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Reliability of Three Dimensional Computed Tomography in Sex Determination from Mandible of a Sample of Libyan Population in Tripoli

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Conventional three-dimensional (3D) computed tomography (CT) is a valuable imaging technique that can be used in the field of human identification and offers several advantages over the conventional radiographic modalities. The aim of this study was to assess the reliability of sex determination using mandibular metrical parameters by 3D-CT in the sample of Libyan population in Tripoli.This study was conducted in National Cancer Institute, Tripoli, Libya on 200 adults for six months (from the beginning of January to the end of June, 2020). All subjects were subjected to 3D-CT scan to assess seven mandibular parameters which were gonial angle, ramus length, minimal ramus breadth, coronoid height, gonion-gnathion length, bicondylar breadth and bigoniallength. There were significant differences between male and female regarding all mandibular parameters except minimal ramus breadth. Ramus length, gonion-gnathion length, coronoid height and bicondylar breadth were the most sexually dimorphic. In stepwise discriminant analysis,three of seven mandibular measurements were selected; ramus length, gonion-gnathion length and bicondylar breadth; cross-validated sex classification accuracy was 98 %.It can be concluded thatsex can be estimated from mandibular metric parameters measured by 3D-CT with high reliability

Keywords: Mandibular metric parameters, 3D-CT, ramus breadth and Sex determination

INTRODUCTION

Identification of human skeletal residues plays essential role in medico legal and anthropological work. Generally, morphological, and metric techniques are used to estimate the sex of a bone (Kallalli et al. 2016).The reliability of sex determination depends on the completeness of the remains and the degree of sexual dimorphism. When the whole skeleton is accessible for examination, sex could be estimated up to 100% accuracy (Datta et al. 2015). Additionally, the degree of accuracy in sexing adult skeletal remains is 95% in case of Pelvis alone, skull alone 90%, Pelvis and skull 98% and long bones alone 80% (Chole et al. 2013). In case of explosions, warfare, aircraft crashes and floods when the fragmented bones are present only, sex determination with 100% accuracy is not available and it relies mainly on the available portionsofthe bones. Skull is the greatest dimorphic and easily sexed portion of skeleton after pelvis(Reddy and Murty, 2014).However, in cases where complete skull is not found, mandible may have a vital role in sex determination as it is the most dimorphic, largest, and strongest bone of the skull (Badam et al. 2011). Furthermore, the presence of a dense layer of compact bone makes the mandible very durable and hence remains well preserved than many other bones. Also, the morphological features of mandible show changes with reference to age, sex, and race (Khan and Sharieff, 2011). Conventional three-dimensional (3D) computed tomography (CT) is useful imaging method which can be used in the process of human identification and presents innumerable advantages compared to traditional radiographic projections (Karjodkar, 2006).This methodis free from the problem of structure superimposition beyond the plane of interest and allows the visualization of small differences in density (Carvalho et al. 2009). So, The aim of present study was to assess the reliability of sex determination using mandibular metrical parameters by 3D-CT in the sample of Libyan population in Tripoli through measuring gonial angle, ramus length, minimal ramus breadth, coronoid height, gonion- gnathion length, bicondylar breadth and bigonial length.

MATERIALS AND METHODS

A cross - sectional study for six months from 1st January to the end of June 2020 was carried out in National Cancer Institute, Tripoli, Libya. The study was carried out on 200 subjects and their criteria fulfilled the inclusion and exclusion criteria. Written informed consent for participation was taken from each research subject.

Inclusion criteria / exclusion criteria:

Age from 18 to 60 years, both sexes, from Tripoli. While, subjects with any mandibular bone deformities for example damaged, mutilated, deformed, pathological diseased, fractured and developmental disturbances of the mandible.

2.2 Operational design

All participants were exposed to 3D-CT scan (Inguinty Philips core 256, Netherlands) to assess seven mandibular parameters according to Krogman and Iscan(Gamba et al. 2014 ; Kano et al. 2015) as follows:a) Gonialangle(G-angle): It is formed by the line tangent to the lower border of the mandible and the line tangent to the distal border of the ascending ramus and condyle (Figure 1A). b) Ramus length (Ramus-L): Distance between the condylion and gonion (Figure 1B). c) Minimal ramus breadth (M-Ramus-Br): Smallest anterior–posterior diameter of ramus (Figure 1B). d) Coronoid height (CO-**Ht):** Projective distance between coronion and lower wall of bone (Figure 1B). e) Gonion-gnathion length (G–G-L): Mandibular base Length (Figure 1B).f) Bicondylar breadth (BIC-Br): Distance between the condyles (Figure 2). g) Bigonial length: Distance between the two gonions (Figure 2). All these measurements were taken from left side of mandible, as there is no statistical significant difference between right and left side (Dakhli and Abu El-Dahab, 2020).

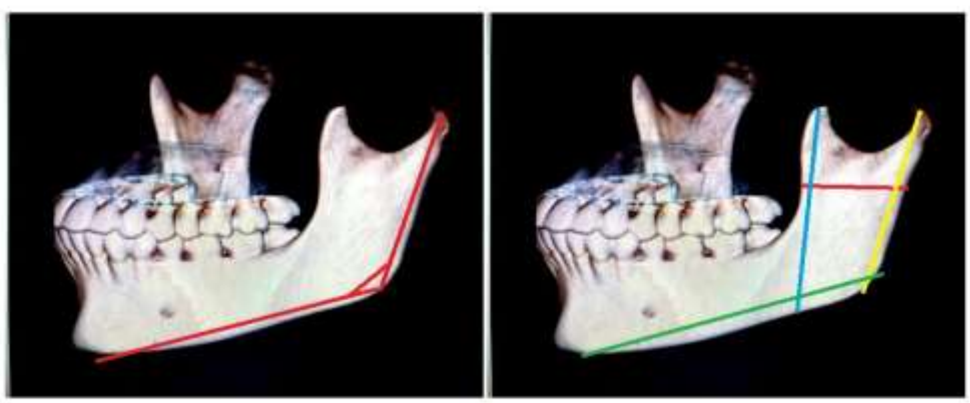

Figure1: Three dimensional computed tomography image of the mandible (lateral reconstruction) showing A) gonial angle. B) yellow line= ramus length, red line= minimal ramus breadth, blue line=coronoid height, green line= gonion- gnathion length

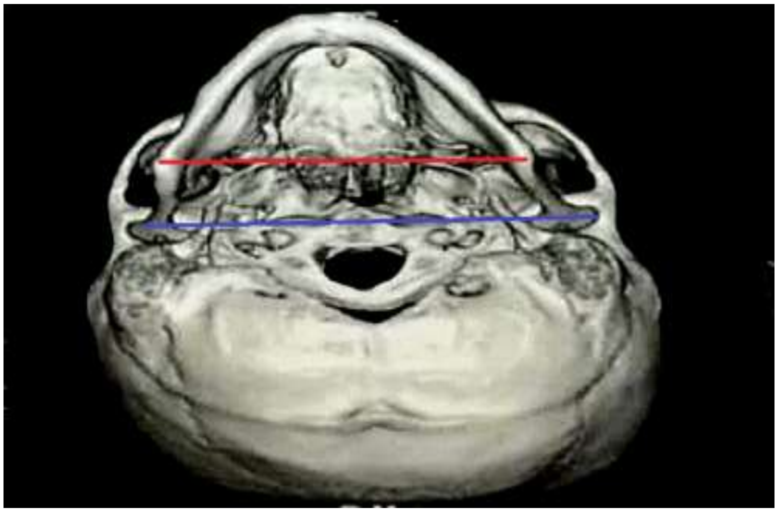

Figure 2: Three dimensional computed tomography image of the mandible (axial reconstruction) showingred line=bigonial length and blue line=bicondylar breadth.

Statistical analysis

All data were collected, tabulated and statistically analyzed using SPSS (Inc., Chicago, IL, USA). Quantitative data were expressed as the mean ± SD & median (range), and qualitative data were expressed as absolute frequencies (number)& relative frequencies (percentage). The following tests were used: Student's t-test was used to compare between two groups of normally distributed variables. ROC curve is created by plotting the fraction of true positives out of the positives (TPR = true positive rate) vs. the fraction of false positives out of the negatives (FPR = false positive rate), at various threshold settings. Cut off levels are calculated using the respective mean of the male and female measurements; only those measurements that classify above 80% accuracy (Aidy et al., 2020). Discriminate analysis: builds a predictive model for group membership.

RESULTSAND DISCUSSION

The mean age of the studied group was 43.36±11.75 years with minimum 18 andmaximum 60 years. As regarding sex, 56.5% were male compared to 43.5% were female. There was no significant difference between male and female regarding mean value of age (Table 1&2).Female were significantly ($p<0.001$) higher than male regarding G-angle. Meanwhile, male were significantly ($p<0.001$) higher than female as regard Ramus-L, CO-Ht, G–G-L, BIC-Br and bigonial length. But there was no significant ($p>0.05$) difference between them regarding M-Ramus-Br (Table 3).The most sexually dimorphic individual measurements are those that yielded the highest expected sex classification accuracy were Ramus-L 90%, G–G-L 84.5%, CO-Ht 80.5% and BIC-Br 80.5% as shown in table (4).

Table1: Age and sex distribution among studied group (n=200).

		Age (years)	
Mean± SD		43.36±11.75	
Median (range)		45.0 (18-60)	
		No.	**%**
Sex	**Male**	113	56.5
	Female	87	43.5
	Total	200	100.0

SD: standard deviation %: percent

Table 2: Statistical comparison between male and female as regard mean value of age using student t-test.

	Male (n=113)	Female (n=87)	t	P – value
	Mean ± SD			
Age	43.25±12.9	44.5±9.87	1.12	0.169 NS

NS: Non significant (p>0.05) SD: Standard deviation

Table 3: Statistical comparison between male and female regarding mean values of mandibular parameters using t-test.

	Male (n=113)	Female (n=87)	t	P -value
	Mean ±SD			
Gonial angle	121.51±2.9	125.0±2.31	9.173	0.001**
Ramus length (cm)	5.82±0.35	4.91±0.44	16.082	0.001**
Minimal ramus breadth (cm)	2.33±0.11	2.34±0.14	0.411	0.681 NS
Coronoid height (cm)	5.37±0.41	4.71±0.45	10.894	0.001**
Gonion-gnathion length (cm)	6.01±0.33	5.03±0.44	13.870	0.001**
Bicondylar breadth (cm)	9.63±0.48	8.79±2.89	14.174	0.001**
Bigonial length (cm)	7.77±0.85	7.67±0.72	3.991	0.001**

NS: Statistically non significant (p>0.05). **: Statistically highly significant (P<0.001)

Table 4: Area under curve (AUC), cutoff and accuracy of mandibular parameters to determine sex.

Variables	AUC	Cut off value	Studied group(n=200)		True diagnose cases	Accuracy%
			Male (n=113)	Female (n=87)		
Gonial angle	0.83	<123.5 >123.5	86 27	16 71	86+71	78.5
Ramus length	0.94	>5.45 <5.45	103 10	10 77	103+77	90
Minimal ramus breadth	0.51	<2.35 >2.35	61 52	48 39	61+39	50
Coronoid height	0.85	>4.95 <4.95	97 16	23 64	97+64	80.5
Gonion-gnathion length	0.90	>5.25 <5.25	105 8	23 64	105+64	84.5
Bicondylar breadth	0.91	>8.95 <8.95	98 15	24 63	98+63	80.5
Bigonial length	0.66	>7.65	80	43	44+80	62

%: percent Accuracy: true detected males +true detect females / total studied* 100

Table 5: Stepwise discriminant analysis of mandibular parameters to detect sex:

	Canonical Discriminant Function Coefficients					
	Un-standardized	Standardized	Wilks' Lambda	Functions at Group Centroids	Sectioning point	Accuracy
Ramus length	1.754	0.697	0. 188	Male= 1.814	-0.2705	98 %
Gonion-gnathion length	1.880	0.729		Female =-2.355		
Bicondylar breadth	1.357	0.564				
constant	-32.383					

%: percent

In the stepwise discriminant analysis of the mandibular parametersas shown in table (5), three of seven mandibular measurements were selected: Ramus-L, G–G-Land BIC-Br; cross-validated sex classification accuracy was 98 %.

Equation for determination sex from mandibular parameters:

Sex= -32.383 + 1.754 *Ramus length + 1.880 *Gonion-gnathion length+ 1.357*Bicondylar breadth

If the result above or equals to -0.2705, this predicts that the mandible belongs to male and below -0.2705 predicts that the mandible belongs to female with accuracy 98 %.

DISCUSSION

Racial, genetic, and regional changes in functional activity of the mandible during the early phases of growth and development may affect its shape and size (Rai et al. 2007). Accordingly, the skeletal featuresvary from one population group to another, and population-specific osteometric standards are needed for sex determination (Saini et al. 2011).

Sex determination is one of the most important biological aspectsin establishing personal identity as the subsequent methods of age and stature estimation are highly sex dependent. Additionally, several studies have shown that sex assessment from the mandibles is population specific due to size changes between population groups (Srivastava et al. 2012). This study was conducted in National Cancer Institute, Tripoli, Libya on 200 adults for six months (from the beginning of January to the end of June, 2020) for estimation of sex using mandibular metrical parameters by three dimensional (3D)-CTin the sample of Libyan population. These parameters were gonial angle, ramus length, minimal ramus breadth, coronoid height, gonion-gnathion length, bicondylar breadth and bigonial length. Regarding the demographic data of this study, the mean age of the studied group was 43.36±11.75 years with minimum 18 and maximum 60 years. As regarding sex, 56.5% were male compared to 43.5% were female. There was no significant difference between male and female regarding mean value of age. Similarly, Gamba et al. (2014) studied the mandibular parameters of159Brazilian populationranging from 18 to 60 years. Furthermore, Abdelsalam et al. (2019) who conducted a study of sexual dimorphism on 102 scans from Egyptian population ranged from 20 to 50 years old. Additionally, Dakhli and Abu El-Dahab (2020) who conducted a study on sample comprised of individuals in the age ranged from 20 to 70 years old. They chose this age range as most sex differentiating functions do not come to be surely visible until maturity.

Regarding sex estimation from mandibular parameters, the results of present study showed that female were significantly ($p<0.001$) higher than male regarding gonial angle. Meanwhile, male were significantly ($p<0.001$) higher than female as regard ramus length, coronoid height, gonion-gnathionlength, bicondylar breadth and bigoniallength,demonstrating that mandible shows strong sexual dimorphism, and can, therefore, be considered an effective sex predictor for Libyan population. But there was no significant ($p>0.05$) difference between both sexes regarding minimal ramus breadth. These results passed in parallel with those of Jayakaran et al.(2000), Franklin et al.(2007), Ranganath et al.(2008), Ongkana and Sudwan (2009) and Vinay et al. (2013) who found that the mean of bigonial breadth, bicondylar breadth and mandibular length is significantly higher in male than female.

Furthermore, Yassir (2013) reported that the length of the mandibular ramus is longer in males than in females. Additionally, Kallalli et al. (2016) found significant difference between male and female as regard gonial angle, ramus length, gonion-gnathion length, bicondylar breadth and coronoid height.

Moreover, Abdelsalam et al. (2019), Dakhli and Abu El-Dahab (2020) and Ostovar Rad et al. (2020) reported that highly statistically significant ($p<0.001$) increase in mean values of mandibular parameters were found in males group except for gonial angle was higher in females. Regarding gonial angle, Rai et al. (2007), Huumonen et al. (2010) and Bhardwaj et al. (2014) found that the mean mandibular angle was greater in adult females than that in adult males.This could be explained by that males have strong masticatory force than females, accordingly, males have more acute gonial angle than females.

Sexual dimorphism of the mandible is the result of many interrelated factors such as environmental, genetic or hormonal and is population specific. These factors have impacton the development and the appearance. The most common is socio-environmental factors including nutrition, food, climate and pathologies (Sandeepa et al., 2017). Amin (2018) who believed that bone deposition, or resorptionappears to have a potential for becoming sexually dimorphic. Accordingly, mandibular ramus and condyle are the most sexually dimorphic as they are the regions associated with the highest morphological variations in size and remodeling during development. During the adult stage of growth, the rate and speed of development are higher in males with the results that craniofacial dimensions are 5-9 % higher when compared to females. Bone growth in the adult stage is controlled by several factors. Among these factors are sex hormones, such as, estrogen and progesterone that could affect the growth rate and developmental stages of male and female mandibles.As females reach puberty earlier than males, growth of their mandible and skull seem to either stop or slow down earlier than that in maturing males, thus contributing to the development of craniofacial morphological changes between sexes (Hu et al. 2006 ; Ongkana and Sudwan, 2009).Another controlling factor is the muscular power, which is considered an inductive factor of bone formation. The contraction of the masticatory muscles, especially, the elevating muscles attached to the mandible; exert tension throughout the mandibular ramus. Males exert more powerful masticatory force than females, and consequently induce more growth of bone on the sites of their muscular influence on the mandibular ramus. This explains why mandibular condyle and ramus are the most sexually dimorphic (Amin, 2018).

This could be explained by differences in study population, race, observers, imaging techniques and software programs (Ostovar Rad et al. 2020). In the current study, by using mandibular parameters cutoff levels and its accuracy to determine sex, it was found that the most sexually dimorphic individual measurements were those that yielded the highest expected sex classification accuracy which were ramus length 90%, gonion-gnathion length 84.5%, coronoid height 80.5% and bicondylar breadth 80.5%. By stepwise discriminant analysis of mandibular parameters to detect sex, three of seven mandibular measurements were selected;ramus length, gonion-gnathion lengthand bicondylar breadth with cross-validated sex classification accuracy 98 %. Analyzing the demarking points (cutoff values) have an important role in identifying the sex when a single variable is available as in damaged or mutilated mandibles. Therefore, statistically it can be found whether the given sample is of a male or a female by comparing with the stated dimension and referring the demarking point (Sambhana et al., 2016). Furthermore, The use of cutoff values increases the accuracy of the results of the study, as proportion of correctly identified sex through limiting value helps in predicting validity of the technique used. Additionally, the multivariate analysis (stepwise discriminate function analysis) obviouslyindicates that all the measurements when studied collectively show significant sexual dimorphism (Sikka and Jain, 2016). Numerousearlier studies from different countries have examined the sexual dimorphism of the mandible and applied almost the same mandibular parameters used in this study but gave different results of prediction accuracy (Sambhana et al. 2016). Also, Franklin et al. (2006, 2008) found that the coronoid height, the ramus height, and the maximum mandibular length univariatelydemonstrated the most sexual dimorphism. Furthermore, the produced discriminant function analysis, when combining these measurements from the Greek population sample, yielded a cross-validated accuracy of 84.1%.Furthermore, Sambhana et al. (2016) reported that all the mandibular parameters showed a significant sexual dimorphism ($P < 0.001$) except for the gonial angle. An overall accuracy of 75.8% was detected and coronoid height was the single best parameter providing an accuracy of 74.1%. insex estimation in South Indians. Additionally, Gamba et al. (2016) used different mandibular measurements made on 3D-cone beam computed tomography (CBCT) images and reported a high accuracy rate (95.1%) for sexual prediction, suggesting that such images can be used for effective and accurate anthropometric measurements. In the study of Sandeepa et al. (2017), 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 was 92.75% .Another study by Bertsatos et al. (2019), it was found that the coronoid height, the ramus height, and the maximum mandibular length are the most sexually dimorphic metric parameters of the mandible, as well as, the produced sex discriminant functions yielded cross-validated classification accuracy up to 85.7% for the Greek sample.In the study of Ostovar Rad et al. (2020), four parameters of ramus height, chin height, the distance between both condyles and coronoid height showed the greatest sexual dimorphism, respectively. Moreover, Dakhli and Abu El-Dahab (2020) found that the significant predictors for gender were bicondylar distance, mandibular base length and ramus length, using osteometric mandibular measurements performed on CBCT images in a sample of Egyptian population.

CONCLUSION

Mandible can be used to differentiate sex as evidenced by that female were significantly higher than male regarding gonial angle. Meanwhile, male were significantly higher than female as regard ramus length, coronoid height, gonion-gnathionlength, bicondylar breadth and bigonial length. Sex can be predicted in Libyan population from this equation:Sex= -32.383 + 1.754 *Ramus length + 1.880 *Gonion-ganthion length+ 1.357*Bicondylar breadth and its accuracy was 98%, indicating high reliability of mandibular measurements made on 3D-CT images in sex determination.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

AUTHOR CONTRIBUTIONS

All authors read and approved the final version.

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