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Mandibular Ramus Radio Morphometry for Sexual Dimorphism in an Egyptian Subpopulation: A Cone-Beam CT Retrospective Study

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Abstract

Introduction: Sexual dimorphism is an important part of studies in the fields of anthropology and forensic sciences. The mandible is the most dimorphic bone in the skull and is crucial in determining sex. The study correlated and assessed the accuracy of mandibular ramus anthropometric parameters for sex prediction.

Materials and Methods: This study included 120 CBCT images (60 males and 60 females, over the age of 18). The scans were taken by I-CAT and exported to on demand 3D™. Five mandibular ramus linear parameters were assessed bilaterally (minimum ramus breadth, maximum ramus breadth, coronoid height, condylar height and ramus projective height). On 3D volume rendering image parameters were measured using the mouse-driven method. Data were analyzed using IBM SPSS (Version 23. The P<0.05 was considered significant).

Results: Prediction accuracy rates of 85.0% for females (51 female scans out of 60) and 50 male scans out of 60 males (accuracy rates of 83.3%). maximum ramus breadth area under the curve (AUC=0.77) was less than 43.94 indicating females, with a specificity of 64.29%. Projective ramus height had an excellent ability to predict females (AUC=0.83). less than 60.85 indicated female, with a specificity of 71.43%. The maximum ramus breadth, coronoid Height has an acceptable ability to predict females with a specificity of 64.29%. and 92.86%. respectively. The coronoid height less than 12.15 indicated female sex, with a specificity of 92.86%.

Conclusion: The mandibular ramus demonstrated significant sexual dimorphism using CBCT with high specificity. Maximum ramus breadth, coronoid height and projective ramus height were the most significant sex predictors.

Keywords: CBCT • Discriminate function analysis • Sex prediction • Ramus height • Condylar height

Introduction

Sexual dimorphism refers to biological differences between the sexes, including anatomical differences. Sex identification is crucial for character recognition for social and legal purposes. Sexual identification with missing people or biological remains has been made in numerous nations [1-3].

Morphologic features of sex dimorphism were identified using a full skeleton with an accuracy of 90% to 100% [4]. However, identification is difficult when bones and other remains have been destroyed, such as in a mass tragedy [5].

Skeletal characteristics such as the skull, pelvis and femora have been used to predict sex from the images of bones to identify human remains. The skull is the most easily classified part of the skeleton, but this ability does not develop until puberty [6].

When a full, dry skull was absent, the mandible, the second-best marker for sex identification after the pelvis, is used to identify the sex [7]. The mandible has a high level of sex identification accuracy of 97% [8,9]. The mandible is the largest, stiffest, bone in the skull. 9 The mandibular ramus has different shapes that are influenced by masticatory forces, growth rates, occlusal status and remodeling that results in dimorphism [10-11].

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Metric standards are preferable because they are objective, precise, inventive and dependable. 3 Numerous studies regarding the impact of various ramus indices on sex and age identification have revealed controversial findings [12].

Finding the most dependable and reproducible mandibular indices is crucial because racial and imaging techniques can influence the reliability of the measured indices in various populations [13].

Each community has specific, unique sex prediction criteria [14]. In Egypt, mandibular sexual dimorphism is not widely studied, despite having been studied elsewhere [15].

Undeniably, CBCT is a 3D imaging technology for postmortem imaging, but its radiological potential is unknown to the public. It is inexpensive and can be used to image the dent-maxillofacial region with submillimeter accuracy and low radiation exposure [16-18].

This research sought to determine the accuracy of mandibular ramus parameters for sex verification in an Egyptian subpopulation.

Materials and Methods

Study design and sample

This retrospective study was conducted following the World Medical Association Declaration of Helsinki, which was first published in 1975 and modified in 2000 and approved by the Alexandria University Faculty of Dentistry Research Ethics Board (IRB no: 0390-02/2022). The study was conducted on CBCT scans of those who visited the Department of oral radiology at Alexandria University between December 2018 and December 2019 and were referred for CBCT imaging for different diagnostic purposes.

The study included 187 scans (93 males and 94 females), 76 scans were excluded due to one of the following criteria pathological abnormalities to the mandible, metabolic bone diseases, a cleft lip or palate, edentate (mandibular molars) and fractures.

Only 120 CBCT scans (60 males and 60 females), met the inclusion criteria and with age over 18 years. Scans with a field of view FOV 16 to 13 cm in height with a 16 cm diameter and scans free from any CBCT artifacts were included. All the scans included were anonymized before reaching the observers.

Sample size calculations

According to Lopez et al. using the maximum ramus height, a total sample size of 119 was to observe a shift from 0.75 to 0.8 in terms of sensitivity [19]. A two-sided binomial test was employed and 82% power to observe a shift between 0.8 and 0.9 in specificity. A two-sided binomial test was used. The target level of significance was 0.05.

Image analysis

All scans were achieved using I-CAT next generation (Imaging Sciences International, Hatfield, Pa) with exposure parameters 120 Kvp, 37.07 mA and 26.9 s exposure time.

CBCT scans were converted from their Digital Imaging and Communications in Medicine (DICOM) format into the on demand 3D™ software for image analysis and evaluation.

The images were evaluated directly on a monitor screen (Monitor 15.6 inch) HD (1366 X 768) Pixels Lenovaideapad 130 PC, under dim lighting and in a quiet room. For a qualified and effective evaluation, two independent examiners looked at each image, 10% of the total sample after 2 weeks reevaluated by the two examiners, average values were recorded and statistically calculated for intraclass Correlation coefficient ICC.

The mandibular ramus indices were evaluated using 3D Volume Rendering (VR) images for all mandibles following these steps:

- The mandible was manually segmented into, two hemi mandibles right and left by the segmentation knife (on the operator's screen's left side) and the segmentation was every time performed between the 2 central incisors
- The mouse-driven method was used to measure the parameters of the chosen hemi mandible by dragging the mouse to points on the hemi mandible on the CBCT image. The measurements were recorded in millimeter (mm) units using a ruler tool from the software.

Ramus measurements

All the measurements were performed on a maximize 3D planar view. The side ruler on the right side of the operator screen was stabilized at 5 cm for the standardization of the measurement. The measurements are displayed in (Figure 1).

Description of the linear measurements (mm) on the mandible

Condylar height (Condylar. H): The height of the condylar process from the condylion to the plane at the deepest point of the sigmoid notch [20].

Coronoid height (Coronoid. H): The long axis from the coronoid point to the plane at the deepest point of the sigmoid notch.

Minimum ramus breadth (Min. R. Br): The smallest anterior-posterior diameter of the ramus 3.

Maximum ramus breadth (Max. R. Br): The distance from the mandibular ramus most anterior point and a line drawn from the angle of the mandible to the condyle most posterior point.

Projective height of the ramus (RAMUS): The estimated distance between the condyle highest point and the intersection of lines in the posterior and underside planes of the mandible.

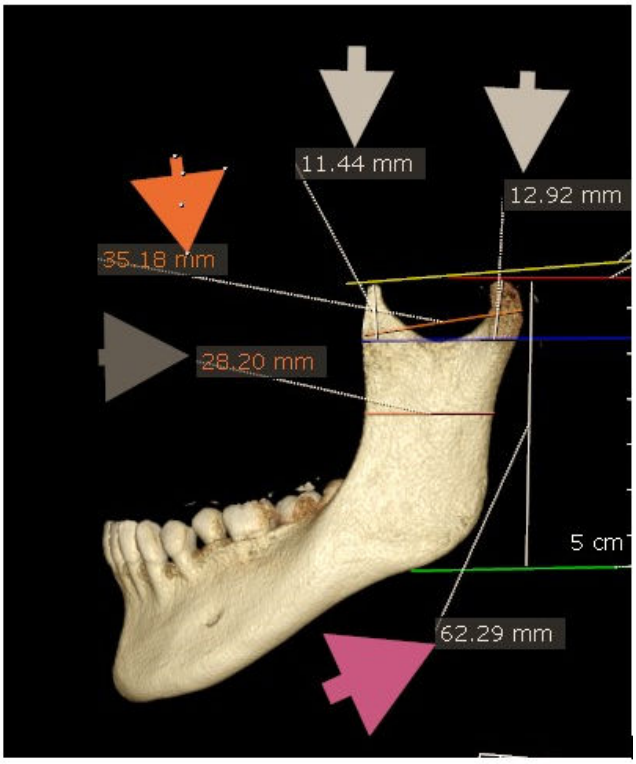

Figure 1. 3D volume rendering liner measurement.

Light gray arrows: coronoid height and condylar height, dark gray arrow: minimum ramus breadth orang arrows: maximum ramus breadth, pink arrow: projective ramus height.

To standardize the measurements of the mandibular ramus, four lines were drawn perpendicular to the side ruler:

- **Line 1:** Yellow line, at the top of the coronoid process.
- **Line 2:** Red line, at the top of the condylar head.
- **Line 3:** Blue line at the deepest point of the sigmoid notch.
- **Line 4:** Green intersection line at the mandibular angle.

Statistical analysis

The values were tabulated using Microsoft Excel 2016. The results were interpreted employing IBM SPSS (International business machines corporation, statistical package for social sciences) for windows (Version 23). Each variable exhibited a normal allocation. The Intraclass Correlation Coefficients (ICCs) were calculated and their range (less than 0.50-Above 0.90). A P value of less than 0.05 was regarded as significant statistically. Independent samples t-tests were employed to correlate CBCT parameters between females and males while comparing the left and right sides of each sex was performed employing a paired t-test. The discriminant function analysis was performed to determine whether the readings could be used to determine sex. The $p<0.05$ values were considered significant. diagnostic accuracy, sensitivity, specificity and the Area under the Curve (AUC) with 95%confidence intervals were assessed.

Results

The investigation involved 120 CBCT scans of 60 males and 60 females. There was a statistically significant difference between males and females in the mean, standard deviation and Wilks' Lambda with mandibular ramus, ($P<0.05$). The F values revealed that the mandibular measurements show that the highest dimorphism with ramus projective height, while the lowest variance was the minimum ramus breadth (Table 1). There was an excellent agreement range (0.999 to 1.000).

Table 1. Descriptive analysis regarding the sex variable, with each parameter (males, females).

	Female		Male		Wilks' Lambda	F	p-value
	Mean	± SD	Mean	± SD			
Max.R.BR	39.74	2.63	43.17	3.16	0.738	41.844	<0.001*
Min.R.BR	31.13	4.17	33.03	2.85	0.933	8.503	0.004*
Condylar H	13.5	2.36	14.77	2.4	0.933	8.532	0.004*
Coronoid H	11.35	2.6	13.3	3.34	0.903	12.718	0.001*
RAMUS	56.98	4.12	63.67	4.92	0.644	65.233	<0.001*

Note: SD: Standard deviation.

Discriminant function analysis was performed by Fischer's exact test Table 2.

Table 2. Linear discriminant function variables.

	Female	Male
Max.R.BR	3.624	3.902
Min.R.BR	2.402	2.568
Condylar H	-0.345	-0.402
Coronoid H	2.23	2.57

RAMUS	2.817	3.176
Constant	-200.691	-242.574

The prediction accuracy value was (83.3%) and (85.0%) in males and females respectively.

Fifty males, out of sixty were accurately identified as males, whereas fifty-one females, out of sixty were accurately identified as females Table 3.

Table 3. Prediction accuracy.

	Predicted group		Total	% Accuracy
	Female	Male		
Sex group				
Female	51	9	60	85
Male	10	50	60	83.3
Overall percentage				84.2

The projective ramus height had an excellent ability to predict females (AUC=0.83). A projective ramus height of more than 60.85 mm indicated male and a projective ramus height of less than 60.85 indicated female, with a specificity of 71.43%.

The maximum ramus breadth had an acceptable ability to predict females (AUC=0.77). A maximum ramus breadth of more than 43.94 mm indicated males and a maximum ramus breadth of less than 43.94 indicated females, with a specificity of 64.29% Table 4.

The coronoid height had an acceptable ability to predict females (AUC=0.76). A coronoid height greater than 12.15 mm indicated the male sex and a coronoid height less than 12.15 indicated the female sex, with a specificity of 92.86%Table 4.

Generally, an AUC of 0.5 shows that the test cannot differentiate between patients.

Patients with and without an A score of 0.7 and 0.8 are acceptable for a disease or condition, with excellent scores of 0.8 to 0.9 and remarkable values greater than 0.9.

Table 4. Agreement (sensitivity, specificity) for mandibular CBCT measurements on both sides to distinguish females from males.

	Sensitivity	Specificity	AUC	Cutoff value (mm)	P-value of AUC
Maximum ramus breadth	100%	64.29%	0.77	F ≤ 43.94<M	0.005*
Minimum ramus breadth	66.67%	57.14%	0.53	F>31.63<M	0.78
Condylar height	83.33%	64.29%	0.66	F ≤ 14.44<M	0.16
Coronoid height	61.11%	92.86%	0.76	F ≤ 12.15<M	0.004*
Projective ramus height	88.89%	71.43%	0.83	F ≤ 60.85<M	< 0.001*

Note: AUC: Area Under the Curve, F: Female, M: Male

Discussion

In the study, a 3D(VR) CBCT image was used to estimate the accuracy of mandibular ramus measurements for sex identification in Egyptians over 18 years, as all skull bones had reached puberty. Previous studies using panoramic radiography are unreliable due to the chance of resulting in incorrect measurements in vertical versus horizontal dimensions. Multi-detector computed tomography MDCT is more expensive and uses more radiation, compared with CBCT.

CBCT measurements are reliable and have a direct connection to anatomic reality, making them suitable for measuring anatomical structures that are difficult to measure with conventional methods.

With an accuracy of 90% to 100%, the morphological characteristics of sex dimorphism were identified. In our study, the overall accuracy was 84.2%. As the CBCT three-dimensional images are close to the real shape and thus facilitate an understanding of the anatomical differences between males and females.

Based on the study findings, three of the five mandibular ramus variables were statistically significant. Males have significantly higher mean values of linear measures than females. (Maximum ramus breadth: 43.17 (3.16) and 39.74 (2.63); Projected ramus height: 63.67 (4.92) and 56.98 (4.12) and coronoid height: 13.30 (3.34) and 11.35 (2.60), respectively, in males and females. Overall accuracy was 84.2%.

These findings were in accordance with previous findings on a survey of the Northern Indian population mandibles (average age of 37.4 years; 92 males; 24 females), which determined that males had higher values for all ramus metrics than females (maximum breadth: 42.81 mm (3.59) and 40.34 mm (3.76), coronoid ramus height: 61.68 mm (5.25) and 54.89 mm (3.54) and projective height: 53.89 mm (6.93) and 47.45 (4.63), males and females, respectively), having an overall accuracy of 80.2% and significant sexual dimorphism.

These findings were in accordance with Saini et al. findings in a survey of the Northern Indian population mandibles (average age of 37.4 years; 92 males; 24 females), which determined that males had higher values for all ramus metrics than females.

Maximum breadth 42.81 mm (3.59) and 40.34 mm (3.76), coronoid ramus height: 61.68 mm (5.25) and 54.89 mm (3.54) and projective height: 53.89 mm (6.93) and 47.45 (4.63), males and females, respectively), having an overall accuracy of 80.2% and significant sexual dimorphism.

Similarly, Taleb and Beshlawy examined 191 panoramic images of an Egyptian sample ranging in age from 6 to 70 years and found that the mean ramus measurements for males were higher than that for females 12. Projected ramus height: 8.3 (0.8) and 7.2 (0.7); ramus breadth: 4.2 (0.3) and 4.0 (0.3); and coronoid ramus height: 7.8 (0.7) and 7.0 (0.6). Prediction accuracy was 81% for men and 77.9% for women and overall, 79.6%.

Additionally, Behl, Ashima Bali, et al. found, based on 400 panoramic images from a North Indian sample, aged 10 to 40 years. 22 Upper ramus breadth, 1.66 (M), 1.59 (F); coronoid ramus, height, 2.89 (M), 2.68 (F); males had higher mean mandibular ramus measurements than females.

In the current study, the prediction accuracy was high, which was in accordance with that of Verma et al who found that males had higher ramus metric variables than females, with a total accuracy of 77.6% and 78.4% in males and 76.8% in females.

Kharoshah et al. investigated 330 Egyptian participants to evaluate the accuracy of six mandibular metrics by spiral computed tomography. 24 Males had significantly higher values than females, with a total predictive accuracy of 83.9%el-sherbiny, et al. in their study performed on 92 females and 90 males of an Egyptian sample, males were found to have significantly higher values than females, with total accuracy of 76.7%. It correctly identified males in 73.9% of cases and females in 20.8% of cases.

Generally, a systematic review reported that significant sex differences were found in 87.5% of mandibular radio morphometric studies and 75% of identified dried mandibular bones.

In the five previously mentioned studies, all findings showed statically showed differences between males and females regardless of differences in the selected parameters, imaging, populations and measurement methods.

Furthermore, it is crucial to note that the linear measurements of the left and right sides did not statistically vary, which supported previous findings.

Our analyses do not support Rai et al. conclusion that age, not sex, is revealed by mandibular measurements in an Indian population of 7–20 year-olds.

In a sample of Sri Lankan population, Hettiarachchi, et al., found that there were no significant differences in mandibular measurements between the sexes, but coronoid ramus height and condylar ramus height were strong predictors of age. Moreover, Ayoub, Fouad, et al. and Rodriguez-Cardenas, et al., neither sex showed any statistical dimorphism during their investigations.

Conclusion

Generally, using the 3DVR images very useful tool in evaluating which parameter of the mandibular ramus can predict sex, in all correlated parameters males recorded higher values than females, with the projective ramus height, maximum ramus breadth and coronoid height being the most significant sex predictors. In conclusion, CBCT can accurately and specifically identify sex, with Projective ramus height recording the highest dimorphism ability with a sensitivity of 88.89% and a specificity of 71.43%. Our findings have implications for fields of orthodontics and maxillofacial surgery and recommend further studies using larger samples, Egyptian governorates and imaging modalities.

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Ethics Statement

The authors confirmed that the current retrospective study was performed in accordance with Alexandria university Accountable Committee (IRB no: 0390-02/2022).

Disclosure

The authors have no financial interest to declare concerning the content of this article.

Declaration of Competing Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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