posterior border of the ramus. This can be attributed to the changes in the mandibular angle, which is acute in youth and becomes more obtuse with age (Basha & Saralaya, 2016). Hayagreev et al. (2021) also found age-related variations in the MF position, but their study focused on individuals under 20 years old, highlighting the importance of age in anatomical studies of the mandible (Yıldırım et al., 2020).Our study also compared the selected measurements between the right and left sides of the mandible. The findings revealed no significant differences in these measurements according to side, aligning with the research by Feuerstein et al. (2020) and Findik et al. (2014), both of which concluded that the MF position does not differ significantly between the left and right sides (Gonzalez et al., 2021). Kilarkaje et al. (2005) also reported that the MF maintains bilateral symmetry in human mandibles, further supporting our results (Gorecki et al., 2017).The implications of these findings are significant for clinical practice. The lack of significant differences in the majority of measurements related to gender and age suggests a degree of predictability in the MF's location, which can be valuable for dental practitioners (Stathopoulou et al., 2019). However, the notable exception of the P-MF distance underscores the need for tailored

Table 1. Comparison between male and female in N-MF in Right and Left side. NS: Non-Significant.

Measurement	Gender	Mean ± SE		T-test (P-value)
		Right side	Left side	
N-MF	Male	19.03 ±0.80	17.99 ±0.60	1.355 NS (0.094)
	Female	16.61 ±0.52	16.75 ±0.44	1.256 NS (0.355)
	T-test (P-value)	1.474 NS (0.110)	1.499 NS (0.102)	---

Table 2. Comparison between male and female in A-MF in Right and Left side. NS: Non-Significant.

Measurement	Gender	Mean ± SE		T-test (P-value)
		Right side	Left side	
A-MF	Male	16.09 ±0.97	15.99 ±0.96	1.72 NS (0.561)
	Female	15.82 ±0.76	15.82 ±0.76	1.37 NS (0.688)
	T-test (P-value)	2.191 NS (0.654)	2.091 NS (0.882)	---

Table 3. Comparison between male and female in I-MF in Right and Left side. NS: Non-Significant

Measurement	Gender	Mean ± SE		T-test (P-value)
		Right side	Left side	
I-MF	Male	14.84 ±0.68	15.05 ±0.66	1.36 NS (0.307)
	Female	13.55 ±0.54	13.62 ±0.46	1.25 NS (0.640)
	T-test (P-value)	1.726 NS (0.187)	1.532 NS (0.107)	---

Table 4. Comparison between male and female in P-MF in Right and Left side. ** (P≤0.01), NS: Non-Significant.

Measurement	Gender	Mean ± SE		T-test (P-value)
		Right side	Left side	
P-MF	Female	32.29 ±0.86	32.73 ±0.87	1.47 NS (0.729)
	Male	27.37 ±0.45	27.12 ±0.57	1.50 NS (0.673)
	T-test (P-value)	1.790 ** (0.0001)	2.008 ** (0.0001)	---

Table 5. Comparison between Age groups in N-MF in Right and Left side. NS: Non-Significant.

Measurement	Age groups (year)	Mean ± SE		T-test (P-value)
		Right side	Left side	
N-MF	18-30	17.31 ±0.77	17.06 ±0.67	1.59 NS (0.692)
	31-40	17.53 ±0.58	17.04 ±0.54	1.38 NS (0.711)
	41-55	18.01 ±1.33	17.86 ±0.73	1.41 NS (0.328)
	LSD value (P-value)	2.309 NS (0.941)	1.847 NS (0.707)	---

Table 6. Comparison between Age groups in I-MF in Right and Left side. NS: Non-Significant.

Measurement	Age groups (year)	Mean ± SE		T-test (P-value)
		Right side	Left side	
I-MF	18-30	27.90 ±0.83	27.90 ±0.99	2.05 NS (0.641)
	31-40	30.20 ±0.92	30.33 ±0.89	1.84 NS (0.588)
	41-55	29.89 ±0.95	29.75 ±1.38	1.91 NS (0.702)
	LSD value (P-value)	3.207 NS (0.250)	2.474 NS (0.327)	---

Table 7. Comparison between Age groups in A-MF in Right and Left side. NS: Non-Significant.

Measurement	Age groups (year)	Mean ± SE		T-test (P-value)
		Right side	Left side	
A-MF	18-30	13.50 ±0.66	13.42 ±0.67 b	1.35 NS (0.831)
	31-40	13.71 ±0.72	13.89 ±0.64 b	1.55 NS (0.752)
	41-55	15.53 ±0.81	12.33 ±0.79 a	1.586 NS (0.7255)
	LSD value (P-value)	2.126 NS (0.198)	2.187 NS (0.148)	---

Table 8. Comparison between Age groups in P-MF in Right and Left side. ** (P≤0.01), NS: Non-Significant.

Measurement	Age groups (year)	Mean ± SE		T-test (P-value)
		Right side	Left side	
P-MF	20-30	17.59 ±0.99 a	17.02 ±0.87 a	2.03 NS (0.266)
	31-40	16.50 ±0.82 a	16.94 ±0.85 a	2.18 NS (0.195)
	41-55	12.09 ±0.67 b	12.33 ±0.79 b	1.07 NS (0.746)
	LSD value (P-value)	2.699 ** (0.0008)	2.576 ** (0.0013)	---

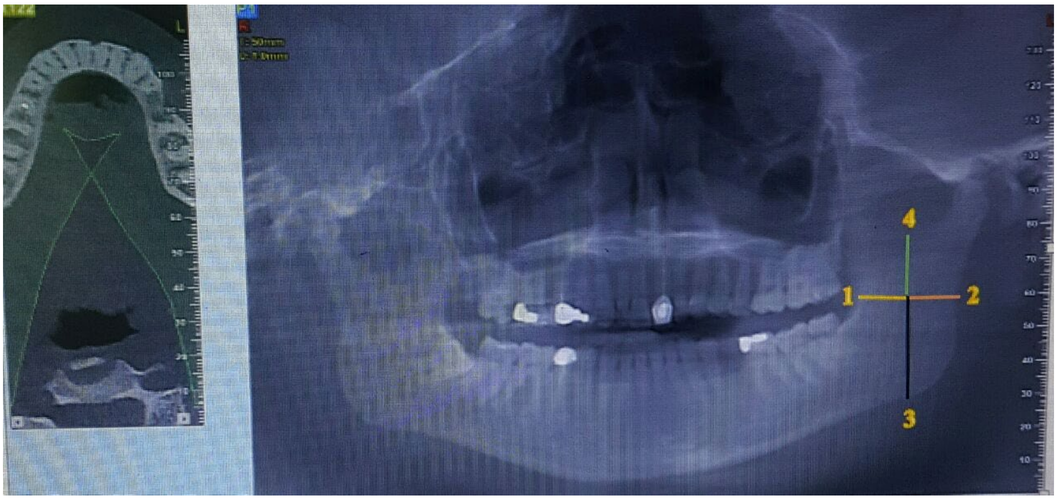

Figure 1. Image of linear measurements included in the study

approaches in procedures that involve this anatomical landmark. Understanding that females generally have a greater P-MF distance can guide clinicians in adjusting their techniques accordingly to improve accuracy and reduce complications (Ahmed et al., 2020).Moreover, the influence of age on the P-MF distance indicates that younger and older patients may require different considerations during dental and surgical procedures. Recognizing that the mandibular angle changes with age can help practitioners anticipate potential challenges and adjust their approaches to ensure effective and safe interventions (Ramirez et al., 2021).This study provides valuable insights into the anatomical positioning of the MF, highlighting the importance of considering both gender and age when planning dental and surgical procedures (Pogrel et al., 2018). The findings emphasize the need for personalized approaches based on individual anatomical variations to improve the precision and success of procedures involving the mandibular foramen. This knowledge contributes to refining clinical techniques, enhancing the overall effectiveness of dental and surgical interventions (Basha & Saralaya, 2016).

5. Conclusion

This study assessed the importance of accurately locating the mandibular foramen (MF) for effective inferior alveolar nerve block anesthesia. It examined variations in MF location based on gender, age, and side. The findings revealed that gender and age did not significantly affect the distances between the MF and mandibular notch, the ramus anterior border, or the mandible's inferior border. However, both gender and age influenced the distance from the MF to the posterior border of the ramus. Additionally, no significant difference was found in MF position between the right and left sides within individuals. Understanding these variations is crucial for improving the precision of dental and surgical procedures, thereby reducing the risk of complications and enhancing patient outcomes

Author contributions

R.G.R. formulated the study objectives, constructed the hypotheses, and revised the manuscript. R.M.A. conducted the literature review. W.Y. collected the data. S.K.I. performed the data analysis. All authors reviewed and approved the final manuscript.

Acknowledgment

Author was grateful to their department.

Competing financial interests

The authors have no conflict of interest.

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