Anatomical Variation in the Mandibular Foramen in Non-Atrophic and Atrophic Mandibles

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ABSTRACT

Objectives: Previous studies of variation in mandibular foramen characteristics with age have involved comparison in different populations, but few data, between non-atrophic and atrophic mandibles are available. The aim of this original article was to compare the position, shape and area of the mandibular foramen between non-atrophic and atrophic mandibles.
Material and Methods: Morphometric methods were used to study the mandibular foramen variation. Fifty adult dry mandibles from the laboratory of anatomy were selected. Mandibles were considered non-atrophic if the distance between the base and alveolar ridge was homogeneous and greater than 25 mm in the anterior region and 20 mm in the posterior region. Conversely, mandibles were considered atrophic if that distances were lower than those described to a minimum of 11 mm in all areas. All measurements were performed with a digital caliper. For statistical analysis, the admitted level of significance was 5%.
Results: When non-atrophic mandibles were compared to atrophic ones, the mandibular foramen shifted significantly to an anterior position (mean difference [MD]: 4.81 mm; $P < 0.0001$) and to an inferior position (MD: 3.04 mm; $P < 0.0001$) and changed from an elliptical shape to round one, with a significant decrease in its area (MD: 3.66 mm^2; $P < 0.05$).
Conclusions: The results indicate that there are significant differences in the position, shape and area of the mandibular foramen between non-atrophic and atrophic mandibles. These data should be considered in anaesthetic techniques and surgical procedures to prevent vascular and nervous lesions.

Keywords: anatomy; atrophy; humans; mandible; mental foramen.

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INTRODUCTION

The mandible arises from the ossification of the embryonic tissue called ectomesenchyme [1,2]. The mandibular foramen (MF) is an opening in the medial part of the mandibular ramus [3]. It marks the entrance of the mandibular canal, which connects the mandibular and the mental foramen [4]. In the MF penetrates the artery and the inferior alveolar vein, which constitute together with the inferior alveolar nerve a neurovascular bundle [5,6]. The alveolar inferior nerve originates the mental nerve that crosses the mental foramen [6]. Mandibular atrophy that occurs predominantly after dental loss may modify the positions of the bundle [7]. The knowledge of the position of the MF and the structures that cross through that are extremely important for dental surgeons [8,9] specially when they used anaesthetic techniques like the pterygomandibular technique. It aims to block, among other nerves, the inferior alveolar nerve, before it penetrates in the MF [10]. Nervous or vascular lesions can occur during this procedure [11]. The correct position of the MF and the mandibular canal can be evaluated by panoramic radiography and mainly by mandible computed tomography. Using three-dimensional reconstruction associated with three-dimensional printing, surgical guides can be prepared. These guides will assist the surgeon in intraoperative procedures [12]. Implants must be positioned carefully in molar and premolar regions mainly in those cases with limited vertical alveolar bone what is verified in atrophic mandibles [11,12]. Moreover, these surgical guides can be used to perform an osteotomy in orthognathic surgery [12]. In these osteotomies, the inferior alveolar nerve is the structure that most suffers lesions [13-15]. Therefore, preoperative planning, early detection of sensory disturbance, and adequate treatment are fundamentals in these surgical procedures [11,15]. This article aimed to evaluate the position, shape and area of the mandibular foramen in non-atrophic mandibles and investigate the alterations that can occur in atrophic ones.

MATERIAL AND METHODS

Ethical considerations

This project was carried out in the Human Anatomy Laboratory of the Nove de Julho University Center in Sao Paulo, Brazil, from August, 2017 to August, 2018. A letter of science and authorization was requested to the managers of the dentistry course for the use of cadaveric specimens. The present study was approved for the Ethical Committee of the University (Ethical Protocol number: 1.962.285).

Selection of the mandibles

Fifty adult dry mandibles were selected without distinction of age, sex, or ethnicity. The non-atrophic mandibles (NAT) were fully or partially dentate and the atrophic mandibles (AT) were edentulous. Mandibles were considered non-atrophic if the distance between the base and alveolar ridge was homogeneous and greater than 25 mm in the anterior region (point A, Figure 1) and 20 mm in the posterior region (points B and C, Figure 1). Conversely, mandibles were considered atrophic if the distances were lower than those described to a minimum of 11 mm in all areas. Mandibles measuring less than 11 mm were considered extremely atrophic and were not included in the analysis of this study. These measures are in agreement with the classification of mandibular atrophy degree proposed by Cawood and Howell [16] in 1988 and by Luhr et al. [17] in 1996. The measurements were performed

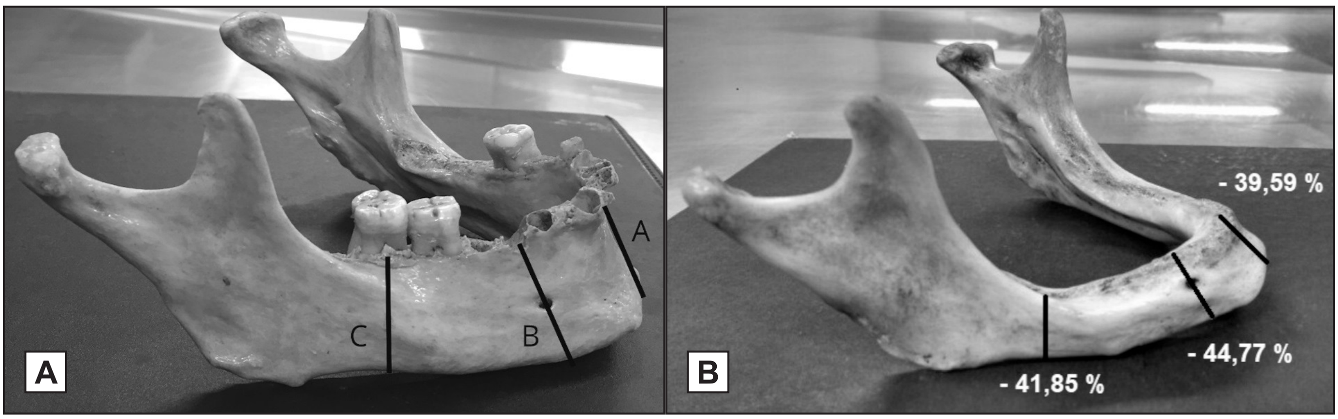

Figure 1. Comparison between non-atrophic and atrophic mandibles. A = points for measurement represented in a non-atrophic mandible; B = average decrease of the mandibular body represented in an atrophic mandible.

in the symphysis region (point A, Figure 1), bilaterally in the foramen mental region (point B, Figure 1) and bilaterally at a specific point in the posterior region of the mandible body (point C, Figure 1). This posterior point was determined by the mean distance between the mental foramen and the MF [16]. All linear measurements were performed with a digital caliper (150 mm capacity, 0.01 mm resolution, accuracy +/-0.03 mm - Digimess precision instruments Ltda; São Paulo, SP, Brazil) by two independent researchers (MBM, LCP). The average between the two measurements was considered [18].

Experimental procedures and data analysis

To evaluate the position of the MF in relation to ramus, straight lines from the geometric centre of the foramen were traced and measured to specific points. The first point was the most concave point of the oblique line, what was considered the anterior margin of the ramus (AM-MF) (Figure 2). The second point was the posterior margin of the ramus (PM-MF). The third point was the most concave point of the mandibular notch, this point was considered the superior margin of the ramus (SM-MF). The fourth and last point was the inferior margin of the ramus (IM-MF). These measures are in accordance with the methodology proposed by Lima et al. [9].

The antero-posterior and latero-lateral diameter of the MF was measured to evaluate their shape and determine if it was circular or elliptical. Afterwards, a formula was applied to determine the area:

$$A = \pi \times R \times r$$

Area is equal to 3.14 times the largest radius times the smallest radius [9].

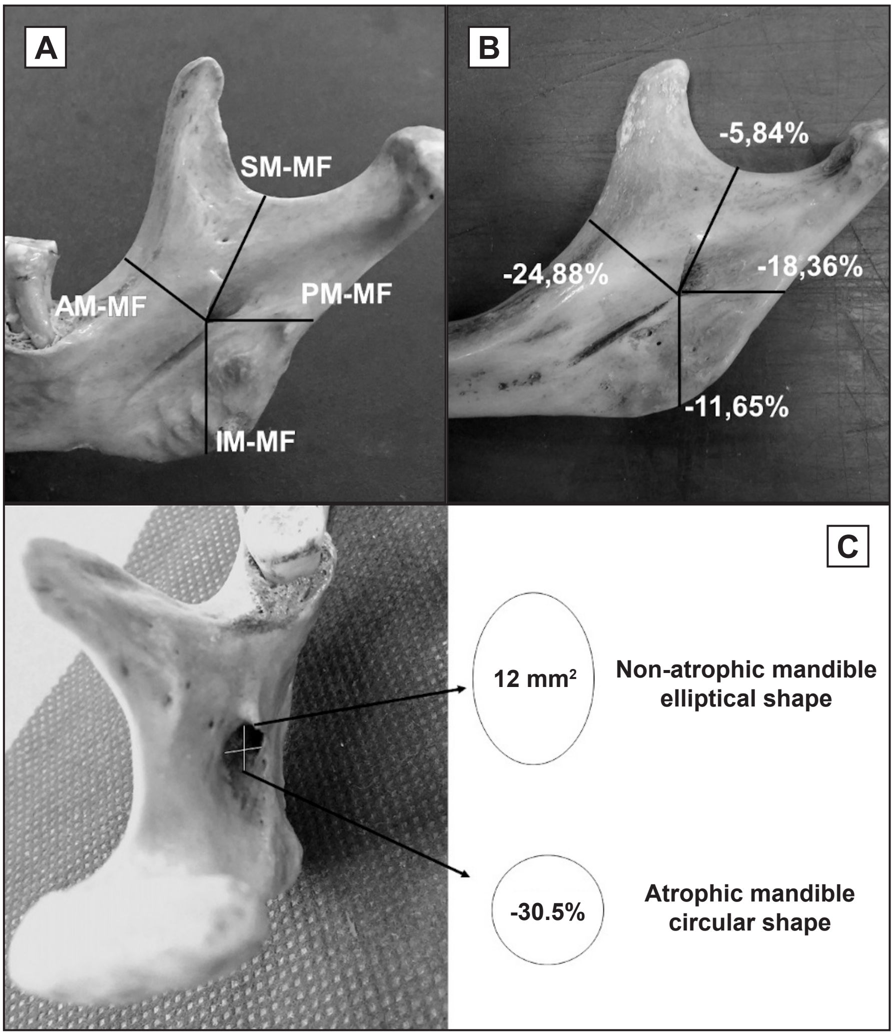

Figure 2. Mandibular foramen: position, shape and area. A = Position of the mandibular foramen to specific points of the ramus in a non-atrophic mandible; B = Average decrease of the measurements in an atrophic mandible; C = Representation of the shape of the foramen in both groups and average decrease of its area.
AM = anterior margin of the ramus; IM = inferior margin of the ramus; MF = mandibular foramen; PM = posterior margin of the ramus; SM = superior margin of the ramus.

Measurement of the gonial angle

Variations of the gonial angle will contributed to changes in MF position. The measurement of the gonial angle was performed with a goniometer at the junction of the inferior and posterior margins of the ramus of the mandibles according to the methodology proposed by Shenoy et al. [18].

Statistical analysis

The data were copied to Microsoft Office Excel program (Microsoft Corporation; Washington, USA) where they were tabulated and therefore, transferred to the GraphPad InStat v3.1 software (GraphPad Software Inc.; San Diego, California, USA). For comparison of the data between the sides of the same group or between the groups of NAT and AT mandibles, the Kolmogorov-Smirnov normality test was used, and later, when $P > 0.05$, the t-test with or without the Welch's correction was applied. If $P < 0.05$, when the Mann-Whitney test was performed. Parametric data were expressed as mean and standard deviation (M [SD]).

RESULTS

Measurement of atrophy

There were no statistically significant differences when comparing measures obtained from the right and left sides of the mandibles in the same group. There was a highly significant difference when was compared the height of the alveolar ridge at points A, B and C between the NAT and AT mandibles (Figure 1, Table 1).

Position of the mandibular foramen

No statistical differences in the position of the MF were observed when the right and left sides of the same group were compared.

The MF in NAT mandibles was closer to the points considered as the posterior margin and superior margin of the ramus when these distances were compared to the points considered the anterior margin and inferior margin of the ramus respectively. The AT mandible demonstrated a similar pattern, but the foramen dislocated its position significantly to an anterior and inferior point. The displacement was observed because the mandible presented a great resorption of the anterior, posterior and inferior margin of the ramus, but not of the superior margin. Therefore, the foramen is more centralized mainly in the superior-inferior axis (Figure 2; Table 2).

Regarding the morphology, which in the NAT mandibles was predominantly elliptical, with an antero-posterior distance greater than latero-lateral, became circular in the AT mandibles. Moreover, the area of the MF decreased significantly between the groups (Figure 2; Table 3 and 4).

Table 1. Comparison of the height of the alveolar at points A, B and C between the non-atrophic and atrophic mandibles

Point	Non-atrophic mandibles	Atrophic mandibles
	Mean (SD), mm	Mean (SD), mm
Point A[a]	31.39 (3.21)	18.96 (2.87)
Point B right[a]	31.58 (2.47)	17.41 (2.03)
Point B left[a]	30.81 (2.44)	17.04 (2.07)
Point C right[a]	26.99 (2.55)	15.29 (2.29)
Point C left[a]	26.17 (2.32)	15.62 (2.12)

[a]Statistically significant at level $P < 0.0001$ (t-test).
SD = standard deviation.

Table 2. Comparison of the position of the mandibular foramen between the non-atrophic and atrophic mandibles

Distance	Non-atrophic mandibles	Atrophic mandibles
	Mean (SD), mm	Mean (SD), mm
AM-MF right[a]	19.18 (1.84)	14.54 (2.9)
PM-MF right[a]	14.69 (2.61)	11.83 (1.47)
SM-MF right[a]	23.26 (3)	21.2 (3.78)
IM-MF right[a]	25.89 (3.94)	23.6 (3.39)
AM-MF left[a]	19.48 (1.82)	14.51 (2.7)
PM-MF left[a]	14.18 (2.44)	11.73 (1.46)
SM-MF left	22.24 (3.3)	21.65 (3.58)
IM-MF left[a]	25.95 (3.44)	22.2 (3.47)

[a]Statistically significant at level $P < 0.0001$ (t-test).
AM = anterior margin of the ramus; IM = inferior margin of the ramus; MF = mandibular foramen; PM = posterior margin of the ramus; SM = superior margin of the ramus; SD = standard deviation.

Table 3. Comparison of the shape of the mandibular foramen between the non-atrophic and atrophic mandibles

Diameter	Non-atrophic mandibles	Atrophic mandibles
	Mean (SD), mm	Mean (SD), mm
AP right[a]	4.4 (0.92)	3.16 (0.72)
AP left[a]	4.23 (1.13)	3.21 (0.81)
LL right	3.46 (0.73)	3.41 (0.81)
LL left	3.5 (0.61)	3.18 (0.91)

[a]Statistically significant at level $P < 0.0001$ (t-test).
AP = antero-posterior distance; LL = latero-lateral distance; SD = standard deviation.

Table 4. Comparison of the area of the mandibular foramen between the non-atrophic and atrophic mandibles

Area	Non-atrophic mandibles	Atrophic mandibles
	Mean (SD), mm	Mean (SD), mm
MF right[a]	12.1 (4.27)	8.44 (2.81)
MF left[a]	11.9 (5.03)	8.25 (3.89)

[a]Statistically significant at level P < 0.05, t-test, Welch's correction.
MF = mandibular foramen; SD = standard deviation.

Values of the gonial angle

No statistical differences were observed in the gonial angle when the right and left side of the same group were compared, but the angle increased significantly when NAT mandibles were compared to AT mandibles (Table 5).

Table 5. Comparison of the gonial angle between non-atrophic and atrophic mandibles

Angle	Non-atrophic mandibles	Atrophic mandibles
	Mean (SD)	Mean (SD)
Right[a]	121.4° (8.17°)	128.9° (7.07°)
Left[a]	121.9° (7.29°)	128.96° (6.61°)

[a]Statistically significant at level P < 0.0001 (t-test).
SD = standard deviation.

DISCUSSION

In this study, morphometric and morphological data about the MF were obtained and compared between NAT and AT mandibles. There are two major findings in the present study. First, the knowledge of the position and shape of the MF in both NAT and AT mandibles are important for performing anaesthetic and surgical techniques in these regions. This is the first demonstration of these changes in morphology and area of the MF when NAT and AT mandibles are compared. Second, the mandibular atrophy is not equally distributed and occurs mainly because of dental loss, which leads to loss of masticatory function and atrophy of the chewing muscles. This is important in clinical practice, because these alterations can be partially reversed with oral rehabilitation [19]. Muscle strength directly influences the shape of the mandible [20]. In this article, resorption zones were detected and compared. Therefore, it contributes to the understanding of this process in mandibles.

The knowledge of the position and shape of the MF in both NAT and AT mandibles are part of the morphometric and morphological studies that adopt specific reference points to position this foramen. MF is located on the medial side of the mandibular ramus. In most studies the anterior reference point is the most concave region of the anterior margin of the ramus, and the superior one is the most concave region of the mandibular notch [9,21-23]. But the points adopted as posterior and inferior references vary widely. In this study, the points assumed as references to the measurements are according to Lima et al. [9].

The present study did not find a significant difference between the right and left sides when the position and shape of the MF were compared in each group NAT and AT mandibles. It is in accordance with the literature [16,21-27].

In addition, it was found that MF in the NAT mandibles was displaced to superior and posterior. These data are in agreement with other studies in the literature [7,9,16,21,26,28].

In the present study, the mandibular atrophy process shows significant resorption in the anterior, posterior, and inferior regions of the mandibular ramus and the MF moved to anterior and inferior. The unique distance that did not change significantly was that between the foramen and the lower region of the mandibular notch, which is in agreement with Prado et al. [21]. However, Matveeva et al. [27] did not find resorption in the anterior part of the ramus.

A few studies in the literature reviewed, evaluated the MF area [9], and we did not find works comparing the shape and area of MF between NAT and AT mandibles. Through the MF runs a neurovascular bundle composed by the artery, vein and inferior alveolar nerve, these structures are separated and involved by connective tissue [4]. In the present study, the MF shape was elliptical, with greater antero-posterior diameter in NAT mandibles. This shape changed to round in AT mandibles, moreover the foramen area decreased significantly. Dental losses can explain these changes. The NAT mandibles evaluated were mostly partially dentate. The dental losses bring to the atrophy process, so there is a decrease in the necessity of blood supply and, therefore, in the diameter of the inferior alveolar artery [29,30]. The same happens in relation to the necessity of innervation thus, a decrease in the number of axons of the inferior alveolar nerve occurs too [31]. In this way, a reduction of the area of the neurovascular bundle and consequently a bone remodelling can be achieved, altering the shape, and decreasing the MF area.

Regarding clinical practice, it is recommended for inferior alveolar nerve block the use of long needles, which penetrate soft tissues up to 2/3 of their length [10]. In this study, the distance between the anterior border of the ramus and the MF was approximately 19.3 mm, so the penetration of the needle should be sufficient to reach the vicinity of the MF in the NAT mandibles and caution is need in the AT. If the needle exceeds MF and the anaesthetic was deposited near the most posterior margin of the ramus, diffusion to the parotid gland may occur. Therefore, the facial nerve can be reached, and a facial mimic muscles palsy will be observed [32,33]. Moreover, damage in the inferior alveolar neurovascular bundle can happen during the anaesthetic procedure [11]. In AT mandibles the morphological alterations observed in the position of the MF and the mandibular canal must be considered to place implants. The superficialization of the neurovascular bundle due to the resorption of the alveolar bone increases the technical difficulty. Early diagnostic of the injury and correct treatment are essential points to reach full recovery of the sensibility [11,34]

In addition to anaesthetic techniques, the mandible ramus is an area where osteotomies are performed to reposition the mandible due to aesthetic and functional problems [13,35,36]. In our study, the mean distance from the foramen to the posterior margin of the NAT mandibles was 14.3 mm and to the upper and anterior margin of the ramus were 22.7 and 19.3 mm. These distances were important in vertical and sagittal osteotomy techniques respectively and are in accordance which the results described in other studies that considered the same reference points [9,21-24].

In the clinical practice, both for anaesthetic techniques and osteotomies, the surgeon should also consider an alteration in the gonial angle when NAT mandibles are compared with AT. In this study, the mean of this angle was 121.6º in the NAT mandibles and 128.9º in AT. The increase of the gonial angle seems to be related to the degree of mandibular atrophy [37] what happens predominantly after dental losses [38,39]. Moreover, the increase in gonial angle can occur by the aging [40]. In addition, the angle appears to be lower in men than in women [41-43]. Changes in the shape of the mandible are related to the force exerted by the masseter and temporal muscles. Therefore, the smaller muscular force leads to an increase in the angle [20].

CONCLUSIONS

The results demonstrate a change in the position, shape and area of the mandibular foramen when non-atrophic mandibles were compared to atrophic ones. The mandibular foramen shifted significantly to an anterior and inferior position and changed from an elliptical shape to a round one with a significant decrease in its area. There was a significant increase in the gonial angle. These changes are related to atrophy that occurs in the mandible due mainly to dental losses. Anaesthetic techniques and surgical procedures should consider these changes to prevent vascular and nervous lesions.

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