The Usefulness of Mandibular Ramus as an Indicator in Sex Differentiation Using 3D Reconstructed Computed Tomography

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ABSTRACT

Background: Determination of sex from an unknown human bone is an important role in forensic and anthropology field. The mandible is the largest and hardest facial bone, that commonly resist postmortem damage and forms an important source of information about sexual dimorphism. Mandibular ramus can be used to differentiate between sexes and it also expresses strong univariate sexual dimorphism. This study was undertaken to assess the usefulness of mandibular ramus as an aid in sex differentiation using CT scanning among Iraqi population.

Materials and methods: 3D reconstructed computed tomography scanning of 140 Iraqi Arab subjects, (7 0 males and 70 females) were analyzed with their age range from 20-60 years old. The linear measurements were located and marked on axial and sagittal sections including right and left sides of the mandible.

Results: For the all measurements for sexes the mean value for male were highly significant than female with (P= value < 0.001).A receiver operating characteristic curves was obtained for each variable to observe their overall performance in sex determination. The area of maximum mandibular ramus height was found to be the best parameter according to ROC analysis to establish the diagnosis of male (ROC=0.952cm for both unilateral and bilateral measurements). Age showed no statistical difference in the current study.

Conclusion: 3D reconstructed computed tomography scanning plays an important role as a diagnostic method for analyzing the linear measurements of the mandibular ramus in sex differentiation. Sex determination for isolated part of the skull (e.g. mandible) could be achieved, instead of complete skull, and the highest accuracy in sex determination can be obtained whether complete or part of mandible is available for examination.

Key words: Sex determination, 3D reconstructed computed tomography, mandibular ramus, and sexual dimorphism. (J Bagh Coll Dentistry 2016; 28(3):92-98).

INTRODUCTION

The identification of skeletal remains is of paramount importance in medico-legal investigations. The highest accuracy in sex determination is achieved if all bones composing the skeleton are present .However, in explosion, warfare and other mass disasters like aircraft crashes, identification and sex determination are not very easy as the soft tissues are commonly no longer present, due to trauma and decomposition. In those cases, forensic anthropology serves an important role in human identification [(1, 2).]

Skull is the most dimorphic and easily sexed portion of skeleton after pelvis, as it provides valuable information about individual human characteristics, its use in personal identification of human remains providing accuracy up to 92%.But in cases where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic, largest, and strongest bone of skull. Presence of a dense layer of compact bone makes it very durable and well preserved than many other bones, its morphological features show changes with reference to age, sex, race, and forms an important source of information about sexual dimorphism [(3,4)].

Radiology is a noninvasive method used to investigate the human body and as such, plays a significant role in medico- legal investigations and in the identification of human remains .The bony details such as form, size, shape, and individual characteristics are evident and consistent as shown by radiological means. Thus, the comparison of earlier with later radiological records is significantly important for forensic medicine and anthropology [(5)]. Computed tomography (CT) has been increasingly used to assist in medico-legal investigations. The potential value of CT in estimation of age or visualizing features likely to enable personal identification is reported [(4,6).]

CT allows for 3D reconstruction of the skull and enables the evaluation of the individual morphological characteristics. CT is quick and extremely precise, and thus well suited as a supplement method in medico- legal investigations, it allows investigation of anatomic structures, and accurate analysis of bony structures. The possibility of being able to reconstruct a variety of images to permit multiple and recurrent analysis long after the event occurred is a further advantage of this applied method[(7-9)].

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MATERIALS AND METHODS

Prospective study of CT scans for (140) Iraqi adult patients, with equal number of each gender (70males and 70 females), age ranged from (20-59) yrs were analyzed. The sample collected from patient attending CT clinic in Al-Neuroscience hospital for different diagnostic purposes from November 2014 to March 2015.

The total study sample was divided into the following groups according to different ranges of age selected, as shown in table 1.

Table 1: Distribution of participating patients according to age and gender

Groups	Age range	Male	Female
1	20-29	25	21
2	30-39	17	19
3	40-49	19	20
4	50-59	9	10
Total		70	70

Pathological, fractured, developmental disturbance of the mandible e.g. (agnathia, micrognathia, macrognathia, and facial hemi hypertrophy), deformed mandibles e.g. (craniofacial disorders, trauma, etc......) and edentulous mandibles were also excluded.

The examination was performed on multi-slice spiral tomography scanner (The Siemens soma tom definition AS).

The patients were prepared for the exposure by asking them to remove any spectacles, jewelry, ear rings, and hearing aids. The patient positioned on the CT examination table. Computed tomography scan of mandibular ramus is performed in sagittal and axial sections. The following measurements will be taken[10,11]:

Maximum mandibular ramus breadth (Max MRB) it is the distance between the most anterior pointon the mandibular ramus and the most posterior point on the condyle, Minimum mandibular ramus breadth (Min MRB) it is the smallest anterior–posterior diameter of the ramus, Condylar height (maximum mandibular ramus height) (Max MRH) it is the 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.

Projective height of ramus (Projective HR) it is the projective height of ramus between the highest point of the mandibular condyle and lower margin of the mandible, Coronoid height (CH) itis the projective distance between coronion(the craniometrical point at the tip of the coronoid process of the mandible)and lower margin of the mandible, as shown in figures 1,2,3,4,5.

Bigonial breadth (Bigonial B) it is the straight distance between two gonia (the angle formed by the junction of the posterior and lower borders of human lower jaw, Bicondylar breadth (Bicondylar B) it is the straight distance between the most lateral points on the two condyles,Mandibular length (ML) it is the distance of anterior margin of the chin from a center point on a projected straight line placed along the posterior border of two gonia, Mandibular index (MI): was calculated as follow:-

$$\text{Mandibular Index} = \frac{\text{Mandibular length}}{\text{Bicondylar breadth}} \times 100$$

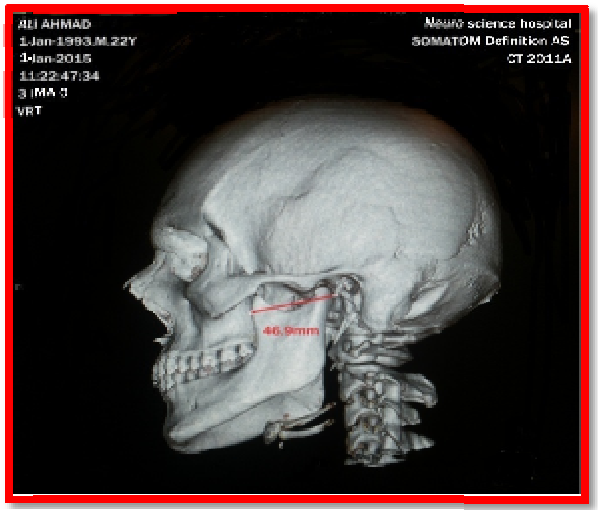

Figure 1:Linear measurements of condylar height (Max MRB) by 3D reconstructed computed tomography image in sagittal section

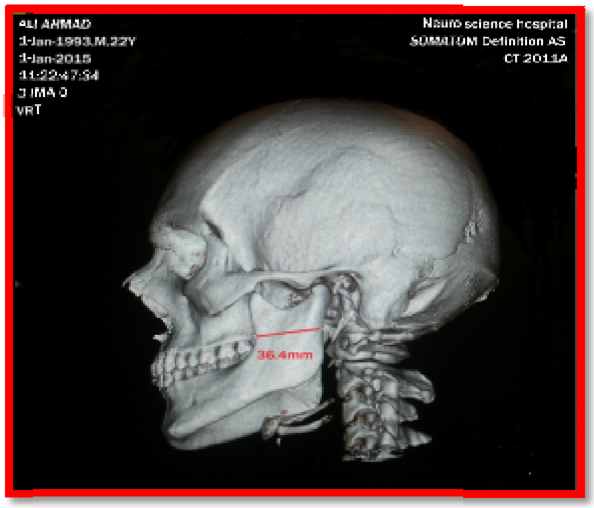

Figure2:Linear measurements of condylar height (Min MRB) by 3D reconstructed computed tomography image in sagittal section.

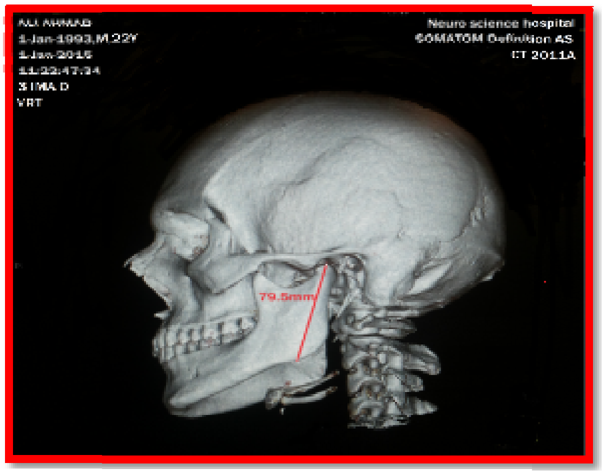

Figure3:Linear measurements of condylar height (Max MRH) by 3D reconstructed computed tomography image in sagittal section.

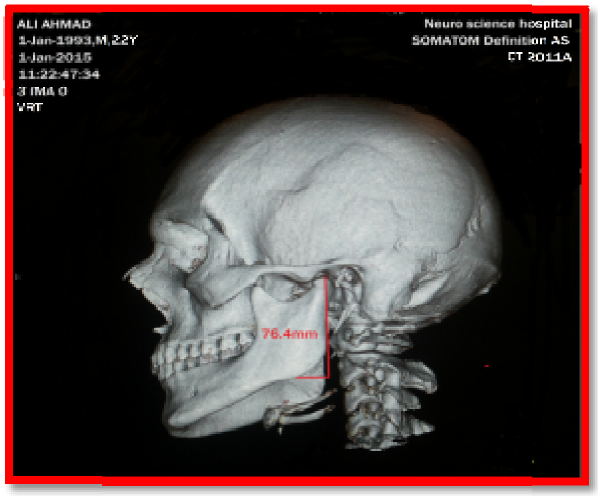

Figure4: Linear measurements of Projective height of ramus (Projective HR) by 3D reconstructed computed tomography image in sagittal section.

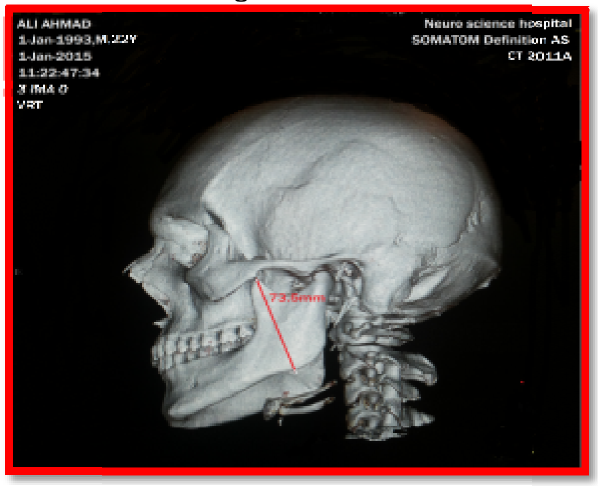

Figure 5: Linear measurements of coronoid hight of ramus(CH) by 3D reconstructed computed tomography image in sagittal section.

Statistical Analyses

Data analysis was computer aided. An expert statistical advice was sought for. Statistical analysis was done using SPSS version 21 computer software **(Statistical Package for Social Sciences).**

The outcome quantitative variables (mandibular measurements and indices calculated) showed no statistically significant departure from normality. They were conveniently described by mean, SD (standard deviation) and SE (standard error), and the parametric statistical tests of significance were used.

Paired t-test was used to test the statistical significance of difference between Left-Right sides. The magnitude of difference between right and left side was estimated by Cohen's d.

RESULTS

Results demonstrated on two categories of measurements, the first category was designed with the suggestion of presence of (hemi mandible) that is why the linear measurements were made for one side of the mandible (either right or left side) separately, such measurements based on the fact there was no statistically significant difference between the right side and the left side of the ramus, this part in result is called **"unilateral linear mandibular ramus measurements".**

The second category was designed with suggestion of presence of (intact complete mandible); this part in result is called **"bilateral linear mandibular ramus measurements".**

The gender difference in the mean of unilateral and bilateral linear mandibular ramus measurements:-

All the selected linear measurements of the anatomical landmarks in both male and female either unilateral or bilateral measurements, demonstrated a highly statistical significant differences between male and female, ($p<0.001$), the highest difference in mean between males and females was for the area of (Max MRH) which was (12.1 mm).

While For transverse measurements The highest difference in mean was for (Bicondylar B) which was (13mm).The gender effect on these tested linear measurements was strong effect when evaluated by Cohen's d for the effect size for all tested parameters, tables (2,3).

Table 2:The gender differences in mean of unilateral linear mandibular ramus measurements

Variables	Gender		Difference in mean	Gender dimorphism	Cohen's d	P
	Female N=140	Male N=140				
		Mean				
Max MRB	40.5	46.3	5.8	14.3	2.05	<0.001
Min MRB	30	35	5	16.7	2.04	<0.001
Max MRH	60.7	72.8	12.1	19.9	2.16	<0.001
Projective HR	57.5	68.2	10.7	18.6	2.24	<0.001
CH	55.8	65.4	9.6	17.2	2.2	<0.001

Table 3: The gender differences in mean of bilateral linear mandibular ramus measurements

Variables	Gender		Difference in mean	Gender dimorphism	Cohen's d	P
	Female N=140	Male N=140				
		Mean				
Max MRB(mean of both sides)	40.5	46.3	5.8	14.3	2.05	<0.001
Min MRB(mean of both sides)	30	35	5	16.7	2.04	<0.001
Max MRH(mean of both sides)	60.7	72.8	12.1	19.9	2.16	<0.001
Projective HR (mean of both sides)	57.5	68.2	10.7	18.6	2.24	<0.001
CH(mean of both sides)	55.8	65.4	9.6	17.2	2.22	<0.001
BicondylarB	111.3	124.3	13	11.7	2.17	<0.001
BigonialB	84.4	95.2	10.8	12.8	2.1	<0.001
ML	66	78.3	12.3	18.6	2.15	<0.001
MI	59.4	63.1	3.7	6.2	0.71	<0.001

ROC analysis for unilateral and bilateral linear mandibular ramus measurements:

Receiver operating characteristic analysis (ROC) was used to assess the validity of different tested measurements in predicting male sex differentiating from female. Analysis was used to rank a set of linear measurements or parameters according to their validity in predicting male sex from female.

Among the computed tomography (Max MRH) was the best parameter in predictinggender (ROC=0.952cm) for both unilateral and bilateral measurements, as shown in table 4. While for transverse measurements the (Bicondylar B) was the best parameter in predicting gender (ROC=0.941cm), according to their validity in predicting male sex from female, as shown in table5.

Table 4:ROC area for unilateral linear mandibular ramus measurements when used as test for gender identification

	ROC area	P
Maximum mandibular ramus height	0.952	<0.001
Projective height of mandibular ramus	0.940	<0.001
Coronoid height	0.939	<0.001
Maximum mandibular ramus breadth	0.935	<0.001
Minimum mandibular ramus breadth	0.921	<0.001

The discriminant function analysis of unilateral and bilateral mandibular ramus measurements in predicting sex

For all parameters used in both unilateral measurements (hemi-mandible) and bilateral measurements (intact complete mandible), the percentage of accuracy according to discriminantfunction analysis was high (94.3% and 97.1%.) respectively with highly significant p-value (p<0.001) to differentiate between male and female.

The age shows no statistical significance difference in mean values of selected measurements between the four age groups for both unilateral and bilateral measurements.

Table 5: ROC area for selected bilateral linear measurements of mandibular ramus when used as test for gender identification

	ROC area	P
Maximum mandibular ramus breadth-Mean of both sides	0.946	<0.001
Minimum mandibular ramus breadth-Mean of both sides	0.925	<0.001
Maximum mandibular ramus height-Mean of both sides	0.952	<0.001
Projective height of mandibular ramus-Mean of both sides	0.944	<0.001
Coronoid height-Mean of both sides	0.942	<0.001
Bicondylar breadth	0.941	<0.001
Bigonial breadth	0.931	<0.001
Mandibular length	0.932	<0.001
Mandibular index	0.690	<0.001

DISCUSSION

The identification of sex from human remains is of fundamental importance in forensic medicine and anthropology, especially in the identification of missing persons. When the entire adult skeleton is available for analysis, sex can be determined up to 100% accuracy, but in cases of mass disasters where usually fragmented bones are found, sex determination with 100% accuracy is not possible and it depends largely on the available parts of skeleton. One of the important aspects of forensics is to determine sex from fragmented jaws and dentition [10,12].

It has been established that socio-environmental factors (e.g. nutrition, food, climate, pathologies, etc.) Influence the development, and thus the appearance of bones. Numerous studies have demonstrated that skeletal characteristics differ in each population and have emphasized the need for population-specific osteometric standards for sex determination[13].

Myers et al.[14]demonstrated that CT allows investigation of anatomic structures that are not easily available by autopsy and allows accurate analysis of bony structures in axial, coronal and sagittal planes with three-dimensional image of the inside of an object from a large series of two-dimensional radiographic images taken around a single axis of rotation.

Rocha et al. [15]reported about the use of 3D-CT reconstructions of linear craniometrical measurements in sex determination demonstrated a low standard error of those measurements and the results obtained from osseous and soft tissue structures were considered to be precise in 3D-CT with high imaging quality and resolution.

In the present study selection of the mandible in gender difference related to the fact that it is the most dimorphic, largest, and strongest bone of skull. Male bones are generally bigger and more robust than female bones. Dimorphism in mandible is reflected in its shape and size, the shape of the mandible is created by the sequential structural modeling while the other bones are increasing in size [12]. In the current study the 2 categories for sex identification were designed, the first category; include only one side of the mandible right or left side (hemimandible) which was available for examination. In the second category both sides of the mandible were present (intact complete mandible), so complete mandible was used for examination, all the measurements for (hemi and intact mandible) showed statistical significant differences between males and females with higher mean value for male as compared for females, ($p<0.001$), and the higher difference in mean was for the area of (Max MRH) and (Bicondylar B). Our findings were in agreement with studies done by Annamalai et al.[3] performed on various linear measurements, measured on the mandibular ramus, showed statistically significant sex difference between males and females, with highest mean difference for the area of (Max MRH), they stated that ramus height expresses strong sexual dimorphism. The mandibular ramus demonstrated greatest univariate sexual dimorphism in terms of (Max MRH), this may be attributed to the fact that the relative development (size, strength, and angulations) of the muscles of mastication is known to influence the expression of mandibular height dimorphism as masticatory forces exerted are different for males and females.

Any site of mandibular bone deposition, resorption, or remodeling for that matter, seems to have a potential for becoming sexually dimorphic. Hence, mandibular ramus height 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[12].

Vinay et al. [16]in their studyon undamaged human mandibles (175 males and 75 females), the measures with greatest dimorphism were (Bicondylar B) of mandible which was 115 mm in males and 103 mm in females, the mean values of male significantly higher than for females with a very strong effect of Cohen's d.

For the (ML), Jayakaran et al.[17] in their studies on 207 mandible found that the mean of (ML) for male mandible was 78.4 mm and for female was 68.6 mm .The mean difference between male and female was 9.8 mm. This study showed statistically significant difference between male and female mandible in the area of (ML). The difference in mean value of male mandible in this study was almost similar to the current study.

Ranganath et al. [18] in their study on 111 mandibles (65 males, 46 females) showed that the mean for (Bigonial B) for male was 93.8 mm and for females was 86.2 mm, the difference in mean between male and female was7.6 mm, this study agreed with the current study in reflecting the importance of (BigonialB), so this parameter had an important role in sex differentiation in several studies.

The validity of linear mandibular ramus measurements in predicting male sex from female

Receiver operating characteristic analysis (ROC) was used to assess the validity of different tested measurements in predicting male sex differentiating from female.

The use of ROC curve to find the optimal cut-off value for sex discrimination (classification of male and female) in each variable and comparing the performance of each variable.

In the present study the (Max MRH) was associated with highest validity in the context of gender identification, which establishes the diagnosis of male with 90.0% confidence.

Giles [19] measured mandibles of known sex using anthropometric measurements and reported (Max MRH) as highly significant, with an accuracy of 85% in American Whites and Negroes, this study agreed with the current study in conclusion that (Max MRH) to be the best parameter in sex determination.

Among transverse measurements of the mandible (Bicondylar B) was the best parameter in predicting gender, which establish the diagnosis of male with 89.6 % confidence.

Steyn and Iscan[20] achieved an accuracy of 81.5% with five mandibular parameters (i.e. Bigonial B, ML, Bicondylar B, Min MRB, and Gonion–Gnathion) in South African Whites, which is comparable with the current study results.

Dayal et al. [21]found mandibular ramus height to be the best parameter in their study, with 75.8% accuracy.

Discriminant analysis of the linear mandibular ramus measurements in predicting sex

In this study, mandibular ramus measurements were subjected to discriminant function analysis. Each of the parameters measured on mandibular ramus using 3D reconstructed image of spiral CT showed statistically significant sex differences between sexes, indicating that ramus expresses strong sexual dimorphism and able to predict gender with an overall accuracy of 94.3% for hemimandible, while for the intact complete mandible the accuracy was 97.1%.

Frankiln et al. [13] reported a very high accuracy of 95% with 10 variables employing geometric morph metric technique on South African population. In their study the (Max MRH) showed an average accuracy of 87.5%, which is comparable with the current study.

Saini et al. [11] conducted a study on northern part of India and found that ramus expresses strong sexual dimorphism in this population. The parameters were Max MRH, CH, and projective HR.

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