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Research Article

Mandibular Indices for Gender Prediction: A Retrospective Radiographic Study in Saudi Population

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Abstract

Background and Objective: Determination of sex and age is a crucial component in forensic field and in view of medico legal purpose. Mandible may play a vital measure in the above as it is the most dimorphic bone which is often recovered intact. In this respect, the accessibility of ample antemortem orthopantomograms may be of great prominence in reviewing and developing population specific standards for accurate sex estimation. Therefore, the purpose of the current study was to appraise the effectiveness of various mandibular measurements on digital panoramic images as indicators for sex in Saudi Arabian population.

Methods: 200 panoramic images (100 males and 100 females) of Saudi patients aged 10-60 were selected. Five mandibular ramus linear measurements (maximum ramus width, minimum ramus width, maximum coronoid height, maximum condylar height and maximum ramus height), two mandibular body measurements (body height in the premolar and molar region), gonial angle and bigonial width measurements were made. Descriptive statistics of nine mandibular measurements for male and female was calculated. Discriminant analysis was executed to determine the most significant predictor of sex.

Results: All the measurements were found to be statistically significant between male and females except for gonial angle and minimum ramus width. Greatest dimorphism was shown by maximum ramus width, maximum coronoid height, body height in the premolar region, maximum condylar height followed by body height in the molar region. Gonial angle, minimum ramus width and bigonial width showed least dimorphism. Discriminant function equations were derived to calculate the sex. The accuracy of each function and combination ranged from 54.8% to 92.75%.

Conclusion: In the selected Saudi population sample, the mandibular ramus showed a high sexual dimorphism and accuracy on combination of 9 parameters was 92.75% and proved to be beneficial in sex estimation.

Keywords: Dentistry, Radiology

Introduction

In the adult skeleton, sex determination is usually the first step of the identification process as subsequent approaches for age and stature evaluation are sex dependent. The entirety of the skeletal remnants and the degree of sexual dimorphism integral to a population are the two features on which the reliability of sex determination mainly depends on [1].

Almost every bone of human skeleton displays sexual dimorphism as per the literature review. Past studies also have shown that skull is the most dimorphic and so easily sexed portion of skeleton after pelvis, providing an accurateness up to 92% [1,2]. When in case where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic bone of skull [3].

In mandible, presence of a dense layer of compact bone makes it very resilient and it is the strongest bone of face and hence remains well conserved than many other bones. Dimorphism in mandible is reflected in its shape and size. The shape of the mandible is made by the progressive structural modeling as the bone is increasing in size [4]. Mandibular development growth rate are noticeably dissimilar in male and female. Additionally, masticatory forces exercised are different for each sex, which is again an influencing factor in shaping mandibular ramus [4].

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Panoramic radiographs are generally used in day-to-day routine dental practices to evaluate the mandibular and maxillary vital structures. The efficacy of orthopantomograms are already demonstrated by the past researches in case of determination of morphological dimensions of the mandible [5,6].

Linear objects in the horizontal plane exhibited the most reliable dimensions in a panoramic radiograph [7]. However, further studies had also shown that when a software-based standardized measurement tool was used, the vertical measurements also had an adequate exactitude and reproducibility [8].

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 and body linear and gonial angle measurements on digital panoramic images and an attempt to set forth the fundamentals of a biometric system to as indicators for sex in Saudi population sample.

In this study, we have used discriminant function for sexual dimorphism assessment which is considered to be specific for the population. Use of population specific methods or national standards gives the best exactness for any discriminant function [9,10]. Due to this reason, many researchers have figured population-specific discriminant functions for maximizing the accuracy rates for sex determination on unidentified skeletal remains [11,12].

From the forensic aspect, many studies had showed earlier that the gonial angle was a very reliable parameter with acceptable accuracy and precision in determining gender [13-15]. At the same time it was also suggested that gonial angle alone is not enough to determine sex and age as there are multiple factors influencing its development. In this regard, further research is required to evaluate other morphological dimensions of the mandible, to provide a more reliable indicator of age and sex. Worldwide, a number of studies have been conducted to assess the efficiency of mandible in determining sex. To date, no such study has been carried out on mandible of Saudi population.

Materials and Methods

Ethical approval for the present research was obtained from Scientific Research Committee of King Khalid University-College of dentistry.

This retrospective radiographic study using digital orthopantomograph was designed to conduct in Saudi population. Radiographs were taken by ORTHOPHOS XG5 Digital Panoramic and Cephalometric System (64 kVp, 8 mA, 14.1s) Digital Radiographs were collected from Radiology department of King Khalid University–College of Dentistry. Target population includes radiographs of both male and female. Total sample size was 200 radiographs, out of which 100 radiographs were of males and 100 radiographs were of females. The age group was divided into 10-20, 20-30, 30-40, 40-50, and 50-60 years. 20 radiographs from each age group was collected and analyzed for the mandibular indices. The variables were measured using mouse driven method by moving the mouse and drawing lines using selected points on the digital panoramic radiograph.

The variables included were maximum ramus width, minimum ramus width, maximum condylar height, maximum ramus height, maximum coronoid height, gonial angle, bigonial width and height of the body of mandible at the premolar and molar region. The analysis was done using Sidexis software. Ideal panoramic radiographs of dentulous patients were selected for the study with minimum alveolar crest resorption in premolar and first molar regions. Patients with fracture history, severe developmental disorders which can lead to an alteration in the size of mandible and completely edentulous mandibles were excepted from the study. The measured values were analyzed statistically. Discriminant function analysis was used to determine variables that categorize male and female.

The measurements were all obtained from the right side of the mandible for each radiograph, assuming that there would not be considerable difference in size of the mandible in the same subject without any pathology.

Aim and objective of the current study was as follows

1) To measure and evaluate various measurements of mandibular ramus and its relationship to sex of the patient.

2) To measure and evaluate mandibular body height and its relationship to sex of the patient.

3) To know the usefulness of mandibular ramus, body and gonial angle as an aid in sex estimation.

All the measurements were taken two times and the averages of the values were used for the result to reduce the intra-observer error. Mouse driven method was used for obtaining the following measurements. These measurements were originally obtained from Vodanovic, et al. [16] (Figures 1 and 2).

Maximum Ramus Width is the distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of jaw. Minimum Ramus Width is the smallest anterior–posterior diameter of the ramus Condylar Height is calculated as height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle, or most protruding portion of the inferior border of the ramus Maximum Ramus height is the Height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle, or most protruding

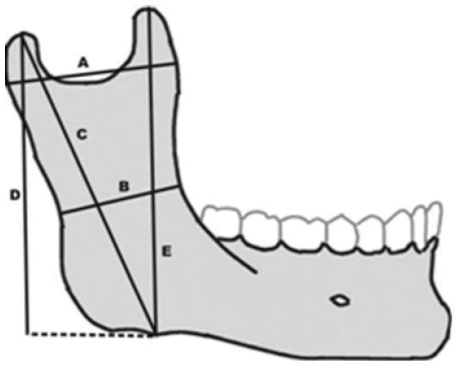

Figure 1: Figure shows all the ramus measurements.
(A) Maximum ramus breadth. (B) Minimum ramus breadth. (C) Condylar height (D) Maximum ramus height (E) Coronoid height.

portion of the inferior border of the ramus. This is obtained by drawing a tangent backward from inferior border to meet the vertical line from most superior point of on the condyle down. Coronoid Height is measured distance between coronion and most protruding portion of the inferior border of the ramus.

Gonial angle was 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 [15]. Bigonial width is measured as the distance between two gonia.

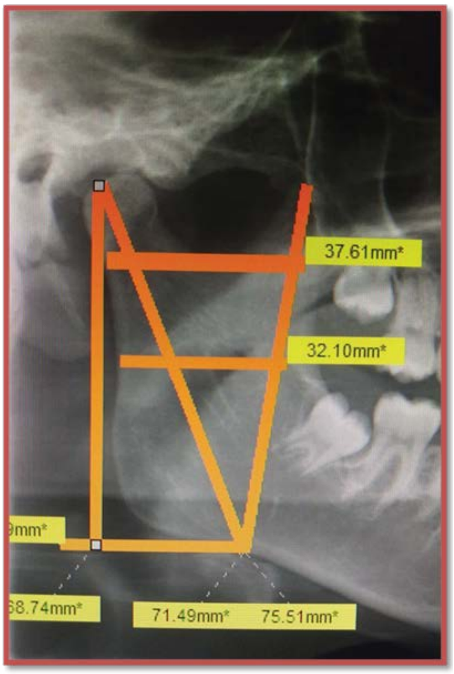

Figure 2: Figure shows ramus analysis.

Body height in the premolar region is obtained by drawing a vertical line drawn from distal aspect of second premolar down to lower border of mandible

Body height in the molar region is calculated by drawing a vertical line drawn from distal aspect of first molar down to lower border of mandible [17] (Figure 3).

Statistical Analysis: The data were analyzed using the discriminant procedure of the statistical package Software used: SPSS version 23 for windows (SPSS Inc., Chicago, IL). The data was analyzed using discriminant Function Analysis to determine/ discriminate between male and female based on continuous variables. This method is to a great degree helpful in those bones like mandible where proper sexual differentiation cannot be obtained from a single variable.

Results

Table 1 show all the observed values for the nine parameters in all age groups of both male and female. Descriptive statistics of nine different mandibular measurements and associated univariate F ration and Wilk Lambda values for male and female are summarized in the table 2. As seen in the table, mean values of all the dimensions are higher for male measurements than

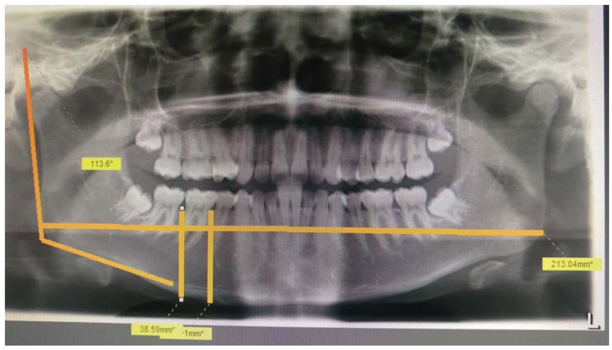

Figure 3: Figure shows mandibular body and gonial angle measurements.

Table 1: shows all the observed values for the nine parameters in all age groups of both male and female.

Location	Sex	10-20	20-30	30-40	40-50	50-60
Maximum ramus breadth	M	42.21 ± 3.05	43.21 ± 2.60	45.49 ± 2.73	41.42 ± 1.26	43.12 ± 2.64
Maximum ramus breadth	F	36.81 ± 2.10	38.61 ± 2.45	38.51 ± 2.59	38.45 ± 1.51	39.04 ± 1.71
Minimum ramus breadth	M	27.72 ± 2.07	30.26 ± 3.47	32.10 ± 1.35	29.56 ± 1.19	30.95 ± 1.75
Minimum ramus breadth	F	27.85 ± 3.45	27.96 ± 1.98	28.06 ± 3.03	28.86 ± 2.63	27.91 ± 1.21
Maximum condylar height	M	79.76 ± 4.42	80.52 ± 3.70	83.14 ± 4.88	79.63 ± 8.62	82.78 ± 3.41
Maximum condylar height	F	73.19 ± 5.06	74.63 ± 3.91	74.56 ± 4.24	76.12 ± 2.11	73.11 ± 2.80
Maximum ramus height	M	73.08 ± 4.93	74.66 ± 2.95	76.56 ± 3.99	76.01 ± 7.83	77.41 ± 3.57
Maximum ramus height	F	68.48 ± 5.62	70.67 ± 4.57	69.89 ± 3.86	72.42 ± 2.16	69.47 ± 2.10
Maximum coronoid height	M	69.73 ± 6.27	72.08 ± 4.51	74.18 ± 5.78	74.33 ± 3.19	73.74 ± 5.17
Maximum coronoid height	F	62.28 ± 5.01	64.05 ± 1.99	63.28 ± 5.06	67.43 ± 2.71	64.34 ± 1.94
Gonial angle	M	128.89 ± 6.02	123.14 ± 4.78	123.96 ± 4.43	119.16 ± 5.31	121.31 ± 5.37
Gonial angle	F	124.41 ± 3.18	121.19 ± 5.99	125.64 ± 5.85	119.22 ± 8.65	130.68 ± 4.58
Bigonial width	M	199.30 ± 14.18	200.97 ± 7.43	211.54 ± 8.28	203.06 ± 10.16	209.66 ± 6.78
Bigonial width	F	190.42 ± 7.12	201.58 ± 10.07	194.12 ± 10.56	203.00 ± 7.48	197.38 ± 3.31
Body height in premolar area	M	37.93 ± 2.17	42.69 ± 2.88	43.60 ± 2.46	42.24 ± 1.22	42.06 ± 1.99
Body height in premolar area	F	37.16 ± 1.88	37.49 ± 2.44	38.21 ± 2.21	36.94 ± 1.44	36.25 ± 2.83
Body height in molar area	M	34.75 ± 3.26	37.46 ± 3.32	39.18 ± 3.60	37.87 ± 2.89	37.69 ± 2.22
Body height in molar area	F	31.42 ± 3.52	33.64 ± 2.53	33.24 ± 3.04	33.85 ± 1.34	33.10 ± 3.08

Table 2: shows descriptive statistics of nine different mandibular measurements.

VARIABLE	NUMBER	MEAN	STD DEVIATION	Wilks' Lambda	F ratio VALUE
Maximum ramus breadth MXRB	73	42.97	2.80	.536	131.802
	81	38.72	2.18		
Minimum ramus breadth MNRB	73	29.89	2.45	.900	16.906
	81	28.26	2.47		
Maximum condylar height MXCDH	73	81.18	5.76	.668	75.549
	81	74.29	3.99		
Maximum ramus height MXRH	73	75.89	5.51	.737	54.134
	81	70.16	4.11		
Maximum coronoid height MXCRH	73	72.64	5.44	.569	115.099
	81	64.42	4.02		
Gonial angle GA	73	123.89	6.23	.994	.931
	81	124.91	6.84		
Bigonial width BGW	73	205.49	9.95	.843	28.273
	81	197.42	8.87		
Body height in premolar area BH/PM	73	41.74	3.25	.587	107.108
	81	37.132	2.22		
Body height in molar area BH/M	73	37.53	3.64	.683	70.689
	81	33.03	2.98		

females. All the measurements were found to be statistically significant between male and females *(P<.001)* except for gonial angle and minimum ramus width *(P>.05)*.

When compared with each age group and mandibular measurements, it was found that in all age groups, males showed higher values. But there was no correlation of values among the age groups studied. In case of maximum ramus width, minimum ramus width, maximum condylar height and maximum ramus height there was no correlation among age groups in males but showed maximum value in 30-40 yrs of age group. Maximum coronoid height showed steady increase in values as the age increases except in 50-60 yrs of age where it was less than 30-40 yrs of age group. In case of gonial angle in males' high value was seen in 10-20 yrs of age group compared to all other age groups and it was decreased as age increased but was not a consistent decrease among the rest of age group. Bigonial width was also higher in 30-40 yrs of age and there was no significant difference among age groups. Body height was less in 10-20 yrs of age group and other age groups did not show much differences and 30-40 yr age group showed highest value. In case of females also variables did not show any significant increase or decrease or correlation with the age. Gonial angle showed higher values in the 50-60 yrs of age compared to 10-20 and other age groups.

Mandibular measurements with greatest dimorphism based upon Wilk's Lambda value and f –statistics were maximum ramus width, maximum coronoid height, body height in the premolar region, maximum condylar height followed by body height in the molar region. Measurements showing least dimorphism were gonial angle, minimum ramus width and bigonial width.

Discriminant Analysis is shown in Tables 3 and 4 depicts the standardized, raw and structure discriminant function co-effecient along with group centroids and sectioning points of the variables. The sex can be calculated from these functions by multiplying the variables values of the dimensions by corresponding coefficients plus the constant, which forms the discriminant equation for the particular function. Example: (for function 4) D = [MXRB X 0.198] + [MXCRH X 0.094] + [BH/PM X 0.186] – 21.800. The discriminant value (D) greater than sectioning point of the particular function or variable indicates male and less than the sectioning point indicates female. Table 5 shows percentage of correct classifications for the discriminant functions. The table presents the percentage of correct prediction. It shows the average / accuracy (in Percentage) of prediction for each function. The accuracy ranged from 54.8% to 92.75%.

Discussion

Since past, jaws and teeth have been used to determine the sex of an individual, because they show sexual dimorphism in morphological features. At the same time, there are high chances of variation prone to the skill of a worker. Thus, there is need of some morphometric criteria to be put in place as a reference for sex determination when combined with some other features. Various studies have clearly stated that the skeletal characters diverge among population, and thus there is a need to set up population specific standards [18].

Sexual dimorphisms of the mandible are the result of various correlated factors such as environmental, genetic or hormonal and thus are population specific [19]. It has been found that there are many factors which influence the development and thus the appearance. The most common is socio-environmental factors which include nutrition, food, climate and pathologies. There may be slight difference in pattern of bone in variable population [20].

To determine the sex from skeleton, a reliable analysis is necessary and discriminant function analysis is increasingly used which is reproducible and lessens the examiner's subjective judgment.

It is well established that discriminant function derived from one specific population cannot be applied to another as magnitude of sex-related differences vary significantly among regional populations. So, there is always a need to develop population-specific standards for accurate sex determination from a skeleton deriving from that population. Hence, standards have been developed for different population worldwide [21,22].

Table 3: shows discriminant Analysis.

Table 3A

Functions and Variables	Raw Coefficients	Standardized Coefficients	Structure Coefficients	Centroids	Sectioning Points
MXRB MNRB MXCDH MXRH MXCRH GA BGW BH/PM BH/M	.171 .040 .045 -.029 .117 .038 -.016 .179 .006 CONSTANT= -26.249	.428 .100 .222 -.140 .554 .246 -.147 .493 .019	.428 .100 .222 -.140 .554 .246 -.147 .493 .019	Male= 1.393 Female= -1.235	0.079

Table 3B

Functions and Variable	Raw/ Unstandardised Coefficients	Standardized Coefficients	Structure Coefficients	Centroids	Sectioning Points
MXRB MXCDH MXRH MXCRH BGW BH/PM BH/M	.198 .049 -.035 .105 -.021 .173 .011 (constant= -19.326	.494 .243 -.170 .496 -.202 .479 .037	.715 .668 .645 .542 .524 .458 .331	Male= 1.362 Female: -1.228	0.067

Table 3C

Functions and Variables	Raw/ Unstandardised Coefficients	Standardized Coefficients	Structure Coefficients	Centroids	Sectioning Points
MXRB MXCDH MXCRH BH/PM BH/M	.196 .008 .092 .191 -.010 (constant= -21.998)	.488 .039 .439 .528 -.035	.726 .678 .654 .550 .532	Male : 1.342 Female: -1.210	0.066

Table 3D

Functions and Variables	Raw/ Unstandardised Coefficients	Standardized Coefficients	Structure Coefficients	Centroids	Sectioning Points
MXRB MXCRH BH/PM	.198 .094 .186 (constant) = -21.800	.494 .449 .514	.726 .679 .655	Male = 1.341 Female = -1.209.	0.066

Table 4: depicts the standardized, raw and structure discriminant function co-effecients along with group centroids and sectioning points of the variables.

Functions and Variables	Raw/ Unstandardised Coefficients	Standardized Coefficient	Structure Coefficients	Centroids	Sectioning Points
MXRB	0.401 CONSTANT= -16.245	1	1	MALE: 0.974 FEMALE: -878	0.048
MNRB	0.405 CONSTANT: -11.771	1	1	MALE: 0.349 FEMALE: -0.315	0.032
MXCDH	0.204 CONSTANT= -15.787	1	1	MALE= 0.738 FEMALE: -0.665	0.037
MXRH	0.207 CONSTANT = -15.100	1	1	MALE= 0.625 FEMALE: -0.563	0.031
MXCRH	0.211 CONSTANT= -14.384	1	1	MALE:0.911 FEMALE: -0.821	0.045
GA	0.152 CONSTANT= -18.963	1	1	MALE: -0.082 FEMALE: 0.074	-0.004
BGW	0.106 CONSTANT= -21.407	1	1	MALE: 0.451 FEMALE: -0.407	0.022
BH/PM	0.362 CONSTANT= -14.248	1	1	MALE: 0.878 FEMALE: -0.792	0.043
BH/M	0.302 CONSTANT= -10.606	1	1	MALE: 0.714 FEMALE: -0.643	0.035

The present study was planned to evaluate various mandibular indices in digital panoramic radiograph of Saudi population to identify possible interrelationships between indices and sex of the patient and to compare the results with review of literature and adding new records in the branch of forensic odontology.

In the present study, direct discriminant analysis was

Table 5: shows percentage of correct classifications for the discriminant functions.

Functions and variables	Males		Females		Average Accuracy %
	N=73	%	N=81	%	
MXRB+ MNRB+ MXCDH+ MXRH+ MXCRH+ GA+ BGW+ BH/PM+ BH/M	66	90.4	77	95.1	92.75
MXRB+ MXCDH+ MXRH+ MXCRH+ BGW+ BH/PM+ BH/M	65	89	78	96.3	92.65
MXRB+ MXCDH+ MXCRH+ BH/PM+ BH/M	64	87.7	78	96.3	92
MXRB+ MXCRH+BH/PM	63	86.3	78	96.3	91.3
MXRB	55	75.3	67	82.7	79
MNRB	45	61.6	57	70.4	66
MXCDH	61	83.6	65	80.2	81.9
MXRH	52	71.2	61	75.3	73.25
MXCRH	58	79.5	69	85.2	82.35
GA	35	47.9	38	61.7	54.8
BGW	52	71.2	60	74.1	72.65
BH/PM	55	75.3	72	88.9	82.1
BH/M	52	71.2	65	80.2	75.7

employed, testing each combination of variables. Each of the nine variables measured on mandible of the Saudi population showed statistically significant sex differences between sexes, indicating that ramus expresses strong sexual dimorphism in this population. It was found that in the present study, there was no correlation of measurements with the age of the person though some studies have found that values decrease or increase as the age progresses.

Ramus shows greatest univariate sexual dimorphism in terms of maximum ramus width followed by coronoid height. The variables of least use for discrimination were gonial angle, minimum ramus width and bigonial width. Overall prediction rate using all nine variables was 92.75%. When minimum ramus width was removed; accuracy was 92.65%. When combined maximum ramus width, maximum condylar height, maximum coronoid height and height of mandible in premolar region excluding maximum ramus height, accuracy was 92%. Even when 3 parameters were combined accuracy was 91% variable being maximum ramus width, coronoid height and body height in the premolar region.

In American white and Negros, Giles reported that mandibular ramus height, maximum ramus width, and minimum ramus width are noteworthy with an accuracy of 85% [19].

In South African whites, Steyn and Iscan studied five mandibular parameters including bigonial width, total mandibular length, bi condylar width, minimum ramus width, and gonion-gnathion and the accuracy was 81.5% [21].

Study done by Dayal, et al. found that mandibular ramus height is the best parameter with 75.8% accuracy [22]. He studied six mandibular measurements of South African Blacks and noted that average accuracy for sexing varies from 80 to 85%. Six mandibular measurements showed the highest classification rate of 85.0% with the selection of bigonial width, mandibular ramus height and total mandibular length

Franklin et al. studied on South African population and reported a very high accuracy of 95% with 10 variables. Combination of ramus and coronoid height had an average accuracy of 87.5% [23]. In a study by Boddu, et al in Indian population, the best parameter was bi condylar width followed by bigonial width, maximum width of ramus, minimum width of ramus and mental foramen width. Overall accuracy for the prediction rate using all five variables was with 70.4% [24].

While utilizing 18 mandibular measurements from two Croatian archaeological sites, Vodanovic *et al.,* found 92.06% accuracy. Length of the mandibular body, mandibular angle and minimum ramus width exhibit the highest degree of sexual dimorphism [16].

In our study, least sensitive parameter was gonial angle followed by minimum ramus width. Controversial results have been found in different researches which show that males showed statistically significant lower mean gonial angle values than females [25-28]. Conversely, other researchers found that males showed statistically significant higher mean gonial angle values than females [29] and others did not find any statistically significant differences between both sexes as in our study [30].

Conclusion

This preliminary study on mandibles from the Saudi population clearly indicates that the ramus of mandible has satisfactory potential for determination of sex. It can especially be used for forensic cases where damaged and partially preserved mandibles are frequently found. We suggest that larger samples and populations from more diverse geographic regions may enhance the effectiveness of these parameters. The derived discriminant function and equations can be used as a reference for the sex estimation and future researches.

References

1. Scheuer L. Application of osteology to forensic medicine. *ClinAnat.* 2002;15(4):297-312.
2. Cox M, Mays S. Human osteology in archeology and forensic science. London, UK: Cambridge University Press. 2000.
3. Duric M, Rakocevic Z, Donic D. The reliability of sex determination of skeletons from forensic context in the Balkans. *Forensic Sci Int.* 2005;147(2-3):159-64.
4. Loth SR, Henneberg M. Sexually dimorphic mandibular morphology in the first few years of life. *Am J Phys Anthropol.* 2001;115(2):179-186.

5. Kitai N, Mukai Y, Murabayashi M, et al. Measurement accuracy with a new dental panoramic radiographic technique based on tomo synthesis. *Angle Orthod*. 2013;83(1):117-126.

6. Nohadani N, Ruf S. Assessment of vertical facial and dentoalveolar changes using panoramic radiography. *Eur J Orthod*. 2008;30(3):262-268.

7. Schulze R, Krummenauer F, Schalldach F, d'Hoedt B. Precision and accuracy of measurements in digital panoramic radiography. *Dentomaxillofac Radiol.* 2000;29(1):52-56.

8. Vazquez L, Nizamaldin Y, Combescure C, et al. Accuracy of vertical height measurements on direct digital panoramic radiographs using posterior mandibular implants and metal balls as reference objects. *Dentomaxillofac Radiol.* 2013;42:20110429.

9. Deshmukh AG, Devershi DB. Comparison of cranial sex determination by univariate and multivariate analysis. *Journal of the Anatomical Society of India.* 2006;55(2):48-51.

10. Guyomarc'h P, Bruzek J. Accuracy and reliability in sex determination from skulls: A comparison of Fordisc 3.0 and the discriminant function analysis. *Forensic Sci Int.* 2011;208(1-3):180.

11. Loth S, Iscan Y. Anthropology: Sex Determination. In: Encyclopedia of Forensic Sciences. Edited by Siegel J, Knupfer G, Saukko P: Academic Press. 2000:252-260.

12. Saukko P, Knight B: Knight's Forensic Pathology, 3rd edn. London: Hodder Arnold; 2004..

13. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. *Am J Orthod DentofacialOrthop.* 1986;90(1):45-51.

14. Upadhyay RB, Upadhyay J, Agrawal P, Rao NN. Analysis of gonial angle in relation to age, gender, and dentition status by radiological and anthropometric methods. *J Forensic Dent Sci.* 2012;4(10:29-33.

15. Mattila K, Altonen M, Haavikko K. Determination of the gonial angle from the orthopantomogram. *Angle Orthod.* 1977;47(2):107-10.

16. Vodanovic M, Dumancic J, Demo Z, Mihelic D. Determination of sex by discriminant function analysis of mandibles from two Croatian archeological sites. *Acta Stomatol Croat.* 2006;40(3):263-277.

17. Emin Murat C, Peruze C¸Elenk. Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients Gerodontology.2012;29(1):17-23.

18. Suazo GIC, Pedro SVJ, Schilling QN, et al. Ortopantomographic blind test of mandibular ramus flexure as a morphological indicator of sex in Chilean young adults. *Int J Morphol.* 2008;26(1):89-92.

19. Giles E. Sex determination by discriminant function analysis of the mandible. *Am J Phys Anthropol.* 1964;22:129-135.

20. Rosing FW, Graw M, Marre B, et al. Recommendations for the forensic diagnosis of sex and age from skeletons. *Homo.* 2008;58(1):75-89.

21. Steyn M, Iscan MY. Sexual dimorphism in the crania and mandibles of South African Whites. *Forensic Sci Int.* 1998;98(1-2):9-16.

22. Dayal MR, Spocter MA, Bidmos MA. An assessment of sex using the skull of black South Africans by discriminant function analysis. *Homo.* 2008;59(3):209-221.

23. Franklin D, Higgins PO, Oxnard CE, Dadour I. 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.* 2006;2(4):263-268.

24. Naveen Kumar B, Ramesh RT, Reddy SR, Chennoju SK, Pavani K, Sai Praveen KN. IJSRM Human. 2016;4 (3): 115-122.

25. Xie QF, Ainamo A. Correlation of gonial angle size with cortical thickness, height of the mandibular residual body, and duration of edentulism. *J Prosthet Dent.* 2004;91(5):477-482.

26. Rai R, Madhyastha S, Kumaran M A. Pilot Study of the Mandibular Angle and ramus in Indian population. *Int J Morphol.* 2007;25:353-356.

27. Dutra V, Yang J, Devlin H, Susin C. Mandibular bone remodeling in adults: evaluation of panoramic radiographs. *Dentomaxillofac Radiol.* 2004;33(5):323-328.

28. Kharoshah MA, Almadani O, Ghaleb SS, Zaki MK, Fattah YA. Sexual dimorphism of the mandible in a modern Egyptian population. *J Forensic Leg Med.* 2010;17(4):213-215.

29. Al-Shamout R, Ammoush M, Alrbata R, Al-Habahbah A. Age and gender differences in gonial angle, ramus height and bigonial width in dentate subjects. *Pakistan Oral & Dental Journal.* 2016;32(1):81-87.

30. Raustia AM Salonen MA. Gonial angles and condylar and ramus height of the mandible in complete denture wearers-a panoramic radiograph study. *J Oral Rehabil.* 1997;24(7):512-516.