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Morphological Study of the Mandibular Foramen in Dry Human Mandibles in Northeastern Brazil

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ABSTRACT

Introduction: the mandibular foramen (MF) is an irregular opening in the internal surface of the mandibular ramus. The inferior alveolar nerve and vessels penetrate this foramen and extend through the mandibular canal to the mentual foramen. Variations in MF position are responsible for errors in anesthetic blocks of the inferior alveolar nerve and other surgical interventions on the mandibular ramus.

Objectives: to analyze morphometrically the MF of both edentulous and dentate mandibles in Northeastern Brazil.

Methodology: the sample consisted of 172 adult human mandibles (106 partially dentate and 66 edentulous) of undetermined age and gender from Northeastern Brazil. Linear measurements were performed bilaterally of the MF to the anterior and posterior margin of the mandibular ramus, the mandibular incisure, the mandibular angle and the mandibular condyle. Laterality and dentition were considered in the analysis.

Results: difference was observed between dentate and edentulous mandibles in the distance MF-A ($p=0.004$), MF-D ($p<0.001$) and D-E ($p < 0.001$). No differences were observed in the distance MF-B ($p=0.642$) and FM-C ($p=0.116$) between partially dentate and edentulous mandibles. Regarding the comparison between the right and left sides, both in partially dentate and edentulous groups, no differences were observed ($p>0.05$).

Conclusion: the morphometric analysis of the MF presented some differences between partially dentate and edentulous mandibles, but not between antimers. These differences may be related to greater bone wear and other factors. Caution must be exercised regarding bone deterioration in mandibles, especially considering that the dentition is a determining factor for the location of the MF.

Keywords: Anatomy; Bone; Mandibular Foramen.

Introduction

The mandibular foramen (MF) is an irregular opening in the internal surface of the mandibular ramus[1]. The inferior alveolar nerve and vessels penetrate this foramen and extend through the mandibular canal to the mental foramen on the lateral surface of the mandibular body to supply the inferior teeth and adjacent structures[2].

The location of the MF is used as a reference point for needle positioning in anesthetic blocks of the inferior alveolar nerve and for planning surgical interventions in the mandibular ramus region[3]. However, the location of the MF is not the same in all individuals, presenting variations in its location, one of the main causes of failure of this techniques[4].

The absence of a specific bony anatomical reference, the variations in width and height of the mandibular ramus and the position of the MF are responsible for errors in anesthetic blocks of the inferior alveolar nerve. Some authors estimate a failure rate of about 20-25% in this surgical procedure[5]. The determination of the location of the MF in relation to other anatomical points of the mandible can contribute to the prevention of injuries resulting from the lesion of the inferior alveolar neurovascular bundle. Intraoperative hemorrhages and temporary or permanent neurosensory alterations, such as paresthesias of the lower lip and chin skin, can be avoided with a detailed anatomical knowledge of the region[6,7,8].

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Thus, the aim of this study was to analyze morphometrically the MF of cadaveric mandibles in Northeastern Brazil to provide anthropological data of this population in order to improve anatomical knowledge for safer clinical and surgical interventions in this region.

Materials and Methods

A total of 172 dry adult human mandibles (106 partially dentate and 66 edentulous) of undetermined age and gender (as they were not recorded at the time of acquisition) from Northeastern Brazil were analyzed, belonging to the Morphology Department of Paraiba Federal University. Damaged mandibles, mandibles of children or affected by any pathology were excluded from the study. To determine the mandibles of children, the presence of parallel branches in the mandibles of children and the absence of third molars were considered. Mandibles with preserved teeth or alveolar processes were classified as partially dentate and the others without evidence of dental elements or alveolar processes as edentulous. Then, using a digital caliper with an accuracy of 0.01 mm (Eccofer®, João Pessoa, Paraíba, Brazil), the linear measurements were taken bilaterally as shown in Figure 1.

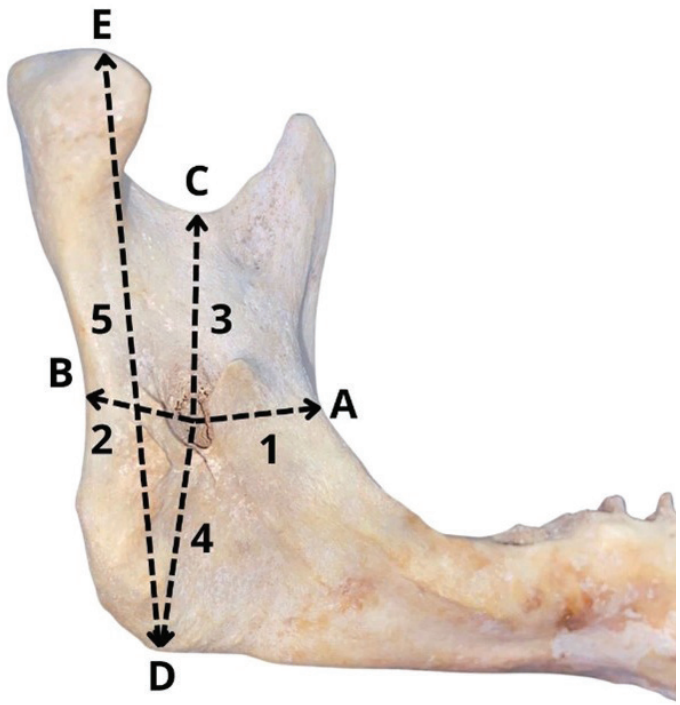

Figure 1. Linear measurements of the mandibular foramen.
Legend: (1) MF-A: Distance of MF to the most concave part of the anterior margin of the mandibular ramus; (2) MF-B: Distance of MF to the most concave part of the posterior margin of the mandibular ramus; (3) MF-C: Distance of MF to the lowest point of the mandibular incisure; (4) MF-D: Distance of MF to the mandibular angle; (5) D-E: Distance of the mandibular angle to the most convex point of the mandibular condyle.

For data analysis, the 2016 version of Word and Excel were used to record the measurements and descriptions. Shapiro-Wilk test was used to verify the normal distribution of the data. For descriptive analysis, the mean was used as a measure of central tendency in parametric data and the median was used as a measure of central tendency in non-parametric data. The standard deviation was used as a measure of dispersion in the parametric data and the IQR was used as a measure of central tendency in the non-parametric data. T test for independent samples was applied to evaluate the difference between the right and left sides of the morphometric parameters in the parametric data analyzed and Mann Whitney test was applied to analyze the difference between the partially dentate and edentulous of the same morphometric parameters in the non-parametric data. The data processing was done in Jamovi software version 2.3.21.

The present study was selected in accordance to the Brazilian Federal Law 8.501 (November 30, 1992). An institutional and ethical approval (CAAE number registration: 58097822.0.0000.5188 - Medical Sciences Center of the Federal University of Paraíba, Brazil) was obtained.

Results

In our study, 172 mandibles were included, 106 (61,63%) partially dentate and 66 (38,37%) edentulous. Table 1 presents the data referring to the linear measurements of MF-A, MF-B, MF-C, MF-D and D-E for dentate and edentulous mandibles. When antimeres were considered in the sample, it was observed a difference in the distance MF-A on the right (13.8mm ± 3.87 versus 14.9mm ± 3.82) and left side (13.17mm ± 3.53 versus 15.10mm ± 3.81) between partially dentate and edentulous mandibles ($p<0.05$). Differences were also observed for the MF-D (24.6mm ± 6.3 versus 22.6mm ± 4.3 on the right side and 24.5mm ± 6.3 versus 21.9mm ± 5.5 on the left side) and D-E (62mm ± 9.6 versus 59.1mm ± 10.1 on the right side and 60.4mm ± 9.4 versus 57.5mm ± 6.7 on the left side) measurements ($p<0.001$). No statistical difference was observed in the measures MF-B, MF-C ($p>0.05$).

When antimeres were not considered in the sample, it was observed a difference between dentate and edentulous mandibles in the distance MF-A ($p = 0.004$), MF-D ($p < 0.001$) and D-E ($p<0.001$). No differences were observed in the distance MF-B ($p=0.642$) and MF-C ($p=0.116$) between partially dentate and edentulous mandibles.

Regarding the comparison between the right and left sides, both in partially dentate and edentulous groups, no differences were observed ($p>0.05$).

Table 1. Median or Mean distance (mm) ± SD or IQR values of the morphometric analysis of mandibular foramen in both sides (right and left) of dentate and edentulous mandibles (N=172).

Measurements	Dentate mandible		Edentulous mandible		Dentate x Edentulous*	Right x Left**
	Right	Left	Right	Left	p-value	p-value
MF-A	13.8±3.87	13.7±3.53	14.9±3.82	15.1±3.81	<0.05	0.969
MF-B	12.8±2.9	12.3±2.5	13.2±3.1	12.8±2.7	0.642	0.191
MF-C	20.5±5.2	19.5±5.2	19±4.9	19.3±5.9	0.116	0.308
MF-D	24.6±6.3	24.5±6.3	22.6±4.3	21.9±5.5	< 0.001	0.682
D-E	62±9.6	60.4±9.4	59.1±10.1	57.5±6.7	< 0.001	0.088

Legend: MF-A: Distance of MF to the most concave part of the anterior margin of the mandibular ramus; MF-B: Distance of MF to the most concave part of the posterior margin of the mandibular ramus; MF-C: Distance of MF to the lowest point of the mandibular incisure; MF-D: Distance of MF to the mandibular angle; D-E: Distance of mandibular angle to the most convex point of the mandibular condyle. MF-A values are described as mean ± SD. The other linear measurements were described as median ± IQR.
*Comparison between edentulous and dentate mandibles without considering their laterality.
**Comparison between the right and left sides without considering the dentition of the mandibles.

Discussion

The mandibular foramen is an important reference point for anesthetic blocks of the inferior alveolar nerve and for planning surgeries in the region of the mandibular ramus. Anatomical knowledge of this region is essential to preserve the neurovascular structures related to this foramen, avoiding lesions and loss of local sensitivity. In addition, structures adjacent to the posterior mandibular ramus region, such as the parotid gland and the facial nerve, can also be injured during anesthesia by incorrect positioning of the needle, causing paralysis and intense discomfort to the patient[9]. Therefore, it is essential that surgeons know the morphological patterns of the mandibular foramen and its possible variations in their routine.

The present study performed a morphometric analysis and interesting findings were observed when compared to the literature[9,10,11,12,13,14,15,16,17,18,19]. It was possible to observe that there is a considerable number of studies analyzing the morphometry of the mandibular foramen from different populations, of different ethnic groups and presenting a large variability in their results (Tables 2 and 3). It is important to note that the anatomical region that was the object of this study has several works published in Brazil (Table 2), which contrasts with previous studies by our group when we morphometrically evaluated other skull anatomical landmarks with clinical and surgical interest[20,21,22].

First, it is important to note that differences between the studies may be related to the methodology applied in data collection. Our study, and Lalitha, Sridevi and Rao[14], for example, adopted the center of the mandibular foramen as a reference point for the measurements. Braga *et al.*[9], Ennes and Medeiros[11], Matveeva *et al.*[16] and Shalini *et al.*[18], in contrast, considered the edges of the mandibular foramen as parameters for their measurements, most of the time using the anterior edge of the MF for the MF-A measurement, the posterior edge of the MF for the FM-B measurement, and the medial edge of the MF for the MF-C and MF-D measurements. This could probably explains why the MF-C measurement in a Brazilian study[11] may have had higher values than in the other studies, since the lower edge of the MF results in the greatest possible distance from the mandibular notch to the MF. Two Brazilian studies[15,19], one Indian[13] and one Turkish study[10] considered the apex of the mandibular foramen as the reference point for the MF, while Hoque *et al.*[12] did not specify the exact location used as reference for the MF.

In this study, a difference was observed in MF-A, MF-D and D-E measurements between dentate and edentulous mandibles (p<0.05). The existing literature indicates that the level of preservation of dental elements can influence the anatomical parameters of the mandible, and this includes the mandibular foramen[23,24,25]. This difference between dentate and edentulous mandibles may be related to greater bone wear resulting from the absence of teeth, which causes changes in the alveolar ridge, unlike the presence of teeth, which stimulates greater bone deposition by the body. Other factors such as age and eating habits can also cause greater bone wear and cause anatomical differences[26,27]. Matveeva *et al.*[16] also noted a difference in the MF-B value when comparing the edentulous and dentate mandible groups on the right side.

In this study, there was no difference between the right and left sides, which agrees with other studies in the literature[9,12,14,18]. However, Kaur *et al.*[13] and Matveeva *et al.*[16] noted a difference when comparing the right and left sides of edentulous mandibles for MF-B measurement (p<0.05). For Matveeva *et al.*[16], the possible differences between the dentition of the two sides of the mandible can lead to a different tooth loss between the sides, causing an unequal absorptive change and, consequently, a difference between the measurements of the two hemispheres of the mandibular ramus. In addition to this factor, we

Table 2. Comparison of the morphometric analysis of the mandibular foramen in different populations of Brazil (Values in mm).

Author			Present study	Braga *et al.*[9]	Porto *et al.*[17]	Valente *et al.*[19]	Lima *et al.*[15]	Ennes and Medeiros[11]
Country			Brazil	Brazil	Brazil	Brazil	Brazil	Brazil
MF-A	Dentate mandible	Right	13.8±3.87	11.36±2.3	17.9±2.5	16.94±2.55	19.48± 2.7	14.6±2.9
		Left	13.7±3.53	12.26±2.7	17.7±2.1	17.32±2.23	19.96±3.07	14.6±3.2
	Edentulous mandible	Right	14.9±3.82	-	-	-	-	13.9±3.0
		Left	15.1±3.81	-	-	-	-	14.3±2.8
MF-B	Dentate mandible	Right	12.8±2.9	-	13.8±2.1	14.24±2.46	-	12.1±2.3
		Left	12.3±2.5	-	13.7±1.9	14.03±2.33	-	12.3±2.3
	Edentulous mandible	Right	13.2±3.1	-	-	-	-	10.6±2.1
		Left	12.8±2.7	-	-	-	-	11.1±1.6
MF-C	Dentate mandible	Right	20.5±5.2	14.76±2.7	20.2±3.5	24.12±3.14	27.7±4.73	24.3±3.3
		Left	19.5±5.2	15.30±3.1	19.6±2.9	23.65±2.74	27.32±3.93	24.4±3.6
	Edentulous mandible	Right	19±4.9	-	-	-	-	22.1±3.9
		Left	19.3±5.9	-	-	-	-	21.3±3.8
MF-D	Dentate mandible	Right	24.6±6.3	21.68±4.1	26.4± 4.3	-	24.27±3.89	22.3±4.8
		Left	24.5±6.3	21.22±3.7	26.2± 4.23	-	24.97±6.41	22.4±5.1
	Edentulous mandible	Right	22.6±4.3	-	-	-	-	18.8±3.3
		Left	21.9 ± 5.5	-	-	-	-	19.4±3.6
D-E	Dentate mandible	Right	62±9.6	-	-	-	-	-
		Left	60.4±9.4	-	-	-	-	-
	Edentulous mandible	Right	59.1±10.1	-	-	-	-	-
		Left	57.5±6.7	-	-	-	-	-

Legend: MF-A: Distance of MF to the most concave part of the anterior margin of the mandibular ramus; MF-B: Distance of MF to the most concave part of the posterior margin of the mandibular ramus; MF-C: Distance of MF to the lowest point of the mandibular incisure; MF-D: Distance of MF to the mandibular angle; D-E: Distance of mandibular angle to the most convex point of the mandibular condyle.

believe that this difference may be due to racial factors and eating habits.

Some studies[28,29,30,31] have already evidenced that age and gender may be factors that influence bone deposition and functioning of the musculoskeletal system. Consequently, these factors can influence the morphology of the mandibular foramen. A Brazilian study observed a difference in function of gender for the MF-C and MF-D measurements, without taking laterality into consideration[9]. Similarly, but considering the laterality, another Brazilian study also observed a difference in the position of the mandibular foramen in function of gender for the FM-C measurement on the right (p=0.001) and left sides (p=0.015) and for the FM-D measurement on the left side (p=0.002) [17]. Altun *et al.*[10] also noted that all the measurements collected had higher mean values for women, and in three of these measurements there was a statistical difference: MF-B (0.002), MF-C (0.001) and MF-D (0.0001). Regarding the aging, a Brazilian study[17] found a difference in the FM-D measurement between the age groups 10 to 20 and 21 to 30 years (p=0.044). Thus, these results demonstrate that several factors can morphologically influence the mandibular foramen.

This study attempted to expand the morphometric data related to the mandibular foramen. We included the D-E measurement, which is not widely described in the literature, but can help health professionals as a reference point in surgical practice. A limitation of this study was that other structures related to the mandibular foramen were not highlighted, such as vessels, nerves, and other soft tissues, since dry mandibles were analyzed. Moreover, it was not possible to classify the mandibles by biotype, gender, age groups, eating habits and socioeconomic conditions, factors that could help us to further interpret the data collected in this study. In addition, the measurements were collected by only one observer, and perhaps an average of the measurement from two observers would ensure a reduction in the chances of methodological errors. However, the results generated from this study can help health professionals to have a

Table 3. Comparison of the morphometric analysis of the mandibular foramen in different populations around the world (Values in mm).

Author			Present study	Matveeva *et al.*[16]	Hoque *et al.*[12]	Lalitha *et al.*[14] *	Kaur *et al.*[13]	Shalini *et al.*[18] *	Altun *et al.*[10] *
Country			Brazil	Macedonia	Bangladesh	India	India	India	Turkey
MF-A	Dentate mandible	Right	13.8±3.87	14.27±2.82	16.34±1.97	**Right** 16.52±2.25	16.41±2.42	**Right** 17.11±2.74	**Right** 18.31±1.98
		Left	13.7±3.53	14.16±3.06	16.27±1.91		16.18±2.47		
	Edentulous mandible	Right	14.9±3.82	13.94±2.97	-		-		
		Left	15.1±3.81	14.23±2.79	-	**Left** 17.77±2.51	-	**Left** 17.41±3.05	**Left** 18.23±1.95
MF-B	Dentate mandible	Right	12.8±2.9	10.68±2.19	14.14±2.36	**Right** 14.05±2.19	13.51±2.10	**Right** 10.47±2.11	**Right** 11.22±2.06
		Left	12.3±2.5	10.75±2.24	14.04±2.32		14.16±2.27		
	Edentulous mandible	Right	13.2±3.1	9.23±1.8	-		-		
		Left	12.8±2.7	9.86±2.02	-	**Left** 13.90±2.35	-	**Left** 9.68±2.03	**Left** 11.36±1.56
MF-C	Dentate mandible	Right	20.5±5.2	22.63±3.37	22.29±3.43	**Right** 20.14±2.5	23.44±3.86	**Right** 21.74±2.74	**Right** 18.40±2.62
		Left	19.5±5.2	22.41±3.20	22.18±3.32		23.05±3.99		
	Edentulous mandible	Right	19±4.9	23.36±3.16	-		-		
		Left	19.3±5.9	23.51±3.55	-	**Left** 19.85±3.15	-	**Left** 21.92±3.33	**Left** 18.75±2.62
MF-D	Dentate mandible	Right	24.6±6.3	22.94±3.09	-	**Right** 27.41±4.16	23.85±4.21	**Right** 22.33±3.32	**Right** 31.31±3.28
		Left	24.5±6.3	22.74±3.74	-		24.81±4.77		
	Edentulous mandible	Right	22.6±4.3	21.77±3.23	-		-		
		Left	21.9±5.5	21.8±2.27	-	**Left** 26.76±4.14	-	**Left** 25.35±4.5	**Left** 31.26±3.73
D-E	Dentate mandible	Right	62±9.6	-	-	-	-	-	-
		Left	60.4±9.4	-	-	-	-	-	-
	Edentulous mandible	Right	59.1±10.1	-	-	-	-	-	-
		Left	57.5±6.7	-	-	-	-	-	-

Legend: MF-A: Distance of MF to the most concave part of the anterior margin of the mandibular ramus; MF-B: Distance of MF to the most concave part of the posterior margin of the mandibular ramus; MF-C: Distance of MF to the lowest point of the mandibular incisure; MF-D: Distance of MF to the mandibular angle; D-E: Distance of mandibular angle to the most convex point of the mandibular condyle. * These studies did not classify the mandibles in dentate and edentulous. They only evaluated the difference between the antimers.

better anatomical knowledge about the region of the mandibular foramen so that they can perform safer procedures, especially in northeastern Brazil.

Conclusion

The morphometric analysis of the MF conducted in this research presented a difference in the MF-A, MF-D and D-E distance between partially dentate and edentulous mandibles, but not between antimers. Caution must be exercised regarding bone deterioration in edentulous mandibles, especially considering that the dentition is a determining factor for the location of the mandibular foramen. The differences between edentulous and partially dentate mandibles may be related to greater bone wear resulting from the absence of teeth. Other factors, such as age and dietary habits, can also cause greater bone wear and respective anatomical differences. Further studies are needed to compare and establish the localization pattern of the mandibular foramen. Disseminating this morphological information in the scientific community regarding the morphometry and variations of the mandibular foramen are essential for safer invasive and non-invasive procedures in this region.

Ethics Statement

The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research[32].

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Mini Curriculum and Author's Contribution

1. Marcílio Ferreira de Paiva Filho: discussion of the results and writing of the manuscript.
2. Lucas Brito Meira: discussion of the results and writing of the manuscript.
3. João Vítor Andrade Fernandes: discussion of the results and writing of the manuscript.
4. Artur Gomes Mendes: discussion of the results and writing of the manuscript.
5. Danyelle Leite Furtado de Araújo: discussion of the results and writing of the manuscript.
6. Rebeca Andrade Laurentino: discussion of the results and writing of the manuscript.
7. Bruna Kelly Oliveira Santos: discussion of the results and writing of the manuscript.
8. João Argel Candido da Silva: discussion of the results and writing of the manuscript.
9. Jalles Dantas de Lucena: discussion of the results and writing of the manuscript, conception and design of the study.

10. Olavo Barbosa de Oliveira Neto: discussion of the results and writing of the manuscript, conception and design of the study.

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