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Anatomical variations in position of mandibular foramen: An East European morphometric study in dry adult human mandibles for achieving a successful inferior alveolar nerve block

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Abstract

In today's era of modern dentistry, the race towards developing painless and trauma-less procedures remain an important goal of all major companies and dental researchers. One such technique of focus is the Inferior Alveolar Nerve Block (IANB) which remains by far the most common anesthetic technique followed worldwide prior to any submaxillary treatment procedure. Despite of it being so popular, the failure rates remain significantly high with estimates at 15-60% among dental practitioners and dental students alike. Major reasons for failure include inaccurate determination of Mandibular foramen, variations in location of foramen, presence of accessory foramen, etc. to name a few. The present article aims to present the morpho-anatomical variations in the position of Mandibular Foramen in East European population. For this reason, the distance of the foramen was measured from 5 different bony landmarks using digital Vernier caliper on dry human adult mandibles. Analyzing the results, the foramen was found to be positioned at a mean distance of 16.88 ± 2.43 mm on the right side and 17.33 ± 2.24 mm on the left side from the anterior border of the ramus. Similarly, it was found to be 12.31 ± 2.49 mm and 11.75 ± 2.47 mm on right and left sides respectively from posterior border of ramus. It was found to be 17.41 ± 3.22 mm and 18.01 ± 3.44 mm and 19.80 ± 3.86 mm and 20.11 ± 4.08 mm on right and left sides from mandibular notch and angle of mandible respectively.

Keywords

Inferior Alveolar Nerve Block, Mandible, Local Anesthesia, Facial Nerve.

Introduction

Most of the available contemporary anatomical literature and text describes the Mandibular foramen as an irregular opening which is located on the medial surface of the ramus of the mandible (Standring, 2008). It leads into the mandibular canal, which runs obliquely downwards and forward within the ramus of the mandible and then run horizontally forward within the body of the mandible below the roots of the

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molar teeth with which it communicates with small openings. The foramen transmits the Inferior Alveolar Nerve and its vessels into the mandibular canal (Varsha S. et al., 2012). The foramen has more or less been studied for its variations in position but has never been done for Eastern European population and compared with other geographic zones to understand the evolutionary as well as environmental differences that include dietary differences, chewing habits, genetic variations etc. The foramen forms the passageway for the Inferior Alveolar Nerve. It is the branch of Mandibular Nerve which is itself the 3rd branch of Trigeminal Nerve. The nerve passes behind the pterygoid muscle before making an entrance into the foramen. Inferior Alveolar Nerve Block is one of the most common anesthetic procedure prior to various submaxillary surgeries. The success of the procedure depends upon the position of the needle tip and Mandibular Foramen at the time of anesthetic injection (Varsha S. et al., 2012). The main complications during this technique are hemorrhage, injury to the neurovascular bundle, fractures, and necrosis of *Ramus Mandibulae* (Daw Dl et al., 1999). The most recurring causes of failure include inapposite location of needle, inaccurate judgement of locus of Mandibular Foramen or by marked variability in its location (Ennes and Medeiros, 2009; Oguz and Boz, 2002; Varsha S. et al., 2012). Earlier, location of the foramen was located by palpating the lingula (Ennes and Medeiros, 2009) or by using radiographs (Hwang TJ. et al., 1990; Mbajiorgu EF, 2000).

The main goal of this study was to locate the Mandibular Foramen and determine its distance from various anatomical landmarks on medial surface of the ramus of the mandible in several adult dry human mandibles in East European populations and then compare our results with studies from other geographical zones, in a desire to add our findings to our predecessors and contribute to ever-growing field of dentistry and anesthesia research.

Materials and Methods

The present study was conducted in Department of Morphology, Institute of Anatomy and Anthropology, Rīga Stradiņš University, Riga, Latvia. The department`s personal collection included 125 dry human adult mandibles which were used for this study. The Mandibles taken had both the left and right Ramus with foramen and hence a total of 250 foramens (125 on each side) were assessed for their location. Figure 1. shows Mandibular foramen on the ramus from posterior view. Each Mandible was assigned a specific serial number starting from 1 to 125 and were observed for the presence, prevalence rate and laterality of the Mandibular Foramen.

Mandibles that were regular in shape and devoid of any irregularities and deformities only were included in this study. The damaged mandibular bones and those having pathological abnormalities were excluded from the scope of this study. Also, the mandibles that didn`t had an erupted 3rd Molar Tooth/Wisdom tooth socket in the Mandible were excluded.

Irrespective of any shape of the lingula, the center of the Foramen was taken as the reference point and marked as Point F for all measurements in the study. Magnifying glass and Digital Vernier Caliper were used for taking measurements. The Digital Vernier Caliper used had a resolution of 0.01 mm (millimeters) with range from 0-300 mm and had a zero error. The external jaws of the Caliper were brought togeth-

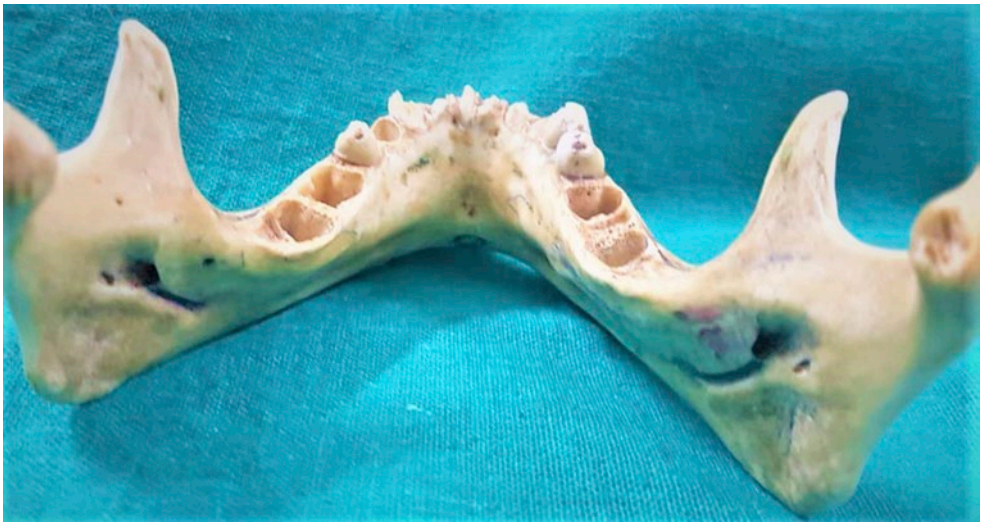

Figure 1. Figure showing the medial surface of right and left Mandibular Ramus from posterior view.

er until they touched each other, and zero button was pressed before taking every individual reading.

Following points were marked on the Mandible:

1) Point F: - It is the center of Foramen. The most inferior position of the Foramen was taken for vertical measurements and the most anterior position was taken for the horizontal measurements.
2) Point A: - The most anterior point on the anterior border of ramus.
3) Point B: - The most posterior extent of the line AB on the posterior border of ramus.
4) Point C: - The most inferior point of the sigmoid notch.
5) Point D: - The point on the angle (inferior border) of the mandible which makes the terminus of the line CD.
6) Point E: - It is a point at the distal surface of the mandibular third molar tooth.

The distances from the foramen to various bony landmarks were recorded by 2 authors. Each author took three independent measurements and the average of both readings from both authors were considered. This was done to eliminate and reduce the chances of human error, parallax and other external sources of errors. The Mean and Standard Deviation were calculated for the right and left sides separately and were presented in tabular form. The reference points and lines of measurements were marked with a pencil and are shown in Figure 2.

All the parameters were carefully measured and then entered in Excel Spreadsheet in Microsoft Excel, 2010 and analyzed using IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 22.0 (Statistical Package for Social Sciences); Armonk, New York: IBM Corp. The results of the present study were compared with the results of previous studies done on various ethnic groups in various geographical locations. The minimum, maximum, mean and standard deviation for each were

Figure 2. Figure representing the reference points used in the study and lines of measurements marked with a marker as: 1) Point A - Anterior Border of Ramus; 2) Point B – Posterior Border of Ramus; 3) Point C – Mandibular Notch; 4) Point D - Angle of the Mandible; 5) Point E – Posterior Border of 3rd Molar tooth; 6) Point F – Center of the Mandibular Foramen.

calculated separately by using the respective statistical formulas on either side of the mandibles.

Results

The mean distances of the position of Mandibular Foramen, along with the standard deviation, maximum distance and minimum distance measured on both the left and right side are concluded in Table 1. Student`s t-test was used as test of significance to compare the mean values of right and left side and a P value of less than 0.05 was taken to be statistically significant. The results from the Student`s t- test are also compared in Table 1. Symmetrical measurements of localization of Foramen on right versus left sides were found in only 22% – 34% of the Mandibles. The Pearson

Table 1. Table concluding the mean, maximum and minimum distance with significance of foramen from various bony landmarks.

Sr. No.	Position of the mandibular foramen from various landmarks	Side of the Mandible	Mean Distance (in mm)	S.D*	Maximum Distance measured (in mm)	MinimumDistance measured (in mm)	P <0.05
1.	Anterior Border to Foramen (Line AF)	Right Side	16.88	2.43	21.12	11.92	0.0371*
		Left Side	17.33	2.24	22.25	13.35	
2.	Posterior Border to Foramen (Line BF)	Right Side	12.31	2.49	20.20	8.87	0.0415*
		Left Side	11.75	2.47	16.85	7.58	
3.	Mandibular Notch to Foramen (Line CF)	Right Side	17.41	3.22	24.16	12.46	0.1080
		Left Side	18.01	3.44	24.04	10.65	
4.	Angle of Mandible to Foramen (Line DF)	Right Side	19.80	3.86	28.03	11.56	0.2515
		Left Side	20.11	4.08	27.74	12.05	
5.	Posterior Border of 3rd Mandibular Molar to Foramen (Line EF)	Right Side	22.88	4.53	31.64	10.97	0.2727
		Left Side	23.22	4.61	31.59	11.12	

* Significant (P < 0.05)

Table 2. Table showing localization of the foramen in Antero-posterior axis.

Side of the Mandible	Mean (in mm)		Midpoint of Line AB	Difference Between Line AF and midpoint of Line AB	Location of Foramen in reference to Midpoint of Line AB
	Line AB	Line AF			
Right Side	29.19	16.88	14.59 mm	2.29 mm	Posterior to midpoint
Left Side	29.08	17.33	14.54 mm	2.79 mm	Posterior to midpoint

Table 3. Table showing localization of the foramen in Superio-inferior axis.

Side of the Mandible	Mean (in mm)		Midpoint ofLine CD	Difference Between Line CF and midpoint of Line CD	Location of Foramen in reference to Midpoint of Line CD
	Line CD	Line CF			
Right Side	37.21	17.41	18.60 mm	- 1.19 mm	Inferior to midpoint
Left Side	38.12	18.01	19.06 mm	- 1.05mm	Inferior to midpoint

Correlation was also used to test the correlation R of measurements of right and left side of each distance and a P value of less than 0.01 was taken to be significant statistically. Line AF on both sides showed a strong positive linear correlation while Line BF showed a moderate positive linear correlation. Line CF had a weak positive linear correlation and both Line DF and Line EF had moderate to strong positive linear correlation on both sides of the Mandibles.

The localization of foramen in anteroposterior and superio-inferior axis of the ramus of the mandible was also determined as shown in Tables 2-3. It was found out that the foramen is not localized at the midpoint of any of the two axes. Neither was it localized at the point of cross section of both axes. Rather it was about 2 – 3 mm posterior from midpoint on anteroposterior axis and about 1 mm inferior from the midpoint of superio-inferior axis. There was statistically significant difference in the location of the foramen on the right and left sides ($p < 0.05$) in the anteroposterior axis ($p = 0.014$) while in the superio-inferior axis ($p = 0.286$), no statistically significant difference found ($p > 0.05$).

Discussion

The knowledge of the position of Mandibular foramen is of great importance for many procedures in dentistry. The location of the foramen is also of great importance to Radiologists and Oncologists. It is also clinically crucial in achieving Inferior Alveolar Nerve Block which is most commonly used for administering local anesthesia for any operative procedure on the Mandible. The commonest reason for failure of the technique is the inappropriate location of the tip of the anesthetic needle due to inaccurate localization of the Foramen (Ennes and Medeiros, 2009; Palti DG. et al., 2011; Patrical and Arthur, 2003). The surgeon has to select an appropriate needle to give the Inferior Alveolar Nerve Block. The average length of the long needles used should be

23 mm long and for short needles should be 21.5 mm long in consideration to the size of the patient`s mandible especially while using the pterygomandibular technique of Inferior Alveolar Nerve Block. If a long needle is used in a patient with small mandible then there is a risk of perforating the capsule of Parotid gland thereby causing damage to the branches of the Facial Nerve. If a short needle is used in a patient with big mandible there may be chances of fracture of needle when it is completely introduced in the oral tissues (Ennes and Medeiros, 2009). Hence localization of the Foramen is very important to select the size of the anesthetic needle. In the present study, the locus of the Mandibular foramen and its distances from various bony landmarks on dry mandibles was determined and calculated. This study also compared the location of the foramen on right and left sides of the Mandible. Mbajiorgu EF. (2000) in his study on adult black Zimbabweans has reported that the Foramen lies 2.56 mm behind the midpoint of width of *Ramus Mandibulae* on the right side and 2.08 mm behind the midpoint of width of *Ramus Mandibulae* on the left side. In the present study, the foramen lied 2.30 mm behind the midpoint of the width of *Ramus Mandibulae* on right side while 2.79 mm on the left side in anteroposterior axis of mandibular ramus. The variability of the distance from anterior border to foramen was also not significant enough to produce failure of Anesthetics. If we compare our study with some other ethnic groups, then we see that the distance of foramen to Anterior Border of *Ramus Mandibulae* which were 16.88 mm and 17.33 mm on right and left side respectively, are in range with that of the other studies (Asma and Imtiaz, 2015; Hoque MM et al., 2013, Oguz and Boz, 2002; Sandhya K. et al., 2015). Oguz and Boz (2002) have tried to localize the Mandibular foramen in the Turkish population. Ennes and Medeiros (2009), Prado et al. (2010), and many others (Afdhali and Flora, 2014; Asma and Imtiaz, 2015; Gopalakrishna K. et al., 2016; Hoque MM et al., 2013; Jin Hoo et al., 2018; Mbajorgu EF, 2000; Prajna and Poonam, 2013; Sandhya K. et al., 2015; Wandee A. et al.,2015), have also studied the location of Foramen in different population. There are variations in the values obtained in each of the studies when compared with the results of the present study as seen in Table 4. Kilarkaje et al. (2005), have reported that the foramen was within 25 mm from the distal edge of third molar tooth. Varma et al. (2011), have reported that the mean distance of mandibular foramen from third molar tooth socket was 15 mm on right side and 18 mm on the left side. Ghorai et al (2016), have reported the distance to be 22.8 mm on right side while 21.7 mm on the left side. The results of the present study are similar to both Kilarkaje et al. (2005), and Ghoraj et al. (2016), as the measured mean distances were 22.88 mm on right side and 23.22 mm on the left side. Kilarkaje et al. (2005), from their study have also reported that the foramen maintains bilateral symmetry in dry mandibles in all ages. In the present study, Bilateral symmetry of the distance of the foramen from various landmarks of the Ramus Mandibulae ranged from 22% to 34% only. In the vertical dimension, the foramen was found at mean distance of 17.41 mm on right side and 18.01 mm on left side from the mandibular notch in our study. Ennes and Medeiros (2009) found that this distance from mandibular notch in Brazilian Population was 18.30 mm on right side and 17.50 mm on the left side. When it was taken in reference to the midpoint of height of ramus, Mandibular foramen was located 1.19 mm superior to midpoint on right side while 1.05 mm superior to midpoint on left side. This is in sharp contrast to our study as well as the study carried out by Nicholson (1938). According to Nicholson (1938), the foramen was predominantly located at the center of the ramus of the

Table 4. Table comparing location of foramen with other geographical regions from previous studies with the present study.

Study Conducted& the Year	Country of Study	Lines (in mm)									
		AF		BF		CF		DF		EF	
		Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side
Mbajiorgu EF (2000)	Zimbabwe	18.95	14.30	22.50	28.44	-	-	-	-	-	-
Oguz & Bozkir (2002)	Turkey	16.90	16.78	14.09	14.37	22.37	22.17	-	-	-	-
Ennes & Medeiros (2009)	Brazil	09.40	06.90	08.60	08.40	18.30	17.50	-	-	-	-
Prado et al. (2010)	Brazil	19.20	18.80	14.20	13.00	23.60	23.10	-	-	-	-
Prajna P. et al. (2013)	India	15.72	16.23	13.29	12.73	22.70	22.27	21.54	21.13	-	-
Hoque et al. (2013)	Bangladesh	16.34	16.27	14.14	14.04	22.29	22.18	-	-	16.70	16.72
Afadhali D. et al. (2014)	Tanzania	19.88	20.19	12.69	12.65	21.54	20.70	26.23	25.68	-	-
Kumari S. et al. (2015)	India	16.00	16.27	10.21	10.28	20.48	20.15	24.15	24.86	12.31	10.93
Wandee et al. (2015)	Thailand	-	-	12.70	17.50	-	-	-	-	-	-
Asma Saher et al. (2015)	Pakistan	17.69	17.65	12.03	11.84	20.51	21.03	-	-	-	-
Gopalkrishnan K. et al. (2016)	India	14.63	15.31	12.34	13.51	21.23	21.16	22.14	22.10	14.37	19.26
Jin Hoo Park et al. (2018)	South Korea	19.69	14.41	21.56	25.18	-	-	-	-	-	-
Present Study	Latvia	16.88	17.33	12.31	11.75	17.41	18.01	19.80	20.11	22.88	23.22

mandible. Soames RW. (1995), also concluded like Ennes and Medeiros (2009) that the foramen was located above the center of the *Ramus Mandibulae* on the medial surface. Mbajiorgu EF. (2000) reported that the foramen is located approximately 8 mm above the midpoint of Ramus Mandibulae height on both sides in the Zimbabwean population. The distance from the foramen to the inferior border of the Angle of Mandible was 19.80 mm on right and 20.11 mm on left side in this study. Again, when compared with studies on different ethnic groups we notice some differences (Afdhali and Flora, 2014; Gopalakrishna K. et al., 2016; Jin Hoo et al., 2018; Mbajorgu EF, 2000; Prajna and Poonam, 2013; Sandhya K. et al., 2015).

The reader may argue that many new diagnostic techniques are available these days in the clinics including the Intraoral Periapical (IOPA), Orthopantomograms (OPG) and Cone beam Computed Tomography (CBCT). Although these may have become a routine, still the "old-school" technique of morphometric measurements of mandibular foramen plays a crucial role in the development and application of Local Anesthesia administering techniques. Knowing the position of the foramen before-hand gives an assurance as well as confidence to the doctor. It gives the doctor a benchmark to compare to while analyzing the foramen for any deformities as well as diseases. It also is useful in patients that show extreme signs of gagging and with patients who can`t afford these diagnostic tools given the relatively high costs associated with them.

Dental Surgeons, Prosthodontists, Endodontists and practicing dental graduates can utilize this information on the locus of the foramen during administering local anesthesia involving the Inferior Alveolar Nerve for different procedures such as dental extractions, placement of mandibular implants and other therapeutic procedures involving Mandibles in the local population. Clinicians can also use internal oblique ridge as a reference point for planning different techniques of Inferior Alveolar Nerve Block.

Conclusions

The precise localization of Mandibular foramen is very important to achieve a successful Inferior Alveolar Nerve Block, prior to dental surgeries in the lower jaw. The present study concludes that the knowledge of the pinpoint position of Foramen Mandibulae with respect to its normality and laterality is important for planning and conducting dental surgeries, which will help for effective management, better clinical results and prognosis. Comparison from other studies shows that geographical, genetic and dietary variations does exist and hence knowing its position in native population is essential as it plays a crucial role in success of "pain-less" and "patient friendly" surgical procedures._

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Conflicts of Interest

None of the authors declare any conflicts of interest.

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