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Study of the Mandibular Canal as an Indicator for Sexual Dimorphism

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ABSTRACT

Introduction: this study aimed to evaluate the volume of the mandibular canal in computerized tomography and to investigate if this anatomical structure presents sexual dimorphism and the probability to determine the sex from the mandibular canal volume by regression analysis.

Methods: Were used 125 computed tomography from adults dried human mandibles selected at random ranging in age from 19 to 100 years (48 females and 77 males). Software Mimics 18.0 was used to image segmentation and to create 3D reconstruction to obtain the volume of the mandibular canal. Statistical tests used were unpaired Wilcoxon-Mann-Whitney comparative test, considering the right and left mandibular canals separately. Regression analysis test was performed to verify the probability to determine the sex. Results showed no significant difference between the sides, p>0,05.

Results: The male distribution of the mandibular canal data was not parametric, considering the right canal separately. Mandibular canal volume presented statistical significance for sexual differentiation.

Conclusion: Our study presented the accuracy over 85% of the regression analysis show a great result to determined sex using the MC volume, should apply the formula in a different sample for best results. It is useful in forensic scenarios for systematic reassessment of cases and improvement of anthropologic methods used secularly.

Keywords: Forensic anthropology; Sex determination by skeleton; Sex characteristics; Mandible.

Introduction

The need for the identification of human remains is observed both in natural death and in disasters, in which bodies are decomposed, dismembered and / or mutilated in a way that recognition is not possible. Forensic anthropology studies showed the physical and biological factors of human remains in a legal and forensic context, such as sex, age, height, skin colour, dental characteristics, skull characters, bone alteration, among others. Forensic anthropology includes the study of bones, measurements in anatomical structures, and any data that may aid in the identification of an individual[1,2,3].

The use of imaging techniques is particularly important in the identification process, especially in forensic anthropology[4]. Computed tomography (CT) has been used for decades and has been shown to be effective in head and neck imaging for both clinical and forensic areas[5]. The images are more consistent with direct measurements, and virtual measurements can be used in cases of numerous post-mortem conditions, such as severe fire destruction[6]. CT enables the reconstruction of bone structures in three-dimensional models that can be viewed from different angles, and that respect perspectives when amplified in software specific for this purpose[7].

Determination of sex is one of the important parameters in establishing the biological profile of the unknown remains in the process of human identification. Some anatomical structures have important value in this search, especially in cases of cadavers in an advanced state of decomposition or bone fragmentation. The pelvis followed by skull is reported as the most reliable parts in sexing of adult skeletal remains using metric or non-metric approaches[8]. The differences between sexes and among ethnic groups regarding morphological characteristics of the mandible are determined by the environment and different growth patterns, making it possible to differentiate the sex by analysing various structures of the mandible[9]. The mandible is the strongest bone of the skull and the best preserved after death, especially in mass disasters[9,10,11], additionally, the mandible is one of the most useful anatomic resource to estimate ancestry, sex, age, and stature in fragmented human bones remains[5].

The mandibular canal (MC) is located inside the mandible body, beginning at the mandibular foramen, and externalizing in the mental foramen, and it may or may not continue its intra-osseous path towards the mental region, as a sole canal[12]. The neurovascular anatomy of the mandible has

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been studied in recent investigations due to the importance of its location before surgical procedures, such as implant an orthognathic surgery. Among the anatomical structures of the region, the MC, the lingual canal and the mental foramen are the most commonly cited in anatomical and radiological books[12,13,14].

Previous studies indicate that the relative position of MC and its mental foramen and mandibular foramen in adults present sexual dimorphism. These differences may have forensic value in determining the identity of human remains[3]. These studies evaluated sexual dimorphism in anthropometric measurements of the mandible in images obtained by cone beam computed tomography, created a logistic regression model that showed, along with other criteria, to be a suggestive bone in identifying the sex of an individual in the forensic scope[9].

Despite the recent studies being directed to surgical evaluation, it is believed that the MC and its variability may also serve as a unique identification framework in forensic applications, to make the use of a new three-dimensional anthropometric methodology possible, enhancing the accuracy of human identification in the legal and forensic scope. The aim of this study was to evaluate the volume of the MC in computed tomography and to investigate if this anatomical structure presents sexual dimorphism. In addition, we verified the probability to determine the sex from the MC volume by the regression analysis test.

Materials and Methods

Ethics

This research was approved by the Ethics Committee from Piracicaba Dental School of the University of Campinas (Protocol number: 133/2015).

Sample

A total of 125 CT scans from adults dried human mandibles selected at random ranging in age from 19 to 100 years, 48 female and 77 males, and acquired by the Aisteion Multislice 4 CT System (Toshiba Medical Systems Corporation - Japan), for the protocol of the skull: 100 MA, 120KV, with cuts of 1mm. CT scans of mandibles belongs to skeleton from a cemetery of Campinas city, São Paulo, Brazil.

Were included in this sample only CT scans that presented the data about sex and age, and the mandible with preserved and intact anatomical structures, without macroscopic deformities. Were excluded the CT scans with any anatomical abnormalities in the MC region, as well as individuals with implants, plates and screws or any other metallic artefact in the region, and tomography in which it was not possible to fully visualize the canals.

Computed tomography segmentation and 3D volume analysis

The Mimics 18.0 software (Materialise, NV, Belgium) was used to produce the segmentation of the images on each CT scan. In segmentation, we selected the region of interest (ROI) for marking MC of the mandibular foramen to the mental foramen in throughout its trajectory. Were selected the threshold to obtain voxels, whose values are in a range according to the anatomical components evaluated: MC (right and left sides).

After the segmentation, the software procedure the three-dimensional reconstruction of each MC.

After the segmentation and three-dimensional reconstruction process, Mimics 18.0 software (Materialise, NV, Belgium) was used to measure the volume (in mm^3) by voxel counting in each MC (Fig. 1). A single previously calibrated evaluator assessed each MC. The evaluator was trained to determine the MC throughout its trajectory, which was evaluated according to its anatomical characteristics observed in the tomography. After training, we established one unique ROI in this research based on images characteristics and MC morphology.

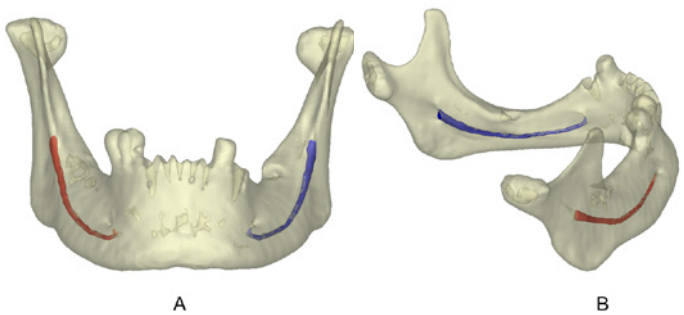

Figure 1. A) Anterior view of the mandible with MC highlighted in three-dimensional reconstruction in Mimics 18.0 software (Materialise, NV, Belgium) for volume measurement (in mm3). B) Posterolateral view of mandible with MC highlighted in three- dimensional reconstruction in Mimics 18.0 software (Materialise, NV, Belgium) for volume measurement (in mm3).

Statistical analysis

Statistical analysis was performed on R CRAN interface software for Linux, Inc. (Bell Laboratories, AT&T, Lucent Technologies). Shapiro-Wilk test was performed to evaluate the normality. The Student's t-test was used for the comparison of the data regarding the sides (right and left). Non-parametric Wilcoxon-Mann-Whitney test was used to compare the difference between females and males. Regression analysis test was performed to verify the probability to determine the sex from the MC volume and Receiver Operating Characteristic (ROC) curve was used for testing the overall ability of the variables in sex estimation. The significance level considered was of 5% for all statistical tests.

Results

The tables 1 and 2 showed the distribution of the sample and the mean of volume (mm3) of the MC according to the sides, left and right, respectively. The distribution was verified from Shapiro-Wilk test (Normality, $p>0.05$.).

Table 1. The distribution of the sample and the data obtained in each sex of the left side.

Left side	N	Mean	SD	Range	*p-value*
Female	45	94.80	29.155	40.67 – 164.59	0.07031
Male	68	141.02	33.850	86.89 – 213.74	0.01773

Table 2. The distribution of the sample and the data obtained in each sex of the right side.

Right side	N	Mean	SD	Range	*p-value*
Female	43	99.13	32.723	32.24 – 208.15	0.05399
Male	71	142.33	33.224	91.97 – 211.98	0.009592

Comparison between left and right MC volume were showed in Table 3. In the t- Student test (Fig. 2), the results showed no significant difference between the sides, p>0,05. Thus, the analysis was conducted according to Non-parametric Wilcoxon Mann-Whitney test, since the distribution MC data was not parametric **(**Table 3), considering the right canal separately (Fig. 3). There was a statistically significant difference p-value of 1.26 × 10-9.

Table 3. Descriptive statistic of de MC volume of left and right side.

MC Side	N	Mean	SD	Range	Shapiro-Wilk *p-value*
Left	125	122.60	39.191	40.67 - 213.70	0.05385
Female	45	94.80	29.155	40.67 - 164.59	0.07031
Male	68	141.02	33.850	86.89 - 213.74	0.01773
Right	125	126.00	39.040	32.24 - 212.00	0.1016
Female	43	99.13	32.723	32.24 - 208.15	0.05399
Male	71	142.33	33.224	91.97 - 211.98	0.009592

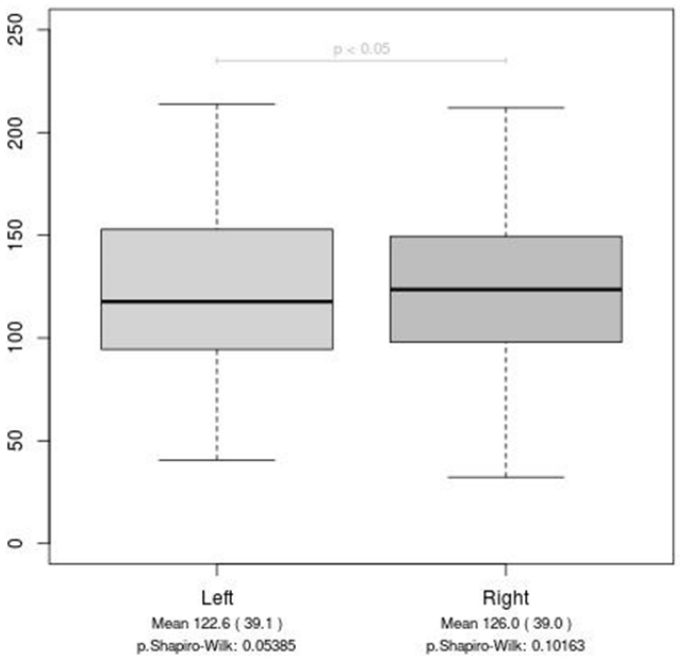

Figure 2. Left and right MC volume (mm³) by Student's t- test (comparison between sides). The analysis resulted in no statistical significance (p<0.05).

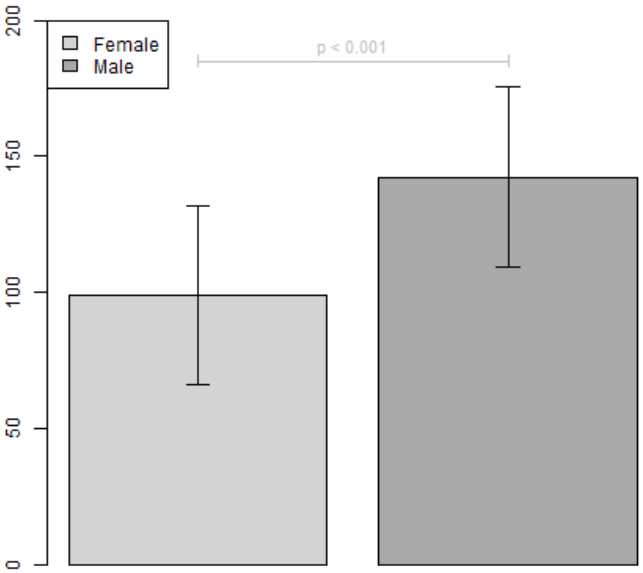

Figure 3. Volume (mm3) of the right MC, p-value = 1.268e-09 or 0.000000001268.

Therefore, the overall outcome showed that the volume of the MC presented sexual dimorphism. To obtain a formula for determining sex from the volume of the MC. A logit function from the right MC '-4.7355 + (0.0440 × Vol.Canal)' was established to calculate a probability of the individual being male and test the accuracy of the formula for the volume data of the left MC.

The logit obtained was:

$$\textbf{logit} = -4.7355 + (0.0440) \times \textbf{Vol. Canal)}$$

$$p(Male) = \frac{1}{1 + e^{-\text{logiy}}}$$

$$p(Femele) = 1 - p(Male)$$

The ROC analysis from the right MC indicated that the sexing potential was satisfied (85.5%) and with scores of 71.1% for females and 77.9% for males, using the left MC sample. Observations of the ROC analysis applied to find the predictability of the variable in sex estimation were showed in figure 4.

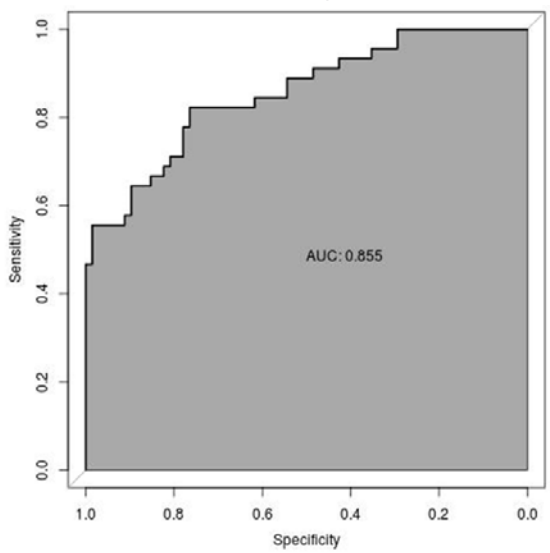

Figure 4. ROC test curve of the right-side Logit, for the sex determination using data from the left MC sample.

Discussion

Studies in computed tomography in a sample of the population of Taiwan indicated that there is a significant difference between the sexes regarding the position of the mandibular foramen and the mental foramen[15,16]. Additionally, Angel *et al.*[5] believed that the relative position of the MC and its mandibular and mental foramens in adults vary with age and may present sexual dimorphism. Based on these results, there was an interest in investigating, in a sample of Brazilian nationality, whether the volume of the MC may be useful to verify sexual dimorphism.

MC volume presented statistical significance for sexual differentiation. Our study presented the accuracy over 85% of the regression analysis show a great result to determined sex using the MC volume, should apply the formula in a different sample for best results. According to Hu *et al.*[9], sexes may be distinguished based on the forms of various mandible parts. The study of these authors showed accuracy and insufficient reproducibility in determining sex of the mandible using non-metric analysis, despite the high positive predictive value in several findings. Whereas osteometric methods proved to be the best choice for sex determination, in which the accuracy of the results was around 96% from a single measurement[3].

Although computed tomography is an expensive method, it is useful in forensic scenarios for systematic reassessment of cases and improvement of anthropologic methods used secularly. Besides that, we believed that the possibility of three-dimensional reconstruction of anatomical structures, mainly from the volume, allows the study and the selection of specific morphologic parameters for investigating sexual differentiation[3].

Virtual osteometry using 3-D reconstruction from computed tomography data may be particularly useful for estimating sex by skeletal robustness analysis using parameters that are not available with conventional procedures[7]. We suggested that the method used in the present study may be a complement for the human identification techniques, for the sexual dimorphism in the forensic dentistry field.

In conclusion, according to our results, the MC volume is a parameter for sexual dimorphism. Moreover, it is suggested that tomographic images and three-dimensional reconstruction in specific software for this purpose may assist professionals in forensic human identification, providing a quick and accurate method. In addition, the Regression analysis test verified the probability to determination of the mandibular canal and showed the sexing potential was satisfied (85.5%) and with scores of 71.1% for females and 77.9% for males.

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