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Sex estimation in a Chilean population by mandibular analysis in cone beam computed tomography images

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Abstract

Background Sex estimation is the first stage in the identification of an individual in the forensic context, and can be carried out from bone structures like the mandible. The aim of this study was to estimate sex from metric analysis of the mandible in cone beam computed tomography images (CBCT) of adult Chilean individuals.

Methods Six mandibular measurements were analysed, five linear and one angular, in CBCT of adult Chilean individuals of both sexes. ROC Curve analysis was performed, with cut-off points, and of the overall model quality. Univariate discriminant function analysis was used to determine the accuracy of each measurement for sex estimation. Multivariate discriminant function analysis, both directly and by steps, was used to obtain the predictive value of the mandible including all the measurements.

Results The data included were 155 CBCT, 105 of females and 50 of males. The mandible presented great sexual dimorphism, with the mandibular ramus presenting greater predictive power than the mandibular body. When each mandibular measurement was analysed separately, the maximum height of the mandibular ramus presented the greatest predictive power (76.5%), while the mandibular angle was the least accurate parameter for sex estimation (58.1%). Direct method analysis presented 87.1% accuracy for sex identification of adult Chilean individuals, and joint analysis of maximum mandibular ramus height (MRH), corono-condylar distance and bigonial breadth presented 86.5% accuracy. In ROC Curve analysis the MRH was the variable with the greatest discriminating capacity (AUC = 0.833), MA was the only variable which presented no discriminating capacity (AUC = 0.386) and also presented low quality in model quality analysis.

Conclusion Metric analysis of the mandible in CBCT images presents an acceptable accuracy for sex estimation in Chilean individuals, and its use for that purpose in forensic practice is recommended.

Keywords Sex estimation, Forensic sciences, Mandible, Cone beam computed tomography

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Introduction

The identification of human individuals from bone remains is a task of interest for forensic anthropology. It is based on the creation of a biological profile by estimating the sex, age, race and other physical characteristics of the individual [1]. Analysis of bone remains for identification is important in the context of natural or man-made disasters, where the cadavers are highly decomposed, dismembered or mutilated [2]. Sex estimation is the first step in the construction of the biological profile; this process is intimately related with the sexual dimorphism displayed by individuals, which is associated with the external physical characteristics exhibited, such as those observed in individual bone structures [3, 4]. Sex estimation methods are varied, and their accuracy is subject to variables such as operator experience, the bone structure used, its state, the age of the individual, and the population analysed, among other factors [3, 5].

According to scientific evidence, analysis through DNA as through peptides such as those present in enamel, and the use of osteology, are currently the most generally recognized methods for sex estimation; DNA analysis and the use of peptides are attractive but high-cost and complex methods that present high precision for sexing, even in ancient samples, with values ranging between 90 and 100% [6–8]. For osteological sex estimation in humans, the bone which offers the greatest reliability is the pelvis, with accuracy of up to 98–100% when the whole bone is analysed [9–11]; however, when this bone is absent or cannot be used for this purpose, the mandible is one of the best alternatives as this bone also displays great sexual dimorphism, with accuracy ranging between 78.5% and 95.6% depending on the sample, the method and the parameters used for analysis [1, 12–14].

The human mandible is a symmetrical, single bone located in the inferior third of the face. It consists of a horseshoe-shaped body and two lateral rami which extend from the posterior ends of the body to superior [15]. It is the most resistant bone in the maxillofacial region and is easy to identify both in its entirety and in fragmented parts, making it very useful in the forensic and anthropological contexts for the creation of the biological profile; due to its resistance, this bone is a common find in forensic practice and is used not only for sex estimation but also for estimating age and even ancestry [16, 17].

Human growth and development are influenced by genetic, hormonal and environmental factors, all of which have a profound impact on the appearance of physical differences that affect the expression of sexual dimorphism in the human skeleton [5, 18]. The sexual dimorphism displayed by a human bone structure may vary between populations, and the same individual may present different degrees of sexual dimorphism between body structures [13, 19]. It is therefore indispensable to study different human bones for sex estimation, and to learn about the structures that present the greatest dimorphism in each population. Today there is little evidence on the use of CBCT for sex estimation in Chilean population; therefore, the aim of this study was to estimate sex from metric analysis of the mandible by CBCT in adult Chilean individuals. We also evaluated sex estimation in different age groups. Our null hypothesis was that the metric analysis of the mandible using CBCT does not provide acceptable accuracy for sex estimation in the adult Chilean population.".

Material and method

Ethical approval

All the patients involved in this study signed an informed consent which stated their free right to participate in the study or not, with no influence on their dental treatment. This study was carried out following Chilean laws and in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants. The study was approved by the Scientific Ethics Committee of La Frontera University, Folio Nº081_22, dated 21 September 2021.

Sample selection

We carried out a descriptive, inferential, cross-sectional study. We examined CBCT images of Chilean individuals of both sexes, aged 18 years or over, who received attention in the Dental Teaching Clinic (CODA) of Universidad de La Frontera, Temuco, Chile, between January 2015 and January 2022.

The a priori sample size was calculated based on the study of Coelho et al. [20], using the G*Power 3.1 software (Heinrich Heine Universität, Düsseldorf, Germany), with size of effect 0.222, alpha error 0.05, beta error 0.95 and power 95%, giving a total sample size of 135 participants.

We used images with good contrast and clarity in which the mandibular structures could be clearly identified. The following CBCT images were excluded: examinations of patients showing orthodontic appliances in one or both dental arches, indications of prior orthognatic surgery or surgical resolution of mandibular fracture (for example osteosynthesis plates), total edentulism, persistent primary teeth, severe mandibular asymmetry and evidence in the image of cyst- or tumour-related lesions; images were also excluded with distortion, any artefact in the image or evident anatomical alterations.

Analysis of CBCT images

The selected CBCT images were obtained using a PAX Zenith 3D (Vatech Co, Gyeonggi-Do, Korea, Series

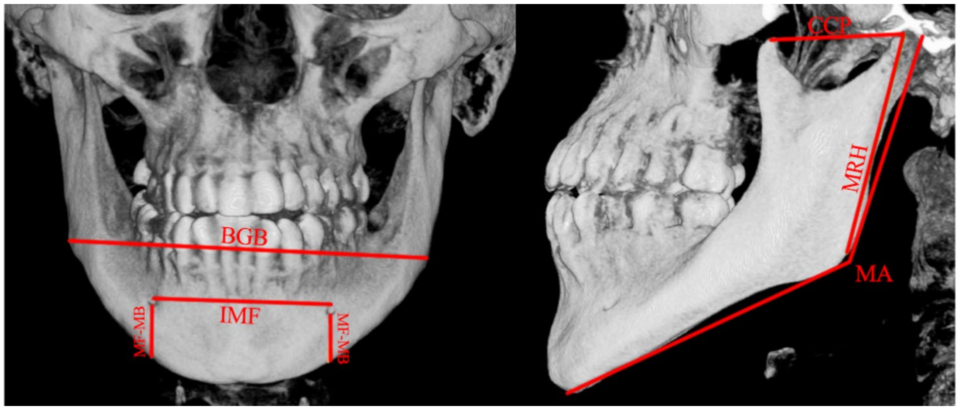

Fig. 1 Linear and angular measurements of the mandible determined in the present study. BGB: bigonial breadth, CCD: corono-condylar distance, IMF: inter-mental foramen distance, MA: mandibular angle, MF-MB: distance between the mental foramen and the mandible base, MRH: maximum mandibular ramus height

Table 1 Description of the mandibular measurements analysed

Mandibular measurement	Abbreviation	Description
Maximum mandibular ramus height	MRH	Height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle of the MA
Bigonial breadth	BGB	The straight-line distance between the two mandibular angles, measured horizontally from the right to the left MA
Corono-condylar distance	CCD	Distance from the highest point of the condyle to the highest point of the coronoid process
Distance from the mental foramen to the mandible base	MF-MB	Linear vertical distance from the lowest point of the inferior margin of the mental foramen to the inferior margin of the mandible, forming a right-angle.
Inter-mental foramen distance	IMF	Linear horizontal distance between the superior margins of the right and left mental foramina.
Mandibular angle	MA	The angle formed by the posterior border of the ramus and the inferior border of the mandibular body

003-0848; 2011), with a configuration of 120 kV, 10 mA, 24 s acquisition; FOV 24 × 19 cm and voxel size 0.3 mm.

The images, exported in DICOM format, were analysed by two examiners, both experienced dental surgeon who were previously calibrated, using the Pixmeo SARL® OsiriX Lite 13 (Geneva, Switzerland) software executed in an Apple® MacBook Air 13.3. The images were analysed with 3D multiplanar reconstruction (3D MPR) and using the volumetric rendering mode for 3D reconstruction with initial window width and level (WW/WL); the screen brightness was adjusted to improve operator visibility, and the lines were traced using a computer USB mouse. To avoid visual fatigue, the operator took breaks every 3 CBCT measured. The data collected were recorded in a Microsoft© Office Excel 365 for MacOS v.16.79 spreadsheet.

The mandibular measurements analysed were taken by line tracing according to the reference anatomical structures (Fig. 1) (Table 1). Five linear mandibular measurements were analysed: maximum mandibular ramus height (MRH), bigonial breadth (BGB), corono-condylar distance (CCD), distance from the mental foramen to the mandible base (MF-MB) and inter-mental foramen distance (IMF); and one angular measurement: mandibular angle (MA). Measurements of the mandibular ramus (i.e. MRH, CCD, MA) were analysed bilaterally (right and left side) in each examination; for the mandible body, only MF-MB was analysed bilaterally (right and left side) in each examination.

The only information available for metric analysis of the images were the patient's age and the date of the examination. Information on the patient's sex in each examination was revealed after all the measurements had been taken and before proceeding with the statistical analysis.

Intra-observer calibration was carried out, consisting of an analysis of 18 examinations by the same observer on two occasions, with an interval of two weeks between them. The images were analysed by two researchers (F.C., N.A). The intraclass correlation coefficient (ICC) was used to quantify the intra-observer and interobserver reliability in analysis of the mandibular parameters, with an agreement index of over 0.88 for all the measurements. The images were analysed with the OsiriX Lite 13 software.

Statistical analysis

Descriptive analysis of the data comprised the mean, standard deviation, minimum and maximum in each mandibular measurement both in total and by sex; the sample was also grouped by age to perform comparative analyses between individuals aged 30 years or younger and 31 years or older. Levene's test was applied to evaluate the homogeneity of the variances, and the Kolmogorov-Smirnov test was used to analyse the normality of the data. Student's t-test for independent samples was used to analyse the difference in the means between sexes, and the age differences between the participants. Student's t-test for dependent samples was used to analyse the difference in the means between sides. The measurements presenting statistically significant differences between sexes were included in the univariate and multivariate discriminant function analyses for sex estimation; for bilateral measurements (i.e. MRH, CCD, MA and MF-MB) both sides were included in this analysis. Analysis was performed of the ROC Curve, with cut-off points, and of the overall model quality; models with value over 0.5 were considered acceptable. Multivariate discriminant function analysis was carried out directly and by steps. Crossed validation was used to validate the effectiveness of the predictive value of the discriminant function. The ICC was classified according to Landis and Koch's parameters [21] as: poor (0.00), slight (0.01–0.20), regular (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.81-1.00). Power analysis was carried out for each predictor variable analysed. The IBM SPSS Statistics for MacOS software (v.28.0) (New York, United States) was used for statistical analysis, with a statistical significance threshold of 5%. The graphs were generated using the GraphPad Prism 9 for MacOS software (v.9.5.1) (Boston, United States).

Results

A total of 230 CBCT were analysed. Of these, 75 were excluded: 61 presented orthodontic appliances; 6 presented total edentulism; 6 presented severe mandibular asymmetries; 1 presented osteosynthesis plates in the mandible; and 1 presented a mandibular cyst-related lesion. The final number included was 155 CBCT of individuals of both sexes, 50 of males and 105 of females. The mean age of the participants was 35.11 years (± 13.34 years), in a range between 18 and 72 years. The mean age of the females was higher than that of the males (females: 35.50 years, ± 12.86 years; males: 34.28 years, ± 14.33 years; $p = 0.036$). The power analysis carried out yielded a value of over 90% in all the variables (values obtained with the statistical power test - MRH: 1.000, BGB: 1.000, CCD: 0.992, MF-MB: 1.000, IMF: 0.995, MA: 0.858). The ICC for inter-observer calibration was higher than 0.93 for all parameters except for MF-MB which was 0.88; for intra-observer calibration, the ICC was higher than 0.97 for all parameters (Online Resource 1).

All six measurements showed a normal distribution with the Kolmogorov-Smirnov test ($p = 0.200$). All the measurements presented homogeneous variances between sexes ($p > 0.05$), except MRH and CCD.

Males presented significantly higher values than females for all the parameters analysed, except for MA which showed significantly higher means for females than for males (Fig. 2) (Online Resource 2).

Analysis by side indicated higher mean values of the MF-MB on the left side ($p < 0.001$), while for CCD the mean values were higher on the right side ($p = 0.020$). On both the right side and the left, the females presented significant higher mean values than the males for MA ($p = 0.013$ and $p = 0.047$, respectively). Males presented significant higher mean values than females for MRH (right side $p < 0.001$; left side $p < 0.001$), CCD (right side $p = 0.006$, left side $p < 0.001$) and MF-MB (right side $p < 0.001$, left side $p < 0.001$) on both sides.

The predictive value of each measurement was determined using the univariate discriminant function. The MRH presented the highest predictive value with 76.5%, followed by the BGB with 76.1%. The measurement which presented the lowest predictive value was the MA, with 58.1% (Table 2).

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In the analysis of the ROC Curve, the MRH was the variable with the greatest discriminating capacity, with area under curve (AUC) of 0.833, followed by MF-MB (AUC = 0.811) and BGB (AUC = 0.801). The only variable which presented no discriminating capacity was MA (AUC = 0.386) (Fig. 3). Cut-off points were also established (points presenting the greatest combined sensitivity and specificity) for each variable (Fig. 3). In the analysis of model quality, only MA showed low quality, with a value lower than 0.5 (0.29) (Fig. 3).

Analysis by age group

For analysis by age groups, 25 males and 46 females aged 30 years or younger, and 25 males and 59 females aged 31 years or older were analysed. In the 30 years or younger group, males presented significantly higher mean values

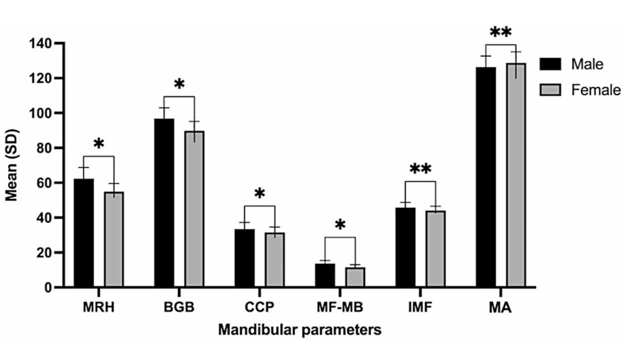

Fig. 2 Mean values and standard deviation (SD) for each mandibular measurement analysed in males and females. *$p < 0.001$; **$p < 0.05$. BGB: bigonial breadth, CCD: corono-condylar distance, IMF: inter-mental foramen distance, MA: mandibular angle, MF-MB: distance between the mental foramen and mandible base, MRH: maximum mandibular ramus height

Table 2 Results of analysis of the univariate discriminant function

Mandibular measurement	Standardization coefficient	Canonic correlation	Wilks' Lambda	Centroid group	Accuracy			Crossed validation
					M	F	Total	
BGB	1.000	0.499	0.751	M: 0830 F: -0.395	74%	77.1%	76.1%	75.5%
CCD	1.000	0.263	0.931	M: 0394 F: -0.188	58%	61%	60%	60%
IMF	1.000	0.275	0.924	M: 0412 F: -0.196	60%	61.9%	61.3%	61.3%
MA	1.000	0.179	0.968	M: 0263 F: -0.125	54%	60%	58.1%	58.1%
MF-MB	1.000	0.531	0.531	M: 0904 F: -0.431	69%	77.1%	74.5%	74.5%
MRH	1.000	0.554	0.693	M: 0960 F: -0.457	74%	77.6%	76.5%	76.5%

Multivariate discriminant analysis indicated the predictive value of mandibular measurements. The accuracy of sex estimation was greater with measurements of the mandibular ramus than of the mandibular body. When the six measurements were analysed jointly, the direct method presented greater predictive value (87.1%) than the step method (86.5%). The step method included the MRH, MF-MB and BGB measurements. In both methods the predictive value was greater for females than for males (Table 3)

Table 3 Results of analysis of the multivariate discriminant function

Function	Standardization coefficient	Canonic correlation	Wilks' Lambda	Centroid group	Accuracy			Crossed validation
					M	F	Total	
Mandibular ramus, direct method								
MRH	0.607	0.626	0.608	M: 1161 F: -0.553	80%	81.9%	81.3%	80.3%
BGB	0.544							
CCD	0.220							
MA	-0.147							
Body of the mandible, direct method								
MF-MB	0.907	0.555	0.692	M: 0964 F: -0.459	74%	80%	78.1%	77.7%
IMF	0.348							
Direct method								
MRH	0.489	0.675	0.544	M: 1318 F: -0.627	82%	89.5%	87.1%	84.5%
BGB	0.329							
CCD	0.160							
MF-MB	0.505							
IMF	0.053							
MA	0.173							
Step method								
MRH	0.583	0.665	0.557	H: 1284 M: -0611	84%	87.6%	86.5%	84.5%
BGB	0.330							
MF-MB	0.502							

for all parameters except for the MA, which showed a higher mean value for females but with no significant difference ($p = 0.072$); when analysed by side, the MA and MF-MB showed higher mean values on the left side, while for CCD and MRH the mean values were higher on the right side. On both the right and the left sides, males presented higher mean values for all parameters except for the MA, which was higher in females but with no significant difference (right $p = 0.296$; left $p = 0.132$); for both sides, only MF-MB and MRH presented a significant difference ($p < 0.001$). In the 31 years or older group, all parameters presented significantly higher mean values in males, except for the MA which was significantly higher in females ($p = 0.007$); for this group, only the MA and MF-MB showed higher mean values for the left side. On both right and left sides males showed significantly higher mean values than females for all parameters except the MA, which showed a significant difference for the right side ($p = 0.019$), but not the left ($p = 0.151$). The mean values for each parameter and the predictive values for univariate and multivariate analysis are available in Online resource 3.

The univariate analysis by age group showed that BGB has the greatest predictive value for the 30 years or younger group (78.9%), while MRH has the greatest predictive value for the 31 years or older group (82.7%). For

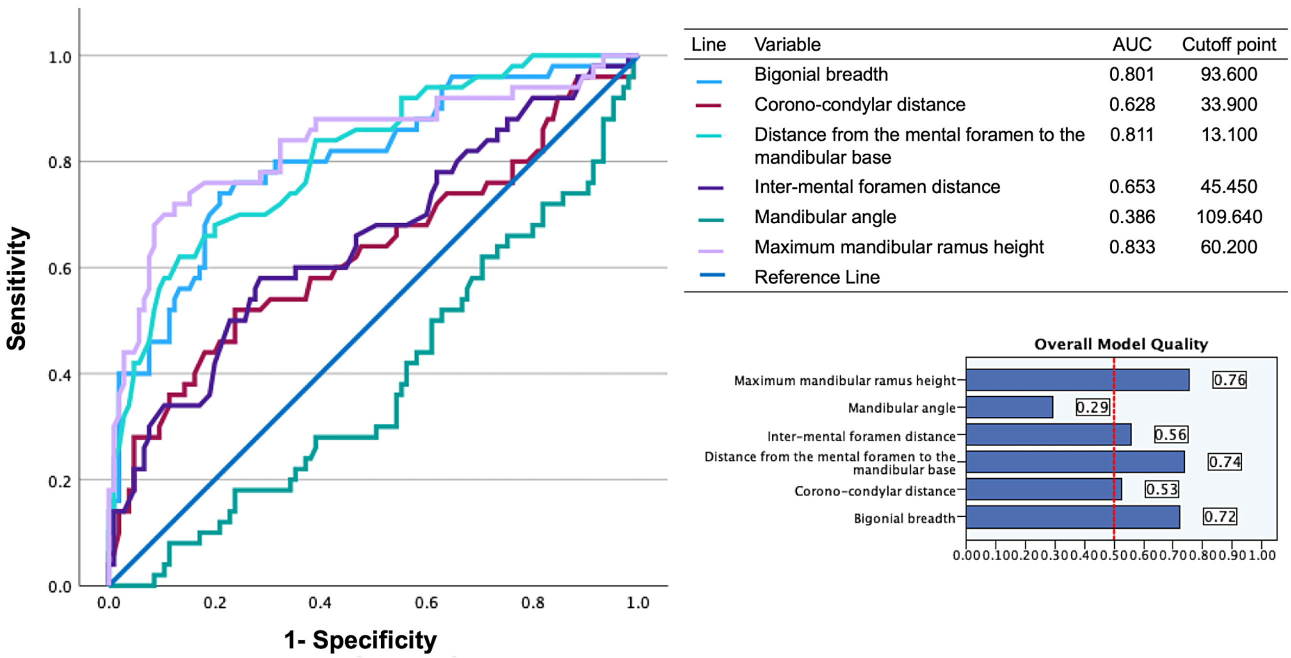

Fig. 3 ROC Curve showing variables analysed for sex estimation. The area under curve (AUC), the cut-off point of the variables and the overall model quality are shown

the 30 years or younger group, CCD presented the lowest predictive value (52.8%), while MA showed the lowest predictive value for the 31 years or older group (58.9%). In both groups the predictive value for univariate analysis was higher in females than in males, except for CCD and BGB in the 31 years or older group, where it was higher for males than for females.

In the analysis by age group, the step method included MRH and MF-MB for discriminant function in both groups, but in the 30 years or younger group BGB was also used (i.e. MRH, MF-MB and BGB), while in the 31 years or older group CCD was used as a third measurement (i.e. MRH, MF-MB and CCD); using both multivariate methods, step and direct, the predictive values were higher for the 31 years or older group (88.7% and 89.9% respectively) than the 30 years or younger group (81.7% and 85.9% respectively) (Online Resource 3).

Discussion

The present study analysed the sex estimation of adult Chilean individuals by analysis of metric parameters of the mandibular ramus and body measured in CBCT images. The results found showed that the predictive value for sex estimation varied according to the parameter analysed. The MRH was the parameter that presented the strongest dimorphism, with an accuracy of 76.5% in sex estimation; and the greatest discriminating capacity, with AUC of 0.833. BGB, followed by MF-MB, also presented good accuracy, with 76.1% and 74.5%, respectively. These findings corroborate the conclusion reported by Alves et al. [13], that the MRH is the variable with the strongest dimorphism, and the best parameter (in isolation) for predicting sex in different populations. In the present study, the accuracy of the MRH for sex estimation was similar to that reported for populations in Brazil (76.1%) [12] and Malaysia (78.5%) [14], but lower than that reported for the Turkish population [22]. The accuracy of the MRH was also similar to that reported previously in another study in the Chilean population using panoramic radiographies (PR), of 74.1% [23].

In the present study, the BGB was the second most accurate variable (in isolation) for sex estimation, with 76.1%. This was higher than the accuracy found for a population in China, with 70.4% [24], and for the Chilean population using PR, with 60.9% [23], but lower that that reported for the population in Brazil, with 80.5% [12]. For some of the variables analysed, the present study showed greater accuracy for sex estimation using CBCT than the study of Deana et al. [23] using PR. This finding suggests that the type of imaging examination may also influence the accuracy of a parameter for sex estimation; further, more specific studies are needed to confirm this finding.

The MA may present strong sexual dimorphism and be a good sex indicator, depending on the population analysed [13]. In Brazilian [25] and Turkish populations [26], the MA has been reported to present strong dimorphism. In the Chilean population, however, in the present study the MA was not found to be a good parameter for sex estimation; it was the least accurate parameter, with

58.1% and AUC of 0.386. This result is similar to that found in a previous study in the Chilean population [23].

During bone development, males have greater periosteal apposition, bone diameter and cortical thickness. These factors determine that males tend to develop larger bones than females; this bone development is influenced by hormonal factors such as the action of growth hormones and the insulin-like growth factor 1 (IGF-1), as well as the limitation of periosteal bone expansion by estrogen in females [27]. In the present study, all parameters presented higher average values for males than for females, except for MA.

The analysis by age group of this study indicated that the 31 years or older group presented a greater predictive value using both direct multivariate analysis (89.9%) and step analysis (88.7%) when compared to the 30 years or younger group; this difference in the predictive value between the two groups may be due to the fact that bone remodelling slows down with age and age-related factors, such as the greater bone resorption due to hormonal factors [27–29]. However, the lack of studies comparing mandible accuracy for sexual estimation between age groups makes it hard to explain this phenomenon. It should also be taken into consideration that the mandible undergoes constant remodelling due to the biomechanical loads to which is exposed during the life cycle, which shape it towards adulthood [30].

To obtain the predictive value for sex estimation we used discriminant function analysis, which is a quantitative method considered effective for estimating sex [31]. Direct multivariate analysis gave a predictive value of 81.3%, showing that the mandibular ramus presents strong sexual dimorphism for the Chilean population, which corroborates previous findings [13, 23, 32]. Although the mandibular ramus presented strong sexual dimorphism, analysis using two measurements of the body of the mandible (MF-MB and IMF) also produced good accuracy, with 78.1%. Similar results to those of the present study were reported for the Israeli population [33], with 79.1% accuracy using four parameters of the body of the mandible (body height - BH; chin height - ChiH; chin width - ChiW; symphysis height - SH). In the study with PR in the Chilean population, Deana et al. [23] analysed the same parameters used in the present study; however, they reported an expressively lower accuracy, of 69.1%. We believe that the type of imaging examination used influenced the analysis, which explains the discrepancy between the results of the present study, with CBCT, and the results reported by Deana et al. [23] in their study with PR.

In the present study, direct discriminant function analysis using the six mandibular measurements presented a predictive power of 87.1%, while the step analysis with only 3 measurements (MRH, MF-MB and BGB) presented a slightly lower accuracy of 86.5%. These findings indicate that the mandible presents pronounced sexual dimorphism and provides a reliable level of accuracy for sex estimation in the Chilean population through metric analysis using CBCT. Considering that an acceptable sex estimation method requires a minimum accuracy of 80% [34], our results prompted the rejection of the null hypothesis." In a previous study using PR, Deana et al. [23] also found good sex discrimination using MF-MB and BGB; however, the accuracy reported was 80.2%, lower than that achieved in the present study with CBCT. Using different parameters to ours (MA, diagonal length of the body - DL, horizontal length of the body - HL and MiRB) Sharma et al. [35] reported an accuracy of 60% for a population in India, which is expressively lower than the result found in the present study. A similar result was reported by Albalawi et al. [36] in an Arab population, with 67% accuracy using four mandibular measurements (MA, BGB, and left and right diagonal length - DL). Dong et al. [24], in their study of sex estimation based on the mandible in a Chinese population, reported a predictive value of 87.7% by multivariate discriminant analysis using the direct method, while with the step method (using four mandibular measurements) they achieved a value of 84.7%; their predictive values were closer to those found in our study in a Chilean population.

This study used CBCT for sex estimation by a metric method in which measurements were performed manually by an operator. Sex estimation by Artificial Intelligence (AI) has recently been proposed, based on Machine Learning (ML) methods. This method uses data to generate algorithms that allow accurate classification or prediction; in the case of sex estimation, studies using ML based on mandibular measurements obtained by CBCT, Toneva et al. [37] reported a predictive value of 95.3% which is higher than that obtained in this study; on the other hand, Baban et al. [38]. also reported accuracies between 80% and 90% using five types of ML algorithms, therefore, although the precision may vary depending on the method, algorithm and type of ML used [39], this can be considered a new and promising field for use in the forensic and anthropological contexts.

Since the mandible is not always found whole in the forensic context, the findings of this study suggest that the MRH is the most practical and feasible measurement for such cases, as it has an acceptable predictive power in isolation and is a bilateral measurement. If, however, the whole mandible is available, we suggest analysis using MRH, MF-MB and BGB, since the use of these three parameters jointly provided the greatest accuracy for sex estimation in Chilean individuals.

Strengths and limitations

This study presents certain strengths as compared with previous studies. Firstly, the sample size was calculated, which is fundamental to ensure the statistical power of the study. In the present study, intra-observer and interobserver calibration was carried out prior to taking the measurements from the examinations; moreover, the ICC was higher than 0.97 and 0.88, respectively, for all the parameters, which increases the reliability of the measurements and the subsequent analyses. Furthermore, we blinded the investigators who carried out the analysis, which is also fundamental to avoid the risk of bias in measurement. Although we did not randomize the selection of the participants, they were well characterized as we excluded edentulate patients and only included participants of Chilean nationality aged over 18 years. At this age a marked differentiation by sex is apparent, which is not observed in younger individuals. However, some conditions or habits that might cause alterations in bone structures could not be controlled, as we did not have access to the patients' clinical records.

This study presents other limitations that should be considered. Although the sample size calculation was carried out, there was an imbalance in the numbers of male and female participants. Nevertheless, the power was shown to be over 90% for all the variables analysed, which increases confidence in the results found. Despite the imbalance in the sample numbers, our study was able to detect statistically significant differences in the variables. Furthermore, our results are similar to those of previous studies in the same population. It is suggested that future studies should base their analysis on a balanced sample; although our study is subject to this limitation, our results are consistent with those found for Chilean populations in previous studies. In this study we measured six mandibular parameters in CBCT images. Although other parameters exist which were not included, and which have been reported to present high predictive power in other populations (for example, the bicondylar breadth or the coronoid height), we still found mandibular parameters with high predictive power for this specific population. The heterogeneity of the Chilean population is probably not reflected in this study, as it was based on a population sample from the south of Chile. Future studies should include other regions of the country to allow the data to be extrapolated to the whole population.

Conclusion

The mandible presented acceptable sexual dimorphism, with the mandibular ramus providing greater accuracy than the mandibular body for sex estimation. In the forensic context, where a whole mandible or hemi-mandible is available, we recommend use of three parameters for sex estimation in adult Chilean individuals: the maximum mandibular ramus height, the corono-condylar distance and the bigonial breadth.

Abbreviations

BCB	Bicondylar breadth
BGB	Bigonial breadth
BH	Body height
CBCT	Cone beam computed tomography
CCD	Corono-condylar distance
CH	Coronoid height
ChiH	Chin height
ChiW	Chin width
DICOM	Digital imaging and communications in medicine
DL	Diagonal length of the mandibular body
GH	Growth hormone
HL	Horizontal length of the mandibular body
IMF	Inter-mental foramen distance
MA	Mandibular angle
MaRB	Maximum ramus breadth
MF-MB	Distance from mental foramen to the mandible base
MiRB	Minimum ramus breadth
MRH	Maximum ramus height
PR	Panoramic radiography
PHR	Projective height of the ramus
SD	Standard deviation
SH	Symphysis height

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-05471-y.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

FC: project development, data collection, data analysis, manuscript writing and manuscript editing.NA: project development, data collection, manuscript writing and manuscript editing.NFD: data analysis, manuscript writing and manuscript editing. All authors have read and agreed to the published version of the manuscript. All authors have read and approved the final manuscript.

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Data availability

All data generated or analysed during this study are included in this published article.

Declarations

Ethical approval

The study was performed in accordance with the Declaration of Helsinki, and informed consent was obtained from all participants prior to study participation. The study was approved by the Scientific Ethics Committee of La Frontera University, Folio Nº081_22.

Consent for publication

No publication consent required.

Competing interests
The authors declare no competing interests.

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