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Sex Determination in the Contemporary Chilean Population by Mandible Analysis in Panoramic Radiographies

Estimación Sexual de la Población Chilena Contemporánea Mediante Análisis de la Mandíbula en Radiografías Panorámicas

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SUMMARY: Sex identification of a deceased human individual by means of the mandible is very important for forensic dentistry. The aim of the present study was to determine the sex of Chilean individuals by mandible analysis in panoramic radiographies. Linear and angular parameters of the mandible were analyzed from panoramic radiographies (PR). The study included PR of adult Chilean individuals, of both sexes, with optimum solution and contrast, and which allowed the angles and rami of the mandible to be viewed. Sex was determined by univariate and bivariate discriminant function analysis. The sample consisted of 594 PR of individuals aged between 18 and 84 years. The best sex predictor using univariate discriminant function analysis was the mandibular ramus height (MRH) (74.1 %), followed by the distance from the mental foramen – mandibular base (DMF-MB) (69.1 %) and the bicondylar breadth (BC) (66.7 %). The parameters that presented the lowest sex prediction were the angle of the mandible (AM) with 55.0 % and the distance between mental foramina (DMF) with 53.7 %. The best sex prediction was obtained by the step model of discriminant function analysis (80.2 %), including only three parameters: MRH, BC and DMF-MB. The parameters height of the mandibular ramus, bicondylar breadth and distance from the mental foramen – base of the mandible are good predictors of sex in Chilean individuals when used in conjunction; they are therefore indicated for sex determination in the contemporary Chilean population.

KEY WORDS: Anatomy; Mandible; Panoramic radiography; Sex estimation.

INTRODUCTION

Determining sex is the first step in the identification of human remains, facilitating the determination of other elements such as age, height and ethnic composition which follow sex-related patterns (Ruff, 2010; Franklin *et al*., 2014). In human sex identification, the pelvic bones are highly reliable; however, in the absence of pelvic bones, analysis of the mandible may be the best alternative due to its strong sexual dimorphism (Alves & Deana, 2019; Alves *et al*., 2022). Identification of a deceased human individual by means of features or characteristics of the teeth or mandible is very important for forensic dentistry (O'Shaughnessy, 2001).

The mandible is an unpaired, symmetrical bone located in the lower third of the face. It consists of an arched body in the shape of a horseshoe and two rami which extend from the posterior ends of the body to cranial (Alves & Cândido, 2016). The mandibular symphysis is a temporary joint in which the left and right halves of the mandible unite in the medial plane; it disappears at the end of the first year of life (Alves & Cândido, 2016). The mandible is the strongest structure in the cranium, due to its dense layer of compact bone. Sexual dimorphism found in the mandible of modern human individuals is due to differences related both with musculoskeletal development, and with the

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different growth trajectories of males and females (Rosas *et al*., 2002). Mandible dimorphism is attributable to its size and shape, the bone being larger and stronger in males than in females (O'Shaughnessy, 2001; Saini *et al*., 2011).

The mandibular ramus presents great sexual dimorphism in different populations, independent of the type of sample used (tomography, macerated mandible or radiography) (Alves *et al*., 2022). The parameters with greater or lesser dimorphism may vary between populations (Vodanovic *et al*., 2006; Alves *et al*., 2022), due to cultural and ethnic factors that may influence mandibular development (Iscan & Kennedy, 1989; Saini *et al*., 2011). The object of the present study was to determine the sex of Chilean individuals by mandible analysis in panoramic radiographies.

MATERIAL AND METHOD

A descriptive, observational, cross-sectional study was carried out, in which panoramic radiographies (PR) of Chilean individuals of both sexes were analyzed, aged over 18 years, who received attention in the Dental Clinic of Universidad de la Frontera, Temuco, Chile, between January 2018 and January 2021. The study was approved by the Scientific Ethics Committee of Universidad de la Frontera, Folio No. 129/20.

The study included PR examinations with optimum solution and contrast, which allowed the angles and rami of the mandible to be viewed. PR of the following patient types were excluded: totally edentulate; who had undergone orthognatic surgery; who presented radiological signs of trauma; with mixed dentition; who presented severe mandibular asymmetry; with presence of intraosseous pathological processes; with accessory mental foramina; and examinations presenting any error in the radiography or over-projection of structures.

Digital PR were taken by PAX-400C Orthopantomograph, Vatech Co., Korea, Series 003-0848, year of manufacture: 2011. Exposure parameters: 68 Kvp, 8 mA. Exposure time: 13 sec. For duplicate analysis, the examiners used a Macbook Pro-retina 14" computer, an Asus vivobook 14 computer, Microsoft Excel 2011 software for MAC, version 14.7.7 (170905), and AutoCAD software.

The PR were examined by two examiners, general dentists, who were calibrated prior to data collection. Calibration consisted of measuring 15 PR examinations twice, with an interval of two weeks between measurements. The intraclass correlation coefficient (ICC) was used to quantify reliability between the first and second measurements of the quantitative variables. The measurements of the samples were taken using autoCAD software.

Metric analysis consisted in tracing lines using the following anatomical structures as references (Fig. 1): Mandibular angle, right (MAr), Mandibular angle, left (MAl), Mandibular ramus height, right (MRHr), Mandibular ramus height, left (MRHl), Bigonial breadth (BG), Condylo-coronoid distance, right (CCDr), Condylo-coronoid distance, left (CCDl), Bicondylar breadth (BC), Distance from the mental foramen – mandibular base, right (DMF-MBr), Distance from the mental foramen – mandibular base left (DMF-MBl), Distance between mental foramina (DMF), Distance from the mandibular notch – mandibular lingula, right (DMN-MLr) and Distance from the mandibular notch – mandibular lingula, left (DMN-MLl).

From these anatomical references, linear and angular parameters were defined, based on Ortiz *et al*. (2020), as shown in Figure 1 and defined in Table I.

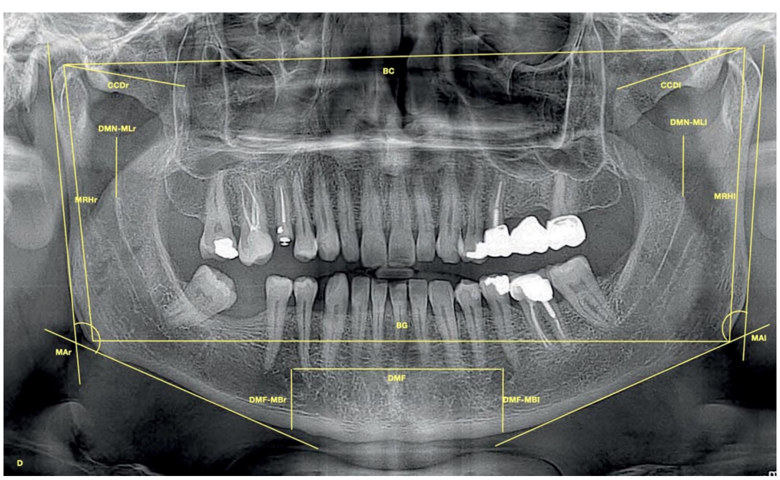

Fig. 1. Linear and angular measurements established in the present study, based on Ortiz *et al*. (2020). Parameters: Mandibular angle, right (MAr), Mandibular angle, left (MAl), Mandibular ramus height, right (MRHr), Mandibular ramus height, left (MRHl), Bigonial breadth (BG), Condylo-coronoid distance, right (CCDr), Condylo-coronoid distance, left (CCDl), Bicondylar breadth (BC), Distance from the mental foramen – mandibular base, right (DMF-MBr), Distance from the mental foramen – mandibular base left (DMF-MBl), Distance between mental foramina (DMF), Distance from the mandibular notch – mandibular lingula, right (DMN-MLr) and Distance from the mandibular notch – mandibular lingula, left (DMN-MLl).

Table I. Description of the parameters analyzed.

Parameter	Abbreviation	Description
Mandibular angle	MA	Measurement oft he angle formed by the intersection of the tangents oft he PMMR and the base of the mandible on each side
Mandibular ramus height	MRH	Length of the line drawn from the highest point of the condyle to the MA
Bigonial breadth	BG	Linear distance between MA right and MA left
Condylo-coronoid distance	CCD	Linear distance from the highest points of the condyle to the coronoid process
Bicondylar breadth	BC	Linear distance between the right and left condyles (highest lateral portion of the condylar apex)
Distance from the mental foramen to the mandibular base	DMF-MB	Vertical linear distance from the highest part of the mental foramen to the MB.
Distance between mental foramina	DMF	Linear distance between the highest edges of the right and left mental foramen
Distance from the mandibular notch to the mandibular lingula	DMN-ML	Linear distance from the lowest point of the mandibular notch to the highest point of the medial cortical of the mandibular canal.

PMMR: posterior margin of the mandibular ramus.

Statistical analysis. The intraclass correlation coefficient (ICC) was used for inter-observer analysis. Association was classified as poor (0.0), slight (0.01 – 0.20), regular (0.21 – 0.40), moderate (0.41 – 0.60), substantial (0.61 – 0.80) or almost perfect (0.81 – 1.00) (Landis & Koch, 1977).

Levene's test was applied to evaluate the homogeneity of the variances, and Kolmogorov-Smirnov test was applied to analyze normality of the data. The t-test was used to analyze differences between the sexes of independent samples. The parameters presenting statistically significant differences between sexes were included in the univariate and multivariate discriminant function analyses. Multivariate discriminant function analysis was carried out both directly and by steps. Crossed validation was used to validate the effectiveness of the predictive model. Statistical analysis was performed using the SPSS software, v. 28.0, with significance threshold of 5 %. The graphs were produced using the Prism 9 for MacOs software, Version 9.5.1 (528), 2023.

RESULTS

In total, 609 panoramic radiographies were analyzed. Fifteen of these were excluded: 7 because the definition of the image was poor; 4 because they were of individuals aged less than 18 years; 2 because they were of totally edentulate individuals; 1 because the patient presented intraosseous pathological processes; and 1 due to incomplete data. The study finally included 594 radiographies of individuals of both sexes, 204 male and 390 female. The mean age was 37.6 years, with minimum of 18 and maximum of 84 years. The mean age among females was 38.43 years and among males 36.22 years. Inter-observer analysis was higher than 0.7 for all the parameters, except DMF-MB where it was 0.470.

After the t-test for independent variables, all the parameters except the DMF presented statistically significant differences between sexes. All the parameters presented larger

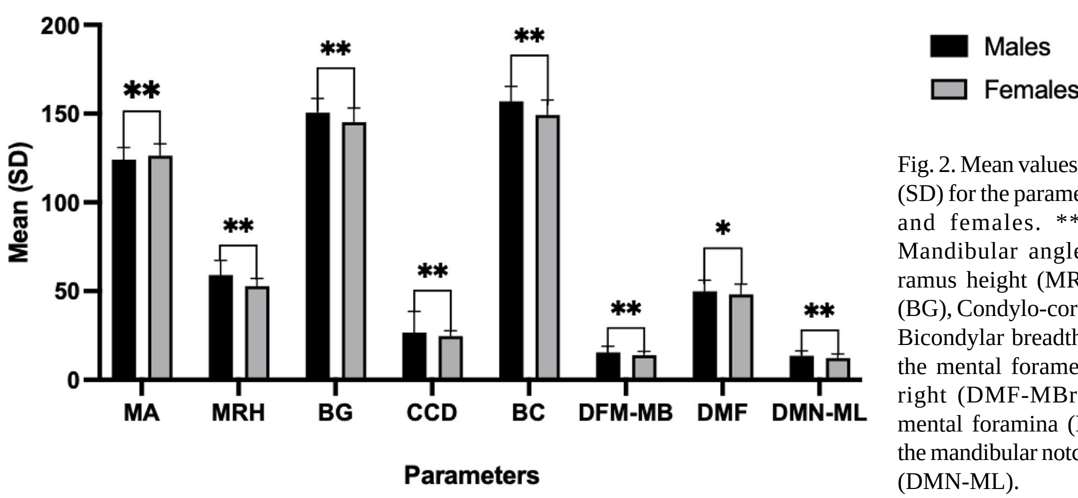

Fig. 2. Mean values and standard deviation (SD) for the parameters analyzed in males and females. **p<0.001; *p<0.05. Mandibular angle (MA), Mandibular ramus height (MRH), Bigonial breadth (BG), Condylo-coronoid distance (CCD), Bicondylar breadth (BC), Distance from the mental foramen – mandibular base, right (DMF-MBr), Distance between mental foramina (DMF), Distance from the mandibular notch – mandibular lingula (DMN-ML).

values in males than in females, except the MA. Figure 2 shows the mean values found for the parameters analyzed, by sex.

To determine the predictive value of each parameter, univariate discriminant function analysis was used; it was observed that the MRH was the parameter with greatest predictive ability (74.1 %), followed by the distance from the DMF-MB (69.1 %) and the BC (66.7 %). The parameters that presented the lowest sex prediction were the MA with 55.0 % and the DMF with 53.7 % (Table II).

Multivariate discriminant function analysis was used for predicting sex using the following parameters: mandibular ramus and mental foramina, both directly generated. In addition, a step model of discriminant function analysis was. The best sex prediction was obtained by the step model of discriminant function analysis (80.2 %), including only three parameters: MRH, BC and DMF-MB. The discriminant function analysis model using the parameters of the mandibular ramus also showed good prediction (78.5 %), although it was slightly inferior to the step model. Finally, the model generated using the measurements in the mental foramina was also predictive (69.1 %), however its predictive value was lower than that of the other models generated. The accuracy was greater for females than for males in all three discriminant analysis models (Table III).

Table II. Results of the univariate discriminant function analysis.

Function	Standardised coefficient	Canonic correlation	Wilks' Lambda	Centroid group	Accuracy			Crossed validation
					Males	Females	Total	
AM	1.000	0.117	0.986	M: -0.163 F: 0.085	59.6 %	54.1 %	56.0 %	55.0 %
HMR	1.000	0.514	0.736	M: 0.828 F: -0.432	76.0 %	73.1 %	74.1 %	74.1 %
BGoB	1.000	0.307	0.906	M: 0.445 F: -0.233	56.4 %	63.3 %	60.9 %	60.9 %
BCoB	1.000	0.184	0.844	M: 0.593 F: -0.310	64.7 %	67.7 %	66.7 %	66.7 %
CCD	1.000	0.177	0.969	M: 0.249 F: -0.130	56.1 %	60.3 %	58.9 %	58.9 %
DMN-ML	1.000	0.242	0.941	M: 0.345 F:-0180	57.1 %	64.3 %	61.8 %	61.8 %
DBMF	1.000	0.092	0.992	M: 0.127 F: -0.067	55.4 %	52.8 %	53.7 %	53.7 %
DMF-BM	1.000	0.387	0.850	M: 0.580 F: -0.303	67.6 %	69.9 %	69.1 %	69.1 %

M: males; F: females; Mandibular angle (MA), Mandibular ramus height (MRH), Bigonial breadth (BG), Condylo-coronoid distance (CCD), Bicondylar breadth (BC), Distance from the mental foramen – mandibular base, right (DMF-MBr), Distance between mental foramina (DMF), Distance from the mandibular notch – mandibular lingula (DMN-ML).

Table III. Results of the multivariate discriminant function analysis.

Function	Standardised coefficient	Canonic correlation	Wilks' Lambda	Centroid group	Accuracy			Crossed validation
					Males	Females	Total	
Mandibular ramus, direct method								
HMR	0.889	0.566	0.679	M: 0.950 F: -0.496	78.4 %	78.9 %	79.0 %	78.5 %
BGoB	0.468							
BCoB	0.625							
CCD	0.317							
DMN-ML	0.359							
Mental foramina, direct method								
DBMF	0.074	0.385	0.852	M:0.368 F: -0.192	67.1 %	70.3 %	69.2 %	69.1 %
DMF-BM	0986							
All the variables, step method								
HMR	0.149	0.603	0.636	M: 1.045 F: -0.545	77.5 %	80.8 %	80.2 %	79.5 %
BCoB	0.046							
DMF-BM	0.250							

M: males; F: females; Mandibular angle (MA), Mandibular ramus height (MRH), Bigonial breadth (BG), Condylo-coronoid distance (CCD), Bicondylar breadth (BC), Distance from the mental foramen – mandibular base, right (DMF-MBr), Distance between mental foramina (DMF), Distance from the mandibular notch – mandibular lingula (DMN-ML).

DISCUSSION

In the present study, sexual dimorphism was found for the linear variables analysed by univariate discriminant analysis in the mandibular body and ramus, varying between 53.7 % and 74.1 %. The parameters MRH, DMF-MB and BC presented the greatest sexual dimorphism, while the DMF and the MA presented the least. In a systematic review on sexual determination in the Chilean population using the mandibular ramus, Alves *et al*. (2022) reported that the height of the mandibular ramus, the BG, the BC and the coronoid height were predictor parameters in the majority of the studies. In the present study, using univariate discriminant analysis, the MRH was the parameter with the greatest dimorphism, and is therefore indicated for determining sex in the Chilean population (Motawei *et al*., 2020). The findings of the present study agree with those of Bucchi *et al*. (2016), who stated that in the Chilean population, vertical variables (like the MRH) are of greater help in determining sex than horizontal variables. As well as being a good sex determiner for the Chilean population, the MRH presents great sexual dimorphism in other populations, for examples in Indians (Damera *et al*., 2016; Samatha *et al*., 2016; Maloth *et al*., 2017) and Egyptians (Kharoshah *et al*., 2010).

In the analysis of parameters related with the mental foramen, the DMF-MB achieved an accuracy of 69.1 % as a sex determiner, while the DMF presented low accuracy of sex determination. In a previous study carried out by our research team using macerated mandibles of Brazilian individuals, a similar finding was reported with accuracies of 55.8 % for the DMF and 64.2 % for the DMF-MB (Alves & Deana, 2019). In a Chinese population, both Deng *et al*. (2017), and Dong *et al*. (2015), reported greater accuracy for the DMF than was found in the present investigation, with 65.3 % and 69.5 % respectively. According to our results, the DMF was not indicated for determining sex in Chilean individuals, however the DMF-MB was a good predictor. The multivariate discriminant analysis model using both parameters produced low accuracy in determining sex, with 69.2 %.

In the present investigation, the angle of the mandible presented low sexual dimorphism. The discriminant function analysis showed that this parameter did not contribute useful data for sex determination, with an accuracy of only 56 %; its use is therefore not indicated in the Chilean population. The same finding has been reported by previous studies (Dong *et al*., 2015; Sambhana *et al*., 2016; Sharma *et al*., 2016; Tunis *et al*., 2017). It should also be noted that, depending on the population analyzed, the MA may present greater sexual dimorphism and thus be a good determiner of sex (Alves *et al*., 2022). Previous studies in Croatian (Vodanovic´ *et al*., 2006), Brazilian (Gamba *et al*., 2016), Turkish (Ilguy *et al*., 2014) and Egyptian populations (Kharoshah *et al*., 2010) have shown that the angle of the mandible was one of the parameters with the highest prediction value. This reinforces the importance of using the most dysmorphic parameters in the population concerned when trying to determine sex. On the other hand, when the origin of the individual to be identified is unknown, it is not possible to choose in advance the best parameter(s) for determining sex. In these cases, the use of several parameters in conjunction may be essential to reach a more accurate conclusion.

According to Alves *et al.* (2022), the mandibular ramus presents great sexual dimorphism and can be used as a predictor of sex in different populations. In the present investigation, using discriminant function analysis by the direct method, the accuracy was 79.0 %; whereas crossed validation using 5 parameters of the mandibular ramus produced an accuracy of 78.5 %. Dong *et al*. (2015) in a study in a Chinese population, found greater accuracy than was produced in our study, with 83.3 % for crossed validation and 84.7 % using 4 mandibular parameters: BC, BG, maximum mandibular length and MRH. In another study, carried out in white South Africans, Steyn & Iscan (1998) achieved 81.5 % accuracy using 4 mandibular parameters (gonion-gnathion, bicondylar breadth, bigonial breadth and minimum breadth of the ramus). We agree with Dong *et al.* (2015) in that the step method of multivariate discriminant function analysis is easy to apply and permits sex determination with the smallest number of variables; this may be useful in practice when it is necessary to identify individuals from damaged or fragmented mandibular remains. In our study in the Chilean population using the step method of multivariate discriminant function analysis, the best accuracy (80.2 %) was obtained with the parameters MRH, BC and DMF-MB.

CONCLUSION

The mandibular ramus height was the parameter with the greatest sexual dimorphism in the Chilean population, while the distance between the mental foramina was the least dysmorphic parameter. The mandibular angle presented low accuracy, and is not indicated for determining sex in Chileans. The use of several parameters in conjunction ensures greater accuracy in sex determination. The height of the mandibular ramus, bicondylar breadth and distance from the mental foramen – base of the mandible are good predictors of sex in Chilean individuals when used in conjunction; they are therefore indicated for sex determination in the contemporary Chilean population.

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DEANA, N. F.; LABARCA, I.; TORRES, H.; GARAY, I. & ALVES, N. Estimación sexual de la población Chilena contemporánea mediante análisis de la mandíbula en radiografías panorámicas. *Int. J. Morphol., 41(6)*:1660-1665, 2023.

RESUMEN: La identificación humana de un individuo fallecido a través de la mandíbula es muy relevante para la odontología forense. El objetivo de este estudio fue estimar el sexo de individuos Chilenos a través del análisis de la mandíbula, utilizando radiografías panorámicas. Fueron analizados parámetros lineales y angulares de la mandíbula, a través de radiografías panorámicas (RP). Se incluyeron RP de individuos chilenos adultos, ambos sexos, con solución y contraste óptimos, y que permitían la visualización de los ángulos y ramas de la mandíbula. Se realizó análisis por función discriminante univariada y bivariada para estimación del sexo. Fueron incluidas 594 RP de individuos entre 18 y 84 años. Para el análisis de función discriminante univariado, la altura de la rama mandibular (ARM) fue el parámetro más predictivo (74,1 %), seguido de la distancia foramen mentoniano – base de la mandíbula (DFM-BM) (69,1 %) y el ancho bicondilar (ABCo) (66,7 %). Los parámetros que presentaron menor predicción sexual fueron el ángulo de la mandíbula (AM) con un 55,0 % y la distancia inter-forámenes mentonianos (DIFM), con el 53.7 %. El análisis por pasos fue el modelo de análisis de función discriminante que presentó la mayor predicción sexual (79,5 %), en el cual fueron incluidos sólo tres parámetros: ARM, ABCo y DFM-BM. Los parámetros altura de la rama de la mandíbula, ancho bicondilar y distancia desde el foramen mentoniano hasta la base de la mandíbula son buenos predictores del sexo en individuos Chilenos cuando utilizados en conjunto y están indicados para estimar el sexo en la población chilena contemporánea.

PALABRAS CLAVE: Anatomía; Mandíbula; Radiografía panorámica; Estimación sexual.

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