Journal of Forensic Research

Taleb, J Forensic Res 2015, 6:5
DOI: 10.4172/2157-7145.1000308

Research Article Open Access

Mandibular Ramus and Gonial Angle Measurements as Predictors of Sex and Age in an Egyptian Population Sample: A Digital Panoramic Study

Noha Saleh Abu-Taleb* and Dina Mohamed El Beshlawy

Faculty of Oral and Dental Medicine, Cairo University, Egypt, Oral and Maxillofacial Radiology, 11 Al-Saraya St., Al-Manyal, Cairo, Egypt[2]Faculdade SEAMA, Macapá, Amapá, Brazil

Abstract

Objective: The determination of sex and age is necessary in forensic practice and medico legal purposes. Mandible may play a vital role in sex estimation as it is the most dimorphic bone of skull that often recovered intact. In this respect, the availability of plentiful antemortem orthopantomograms may be of great value in studying and developing population specific standards for accurate sex and age estimation. Therefore, the purpose of the current study was to assess the usefulness of various mandibular ramus linear and gonial angle measurements on digital panoramic images as indicators for sex and age in an Egyptian population sample.

Methods: 191 panoramic images (105 males and 86 females) of Egyptian patients aged (6-70) years old were selected. Five mandibular ramus linear measurements (upper ramus breadth, lower ramus breadth, projective height, condylar ramus height and coronoid ramus height) and gonial angle measurements were performed bilaterally resulting in a total of 382 rami being assessed. Stepwise discriminant and regression analyses were performed to determine the most significant predictors of sex and age respectively.

Results: Males showed statistically significant higher mean linear ramus measurements and lower mean gonial angle values than females. Condylar and coronoid ramus heights were the most significant predictors for sex and age respectively. The discriminate function equation was: (D=14.698-1.895 Condylar ramus height) with an accuracy of 81% in males and 77.9% in females and an overall accuracy of 79.6%. The regression equation for age estimation in the whole studied sample was: (Age=-32.306+8.481 Coronoid ramus height) that yields no significance on comparing actual and estimated ages.

Conclusion: In the selected Egyptian population sample, the mandibular ramus showed a high sexual dimorphism and proved to be beneficial in sex and age estimation; while, the gonial angle could assist in sex estimation only.

Keywords: Forensic anthropometry; Sex and age estimation; Mandibular ramus; Gonial angle; Digital panoramic radiography; Discriminant function analysis

Introduction

The diagnosis of sex in bone remnants is necessary in forensic practice and forensic anthropology [1]. Sex identification is of significance in cases of mass fatality incidents where bodies are damaged beyond recognition and it depends largely on the available parts of skeleton [2]. Generally, in presence of skeletal elements in good condition, morphological indicators of sexual dimorphism allow a correct diagnosis in more than 95% of cases [3-5].

Skull is the most dimorphic and easily sexed portion of skeleton after pelvis [2]. But in cases where intact skull is not found, mandible may play a vital role in sex estimation, as it is the most dimorphic, largest and strongest bone of the skull that is often recovered largely intact [6-9].

Mandibular ramus can differentiate between sexes, as the stages of mandibular development, growth rates, and duration are distinctly different in both sexes. In addition, masticatory forces exerted are different for males and females, which influence the shape and the size of the mandibular ramus [2]. Moreover, the morphological changes of the mandible are thought to be influenced by the occlusal status and age of the subject where longitudinal studies have shown that remodeling of the mandibular bone occurs with age [10].

Despite the varying anatomical landmarks, numerous studies have been performed using different ramus metric measurements for sex [6,11] and age [12,13] estimation. As well, the gonial angle was used by some researchers for sex [11,14] and age [15,16] estimation with controversial results.

Skeletal characteristics differ in each population emphasizing the need for population-specific osteometric standards for sex estimation [6,17,18]. Only few published studies were conducted on the Egyptian population using the human mandible [19].

Panoramic X-ray technology is commonly accessible and is used in daily clinical routine to assess mandibular vital structures bilaterally. Some studies had concluded that the most reliable panoramic measurements were obtained of linear objects in the horizontal plane [20]. Moreover, other studies had shown that the vertical measurements had acceptable accuracy and reproducibility when a software-based calibrated measurement tool was used [21]. In forensic antrhropology, comparison of antemortem and postmortem radiographs is one

***Corresponding author:** Taleb NSA, Lecturer, Faculty of Oral and Dental Medicine, Cairo University, Oral and Maxillofacial Radiology, 11 Al-Saraya St., Al-Manyal, Cairo, Egypt, Tel: 00201001949580; E-mail: noha.saleh@dentistry.cu.edu.eg

Received July 06, 2015 ; **Accepted** August 26, 2015 ; **Published** August 26, 2015

Citation: Taleb NSA, Beshlawy ME (2015) Mandibular Ramus and Gonial Angle Measurements as Predictors of Sex and Age in an Egyptian Population Sample: A Digital Panoramic Study. J Forensic Res 6: 308. doi: 10.4172/2157-7145.1000308

of the cornerstones of positive identification of human remains. So, antemortem orthopantomograms may be of great value in the identification of human remains [22]. The presence of plenty of panoramic radiographs provides a great opportunity to study the sexual dimorphism and age estimation of individuals in a certain population. This was behind the idea of using panoramic images for mandibular ramus assessment in the current work. Therefore, the purpose of the present study was to assess the usefulness of various mandibular ramus linear and gonial angle measurements on digital panoramic images as indicators for sex and age in an Egyptian population sample.

Materials and Methods

A set of five hundred digital panoramic images taken previously for various diagnostic purposes were evaluated for the present study. The images were acquired using (ORTHOCEPH R® OC200, Instrumentarium Dental, Finland). Exposure parameters were 57-85 kVp, 12-16 mA and 0.1-3.2 s according to patient's age and size. Vistascan (Durr Germany) radiographic dental diagnostic unit was used for imaging plate scanning. Only 191 panoramic images of dentate and partially edentulous subjects (105 males and 86 females) with age ranging from 6 to 70 years old were selected for the present study, for every panoramic image measurements were performed bilaterally resulting in a total of 382 rami being assessed. The selected images fulfilled the following inclusion criteria: Good quality standard panoramic images without any grade of exposure or positioning errors. nce of any pathological lesions, fracture or deformity.

The digital panoramic images were saved in a JPEG file format and exported to the Digora® 2.5 software (Soredex, Helsinki, Finland) where linear and angular measurements were performed. This study was held at the Faculty of Oral and Dental Medicine, Cairo University, Egypt.

After image calibration (to obtain 1:1 magnification), the following mandibular ramus linear and gonial angle measurements were performed in cm (Figures 1 and 2):

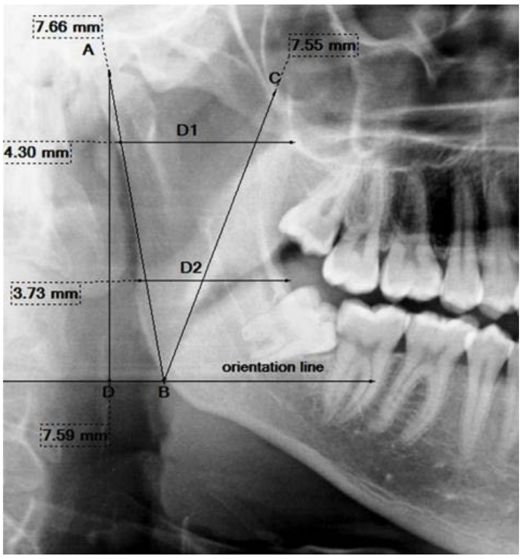

Figure 1: The five linear ramus measurements performed on the digital panoramic image (D1: upper ramus breadth, D2: lower ramus breadth, AB: condylar ramus height, BC: coronoid ramus height, AD: projective ramus height).

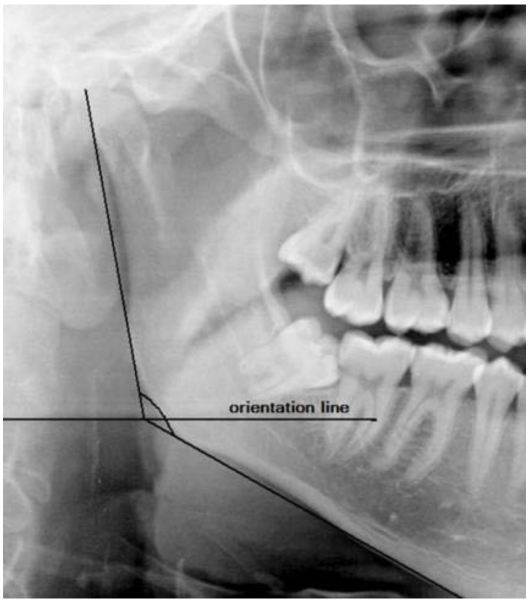

Figure 2: Measurement of the gonial angle on the digital panoramic image.

1. Upper ramus breadth (D1): the horizontal distance between the most anterior to the most posterior point of the ramus passing through the sigmoid notch along a line parallel to the transverse plane.

2. Lower ramus breadth (D2): the horizontal distance between the most anterior to the most posterior point of the ramus at the level of the occlusal plane along a line parallel to the previous one. (An average ramus breadth value of D1 and D2 was calculated for each side and used for further analysis).

For standardization, a horizontal orientation line was digitally traced passing through the summit of the gonial angle and used for the following measurements:

3. Condylar ramus height (A-B): the distance from the condylion (A) to the intersection of the orientation line with the inferior border of the ramus (B).

4. Projective ramus height (A-D): the projective distance between the condylion (A) and the orientation line (D).

5. Coronoid ramus height (C-B): the distance between coronion (C) and the intersection of the orientation line with the inferior border of the ramus (B).

6. Gonial angles: these were measured as the intersection between a digitally traced line tangential to the most inferior points at the angle and the lower border of the mandibular body and another line tangential to the posterior borders of the ramus and the condyle [23].

Data collection and exporting to the software were done by a maxillofacial radiologist who did not participate in measurements taking. All the measurements were performed by two radiologists of similar experience in the field of Oral and Maxillofacial Radiology. The two observers were blinded to the sex and age of the individual where no evidence of sex or age was visible in the included panoramic images. The two observers were also blinded to the measurements taken by each of them. The mean values taken by the two observers was calculated and subjected to statistical analysis.

Statistical Analysis

Data were presented as minimum, maximum, mean, standard deviation (SD) and median values with interquartile ranges (IQR). Paired t-test was used to compare between right and left side measurements. Student's t-test was used to compare between males and females. Pearson's correlation coefficient (r) was used to determine the correlation between the independent variables and the dependent variable. Stepwise discriminant analysis was conducted to predict the sex from the different mandibular measurements. Discriminant analysis started with testing the equality of means between males and females. Stepwise statistics revealed the significant predictors which were used to determine the discriminate function. Then group centroids (group means) were calculated, they represent the determinant points for discrimination between males and females. Classification of the percentage of accurately classified cases according to the discriminate function was performed. Multiple linear regression was used to predict age (Dependent variable) from ramus breadth, ramus height, condylar ramus height, coronoid ramus height as well as gonial angle (Independent variables). The regression equation is: Y=a+bx where (Y) is the dependent variable, (a) is the regression coefficient of the dependent variable (Intercept), (b) is the regression coefficient of the independent variable (s) and (x) is the independent variable (s). Stepwise regression method was used to determine significant predictors of age. Paired t-test was used to compare between actual age values and estimated age. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

Results

Descriptive statistics of the male and female subjects are presented in Tables 1 and 2 respectively. Comparisons between right and left sides were performed and no statistically significant difference was found between the two sides; consequently, the mean of the two sides was used in further statistical analysis.

Comparison between males and females revealed that males showed statistically significant higher mean ramus linear measurements and lower mean gonial angle values than females (Table 3).

Sex estimation

A discriminant analysis was conducted to predict sex. Significant mean differences between males and females were found for all measurements; however, condylar ramus height was the only significant predictor for sex.

The discriminate function equation is as follows:

D=14.698-1.895 Condylar ramus height

The discriminate functions at group centroids (group means) were 0.681 for males and -0.831for females.

Classification results revealed that 81% of the males and 77.9% of the females were correctly classified according to the previous prediction equation and the overall correct classification was 79.6%.

Age estimation

There was a statistically significant positive (direct) correlation between age and ramus linear measurements i.e. an increase in age is associated with an increase in these measurements and vice versa.

Males	**Min**	**Max**	**Mean SD**	**Median (IQR)**
Age (years)	6	70	31 (16)	25 (21-44)
Ramus breadth				
R	3.42	4.97	4.21 (0.32)	4.24 (4-4.43)
L	3.41	5.04	4.22 (0.32)	4.28 (4.03-4.42)
Average	3.43	4.96	4.22 (0.31)	4.23 (4.01-4.43)
Projected ramus height				
R	5.75	9.79	8.26 (0.84)	8.37 (7.88-8.86)
L	5.78	9.71	8.29 (0.82)	8.5 (7.86-8.91)
Average	5.76	9.74	8.27 (0.82)	8.44 (7.87-8.86)
Condylar ramus height				
R	5.87	9.99	8.42 (0.84)	8.58 (7.99-9.02)
L	5.92	9.97	8.44 (0.81)	8.63 (7.94-9)
Average	5.89	9.98	8.43 (0.82)	8.6 (7.93-9.03)
Coronoid ramus height				
R	5.56	9.53	7.81 (0.7)	7.96 (7.39-8.29)
L	5.45	9.82	7.83 (0.72)	7.99 (7.36-8.39)
Average	5.5	9.67	7.82 (0.71)	7.99 (7.37-8.31)
Gonial angle				
R	68.95	133.05	121.66 (6.69)	122.1 (119.85-124.7)
L	112.2	133.15	122.66 (4.18)	122.65 (120.25-125)
Average	95.7	132.25	122.16 (4.84)	122.4 (120.05-124.65)

Table 1: Descriptive data of the male subjects presented as minimum, maximum, mean, standard deviation (SD) and median values with interquartile ranges (IQR). R: right side, L: left side, SD standard deviation, IQR: interquartile ranges.

Females	**Min.**	**Max**	**Mean (SD)**	**Median (IQR)**
Age	7	68	30 (17)	23 (20-38)
Ramus breadth				
R	3.31	5.93	3.99 (0.39)	3.98 (3.71-4.25)
L	3.14	4.92	4.05 (0.34)	3.99 (3.82-4.25)
Average	3.3	5.26	4.02 (0.34)	3.99 (3.79-4.28)
Projected ramus height				
R	3.73	8.75	7.15 (0.74)	7.21 (6.79-7.61)
L	5.19	8.9	7.19 (0.67)	7.18 (6.78-7.68)
Average	5.11	8.83	7.17 (0.69)	7.21 (6.86-7.66)
Condylar ramus height				
R	5.26	8.8	7.30 (0.66)	7.35 (6.85-7.72)
L	5.35	8.9	7.28 (0.69)	7.26 (6.89-7.75)
Average	5.31	8.85	7.29 (0.67)	7.28 (6.88-7.74)
Coronoid ramus height				
R	5.23	8.19	6.98 (0.56)	6.97 (6.58-7.45)
L	5.43	8.2	6.98 (0.56)	7.04 (6.56-7.4)
Average	5.33	8.14	6.98 (0.55)	6.99 (6.56-7.41)
Gonial angle				
R	113.8	134.8	125.05 (4.41)	125.4 (121.5-127.7)
L	113.7	134.5	125.12 (4.43)	125.45 (121.7-128.6)
Average	113.75	134.05	125.09 (4.29)	125.28 (121.4-128.3)

Table 2: Descriptive data of the female subjects presented as minimum, maximum, mean, standard deviation (SD) and median values with interquartile ranges (IQR). R: right side, L: left side, SD standard deviation, IQR: interquartile ranges.

However; there was no statistically significant correlation between age and gonial angle values (Table 4).

Stepwise regression analysis results showed that the coronoid ramus height was the only statistically significant predictor of age in males,

Variable	Males (n=105)	Females (n=86)	P-value
Ramus breadth	4.2 (0.3)	4.0 (0.3)	<0.001*
Projected ramus height	8.3 (0.8)	7.2 (0.7)	<0.001*
Condylar ramus height	8.4 (0.8)	7.3 (0.7)	<0.001*
Coronoid ramus height	7.8 (0.7)	7.0 (0.6)	<0.001*
Gonial angle	122.2 (4.8)	125.1 (4.3)	<0.001*

Table 3: Mean standard deviation (SD) values and results of Student's t-test for comparison between males and females. *Significant at P ≤ 0.05.

Variable	Correlation coefficient (r)	P-value
Ramus breadth	0.181	0.012*
Projected ramus height	0.280	<0.001*
Condylar ramus height	0.300	<0.001*
Coronoid ramus height	0.405	<0.001*
Gonial angle	-0.052	0.477

Table 4: Results of Pearson's correlation coefficient for the correlation between age and different variables *Significant at P ≤ 0.05.

females and in the whole studied sample (Tables 5-7 respectively).

According to the stepwise regression model, the regression equations for prediction of age in males, females and in the whole studied sample were as follows:

Age (males)=-54.290+10.954 Coronoid ramus height

Age (females)=-57.269+12.519 Coronoid ramus height

Age (regardless of sex)=-32.306+8.481 Coronoid ramus height

Comparison between actual and estimated ages according to the prediction equation showed non-statistically significant difference between the values in males, females and in the whole studied sample (Table 8).

Discussion

The study of sex estimation is not only important from a forensic point of view but also for regional variations and population history [24]. Moreover, age estimation is one of the important duties of medico legal officers in recent time as crimes of varied nature are increasing [25,26].

Mandibular condyle and ramus in particular are generally the most sexually dimorphic as they are the sites associated with the greatest morphological changes in size and remodeling during growth [27-29]. Hence, in the present study, the mandibular ramus was selected for sex and age estimation.

Regarding the current study, during the image analysis, the authors strained to standardize the parameters in order to reduce the percentage of error in the subjective judgment as possible. Therefore, novel reference points and planes for the ramus linear measurements were introduced. For the ramus breadth, the transverse plane was taken as a reference plane and two measurements were performed (the upper and the lower ramus breadths) and an average ramus breadth value was then calculated. Regarding the ramus height parameters, a horizontal orientation line was digitally traced passing through the summit of the gonial angle and the intersection of this orientation line with the inferior border of the ramus was used as a reference point in measuring the condylar and coronoid ramus heights, and the projective distance from the condylion to this line was used in measuring the projective

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.*
	B	Std. Error	Beta		
Constant	-54.290	14.905		-3.642	0.000
Coronoid ramus height	10.954	1.898	0.494	5.771	0.000

Table 5: Stepwise linear regression analysis and regression coefficients for significant predictors of age estimation among males. *Significant at P ≤ 0.05.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.*
	B	Std. Error	Beta		
Constant	-57.269	20.737		-2.762	0.007
Coronoid ramus height	12.519	2.962	0.419	4.227	0.000

Table 6: Stepwise linear regression analysis and regression coefficients for significant predictors of age estimation among females. *Significant at P ≤ 0.05.

	Unstandardized coefficients (B)	Standard error	95% Confidence interval for B		P-value
			Lower bound	Upper bound	
Constant	-32.306	10.418	-52.857	-11.755	0.002*
Coronoid ramus height	8.481	1.392	5.734	11.228	<0.001*

Table 7: Stepwise linear regression analysis and regression coefficients for significant predictors of age estimation in the whole studied sample. *Significant at P ≤ 0.05.

	Minimum	Maximum	Mean (SD)	t	p-value
Males	6	70	31.39 (15.64)	-0.016	0.987*
Actual age	5.96	51.64	31.41 (7.72)		
Estimated age					
Females	7	68	30.12 (16.58)		0.992*
Actual age	9.46	44.64	30.13 (6.94)	0.01	
Estimated age					
Whole sample	6.00	70.00	30.82 (16.04)	-0.014	0.992*
Actual age	12.90	49.71	30.83 (6.49)		
Estimated age					

Table 8: Minimum, maximum, mean, standard deviation (SD) and results of paired t-test for comparison between actual and estimated ages among males, females and the whole studied sample according to the prediction equation. *Significant at P ≤ 0.05.

ramus height.

No statistically significant difference was found between the right and left sides regarding the linear and angular measurements which was in accordance with previous studies [10,11,23,30]; subsequently, the mean of the two sides was used for further statistical analysis.

Osteometric assessment by means of discriminant function analysis is one of the most commonly used methods of estimating sex in unidentified skeletal remains [24]. However, levels of sexual dimorphism are population specific due to a combination of genetic and environmental factors [31]. Consequently, in the present study, discriminant function analysis was performed in a trial to predict the most significant parameter for sex estimation in the Egyptian population.

The present study results revealed that males had statistically significant higher mean values regarding all the mandibular ramus linear measurements than females (Ramus breadth: 4.2 (0.3) and 4.0 (0.3); projected ramus height: 8.3 (0.8) and 7.2 (0.7); condylar ramus height 8.4 (0.8) and 7.3 (0.7); and coronoid ramus height: 7.8 (0.7) and 7.0 (0.6) in males and females respectively). Discriminant function analysis revealed that condylar ramus height was the only significant predictor for sex estimation. By using this variable, a prediction equation was performed resulting in 81% of the males and 77.9% of the females correctly classified with an overall accuracy of 79.6%.

This was in agreement with Saini et al. [6] in a study on mandibles of Northern Indian population (92 males, 24 females, mean age 37.4 years) who found that all the ramus metric parameters were higher in males than females (coronoid height: 61.68 mm (5.45) and 54.89 (3.54), projective height: 53.89 (6.93) and 47.45 (4.63), condylar height: 60.67 (5.32) and 54.46 (4.97), maximum breadth: 42.81 (3.59) and 40.34 (3.76) and minimum breadth: 31.29 (2.99) and 29.65 (1.96) in males and females respectively) and showed significant sexual dimorphism with an overall accuracy of 80.2%. Similarly, Indira et al. [28] found that all linear ramus dimensions measured on orthopantomographs (50 males, 50 females aging 20-50 years) were significantly higher for Bangalore males compared to females (coronoid height: 119.70 mm (10.87) and 111.15 (9.51), projective ramus height: 129.05 (9.51) and 120.82 (7.85), condylar height: 131.30 (9.26) and 123.27 (7.36), maximum breadth: 74.20 (6.34) and 68.98 (5.75) and minimum breadth: 51.35 (4.43) 46.96 (3.83) in males and females respectively) and 76% of the cases were classified correctly. Besides, Vodanovic et al. [17] in their study on Croatian archeological samples (263 adult and sub adult male and female mandibles) found that mandibular ramus dimensions were significantly higher for male samples compared to female ones (maximum ramus height: 67.42 (4.31) and 61.46 (3.63), maximum breadth: 44.2 (3.89) and 41.23 (3.76), minimum breadth: 31.26 (2.94) and 28.36 (2.15) for male and female samples respectively). Additionally, Al-Shamout et al. [11] in their study on panoramic radiographs of Jordanian dentate subjects (103 males and 106 females, aged 11-69 years, mean: 33.51) found that male subjects had higher values of ramus height compared to female counterparts (53.22 mm (5.82) and 49.11(4.45) in males and females respectively). And, Rai et al. [32] in their study on human dentate dry mandibles of Indian population (88 males and 29 females) found that the height of the ramus of the male mandibles showed a significant difference than that of the female mandible; however, there was no significant difference in the breadth of the ramus between both sexes.

Generally, the overall size and bone thickness of the male skeleton is greater than that of the female; however, this is not universal, since bone size and thickness are related to many things other than sex; better nutrition and heavy physical activity [33]. On average, males have greater masticatory force than females [11] that influences the bone size.

As regards the gonial angle, males showed statistically significant lower mean gonial angle values than females (122.2° and 125.1° respectively). This was in agreement with many researchers [14,32,34]. Conversely, other researchers found that males showed statistically significant higher mean gonial angle values than females [19], and others did not find any statistically significant differences between both sexes [11,12,30,35,36]. It was found that females had a downward and backward rotation in mandible while males had a forward rotation in mandible [36]. Hence, the gonial angle values in females are higher than in males.

It is worth mentioning that the mandibular angle varies in different human population groups where the average values were (119°) in Indian, Chinese and Peruvian mandibles, (110°) in that of the Neanderthals, (128°) in the European population, (120°) in Xanthoderms and African Negroes [32] and (124°) in Jordanians [11]. In the present study, the mean gonial angle was (123.6°) for the included Egyptian population sample. The small the difference in mandibular angle measurements between different population groups indicates some degree of homogeneity between these groups; however, when this difference is relatively high, it may be considered for racial/population identification [32].

Despite the differences in the selected measurements, it is worth mentioning that a previous study was conducted by Kharoshah et al. [19] on Egyptian population (250 males, 250 females, age range from 6 to 60 years) using osteometric mandibular measurements on spiral CT scan with three dimensional reconstruction. In their study, six mandibular measurements were assessed of which the bicondylar breadth, gonial angle and minimum ramus breadth showed significant results between both sexes and the overall predictive accuracy of their prediction model was 83.9% for the whole sample.

Regarding age estimation, in the present study, a statistically significant positive (direct) correlation was found between age and the mandibular ramus linear measurements, regression analysis results showed that coronoid ramus height was the only statistically significant predictor of age in males, females and in the whole studied sample. Prediction equations were performed using this variable and comparison between actual and estimated ages according to the prediction equations showed non-statistically significant difference between the values.

The current results regarding the correlation between age and ramus height were close to Oksayan et al. [13] in their study on completely edentulous (n=24, mean age 69.7), old dentate (n=24, mean age 62.2 years) and young dentate (n=24, mean age 18.8 years) subjects whose results revealed that ramus height increased with age but decreased with edentulous states. Also, Al-Shamout et al. [11] found that ramus height increased in the second and third decades then decreased with age. However, in their study Raustia and Salonen [12] found no correlation between age and ramus height in their study on complete denture wearers (12 males, 18 females, age range 42-74 years mean 61 years). Moreover, our results regarding age and ramus breadth were against Ghaffari et al. [16] in their study using CT scans obtained from 124 subjects (70 males, 54 females, aged 21-50 years) who reported that for both genders ramus breadth decreased with increasing age. The results of the aforementioned studies were compared to the present study as they used samples that fall within the wide age range of the current study. However, one of the limitations of this work is that the dental status was not considered as a variable.

Regarding the gonial angle, in the current work there was no correlation between gonial angle values and age. This was in agreement with Chole et al. [15] in a study on panoramic radiographs (854 dentulous subjects, 206 edentulous subjects; aged 15-66 years) where the gonial angle was not influenced by the age or by dental status. Similarly, Dutra et al. [35] in their study on panoramic radiographs (119 males, 199 females, age range 40–79 years) found that the gonial angle did not show any change with gender, age and dental status. Likewise, Oksayan et al. [13] did not found significant differences in the gonial angle values, when comparing the young dentate, old dentate and completely edentulous subjects. Moreover, Raustia and Salonen [12] found that the correlation between age and gonial angle was statistically insignificant. On the other hand, this contradicts some researches where the gonial angle increased with age [11,16] and other researches where the gonial angle decreased with age [36]. The different results of the correlation between gonial angle and age observed among various studies may be attributed to the different age ranges and different dental status selected among those studies.

To sum up, our results support previous research on other populations that the mandibular ramus showed high sexual dimorphism and proved to be beneficial in sex and age estimation with the condylar ramus height was the most significant predictor for sex and the coronoid ramus height was the most significant predictor for age; whereas, the gonial angle could assist in sex estimation only. Hence, the use of mandibular ramus is recommended as an aid for sex and age estimation in forensic analysis. However, further studies using larger sample size from diverse Egyptian regions and different imaging modalities are recommended to set our population standards for sex and age estimation.

Conclusions

In the selected Egyptian population sample, the mandibular ramus showed a high sexual dimorphism and proved to be beneficial in sex and age estimation; while, the gonial angle could assist in sex estimation only.

Acknowledgement

The authors would like to acknowledge Dr. Nagla'a Abdelwahed; Professor of Oral Radiology, Faculty of Oral and Dental Medicine, Cairo University for the great role in data collection throughout this work.

References

1. Rösing FW, Graw M, Marré B, Ritz-Timme S, Rothschild MA, et al. (2007) Recommendations for the forensic diagnosis of sex and age from skeletons. Homo 58: 75-89.
2. Raj JD, Ramesh S (2013) Sexual dimorphism in mandibular ramus of south Indian population. Antrocom Online Journal of Anthropology 9: 253-258.
3. Baughan B, Demirjian A (1978) Sexual dimorphism in the growth of the cranium. Am J Phys Anthropol 49: 383-390.
4. Franklin D, Freedman L, Milne N (2005) Sexual dimorphism and discriminant function sexing in indigenous South African crania. Homo 55: 213-228.
5. Kimmerle EH, Ross A, Slice D (2008) Sexual dimorphism in America: geometric morphometric analysis of the craniofacial region. J Forensic Sci 53: 54-57.
6. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, et al. (2011) Mandibular ramus: an indicator for sex in fragmentary mandible. J Forensic Sci 56 Suppl 1: S13-16.
7. Scheuer L (2002) Application of osteology to forensic medicine. Clin Anat 15: 297-312.
8. Duri M, Rakocevi Z, Doni D (2005) The reliability of sex determination of skeletons from forensic context in the Balkans. Forensic Sci Int 147: 159-164.
9. Hu KS, Koh KS, Han SH, Shin KJ, Kim HJ (2006) Sex determination using nonmetric characteristics of the mandible in Koreans. J Forensic Sci 51: 1376-1382.
10. Huumonen S, Sipilä K, Haikola B, Tapio M, Söderholm AL, et al. (2010) Influence of edentulousness on gonial angle, ramus and condylar height. J Oral Rehabil 37: 34-38.
11. Al-Shamout R, Ammoush M, Alrbata R, Al-Habahbah A (2012) Age and gender differences in gonial angle, ramus height and bigonial width in dentate subjects. Pakistan Oral & Dental Journal 32: 81-87.
12. Raustia AM, Salonen MA (1997) Gonial angles and condylar and ramus height of the mandible in complete denture wearers--a panoramic radiograph study. J Oral Rehabil 24: 512-516.
13. Okşayan R, Asarkaya B, Palta N, Şimşek İ, Sökücü O, et al. (2014) Effects of edentulism on mandibular morphology: evaluation of panoramic radiographs. ScientificWorldJournal 2014: 254932.
14. Xie QF, Ainamo A (2004) Correlation of gonial angle size with cortical thickness, height of the mandibular residual body, and duration of edentulism. J Prosthet Dent 91: 477-482.
15. Chole RH, Patil RN, Balsaraf Chole S, Gondivkar S, Gadbail AR, et al. (2013) Association of mandible anatomy with age, gender, and dental status: a radiographic study. ISRN Radiol 2013: 453763.
16. Ghaffari R, Hosseinzade A, Zarabi H, Kazemi M (2013) Mandibular dimensional changes with aging in three dimensional computed tomographic study in 21 to 50 year old men and women. Journal of Dentomaxillofacial Radiology Pathology and Surgery 2: 7-12.
17. Vodanovic M, Dumancic J, Demo Z, Mihelic D (2006) Determination of sex by discriminant function analysis of mandibles from two Croatian archaeological sites. Acta Stomatol Croat 40: 263-277.
18. Giles E (1964) Sex determination by discriminant function analysis of the mandible. Am J Phys Anthropol 22: 129-135.
19. Kharoshah MA, Almadani O, Ghaleb SS, Zaki MK, Fattah YA (2010) Sexual dimorphism of the mandible in a modern Egyptian population. J Forensic Leg Med 17: 213-215.
20. Schulze R, Krummenauer F, Schalldach F, d'Hoedt B (2000) Precision and accuracy of measurements in digital panoramic radiography. Dentomaxillofac Radiol 29: 52-56.
21. Vazquez L, Nizamaldin Y, Combescure C, Nedir R, Bischof M, et al. (2013) Accuracy of vertical height measurements on direct digital panoramic radiographs using posterior mandibular implants and metal balls as reference objects. Dentomaxillofac Radiol 42: 20110429.
22. Kahana T, Hiss J (1999) Forensic radiology. Br J Radiol 72: 129-133.
23. Mattila K, Altonen M, Haavikko K (1977) Determination of the gonial angle from the orthopantomogram. Angle Orthod 47: 107-110.
24. Saini V (2013) Metric study of fragmentary mandibles in a North Indian population. Bull Int Assoc Paleodont 7: 157-162.
25. Thevissen PW, Kaur J, Willems G (2012) Human age estimation combining third molar and skeletal development. Int J Legal Med 126: 285-292.
26. Rai B, Krishan K, Kaur J, Anand SC (2008) Technical note: Age estimation from mandible by lateral cephalogram: a preliminary study. J Forensic Odontostomatol 26: 24-28.
27. Humphrey LT, Dean MC, Stringer CB (1999) Morphological variation in great ape and modern human mandibles. J Anat 195: 491-513.
28. Indira AP, Markande A, David MP (2012) Mandibular ramus: An indicator for sex determination - A digital radiographic study. J Forensic Dent Sci 4: 58-62.
29. Franklin D, O Higgins P, Oxnard CE, Dadour I (2006) Determination of sex in South African blacks by discriminant function analysis of mandibular linear dimensions: A preliminary investigation using the Zulu local population. Forensic Sci Med Pathol 2: 263-268.
30. Shahabi M, Ramazanzadeh BA, Mokhber N (2009) Comparison between the external gonial angle in panoramic radiographs and lateral cephalograms of

adult patients with Class I malocclusion. J Oral Sci 51: 425-429.

31. Macaluso PJ Jr (2010) Sex determination from the acetabulum: test of a possible non-population-specific discriminant function equation. J Forensic Leg Med 17: 348-351.

32. Rai R, Madhyastha S, Kumaran M (2007) A Pilot Study of the Mandibular Angle and ramus in Indian population. Int J Morphol 25: 353-356. Lyle DP (2008). Howdunit Forensics: A guide for writers. (1st edn), F+W publications, Inc, Ohio, Canada.

33. Kumar MP, Lokanadham S (2013) Sex determination & morphometric parameters of human mandible. Int J Res Med Sci 1: 93-96.

34. Dutra V, Yang J, Devlin H, Susin C (2004) Mandibular bone remodelling in adults: evaluation of panoramic radiographs. Dentomaxillofac Radiol 33: 323-328.

35. Upadhyay RB, Upadhyay J, Agrawal P, Rao NN (2012) Analysis of gonial angle in relation to age, gender, and dentition status by radiological and anthropometric methods. J Forensic Dent Sci 4: 29-33.

36. Pecora NG, Baccetti T, McNamara JA Jr (2008) The aging craniofacial complex: a longitudinal cephalometric study from late adolescence to late adulthood. Am J Orthod Dentofacial Orthop 134: 496-505.