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Sex Determination of the Egyptian Population Using Mandibular CBCT Scans: Retrospective Study

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Abstract: **Although human sex identification is now well known all over the world, few osteometric studies specially designed for sex identification were made by cone beam CT. The aim of this study was to achieve sexual determination using eight anthropometric measurements on mandibular CBCT images .Sample consisted of 120 CBCT scans, equally divided between sexes, collected from modern Egyptian population. Two calibrated Oro maxillofacial radiologists conducted the experiment. For statistical analysis: intra-class correlation was used to evaluate intra- and inter-reviewers reliability , analysis of variance to compare measurements with sex, logistic regression formulas were made to predict sex , and Pearson co-relation coefficient was done to detect the relation between measurements and age variable. Four measurements showed significant difference (ramus length, body height at canine, bigonial breadth and distance from condyle to coronoid). The resultant percentage of accuracy was 85.8%. The correct predictive accuracy for males was 86.7% and 85% for females.**

Keywords: **CBCT, Dentistry, Egypt Forensic, Mandible, Sexual dimorphism.**

1. INTRODUCTION

Identity is defined as a group of characteristics that mark each human being. Those characteristics provide each human with a unique entity [1]. In other words, identification means comparing different details of human and searching for similarities based on previous database [2] Sexual Prediction was one of the primary needs in forensic medicine used for identification of missing or severely deteriorated personnel. Unique morphologic characteristics of sexual identification have been detected in different countries including: Europe, China, Japan and the United States of America [1,2] . Such differences have been reported in many studies, therefore it is necessary to target a specific population with current skeletal features. Skull bones had the privilege of being very dense and were hardly destructible [2,3].Thus skull parts such as mandible could be of high diagnostic value if circumstances allowed to be well preserved [2,4]. Nonetheless to say, our Country faced Lots of terroristic acts and disasters [3] that reflected the importance of identification to apply the hand of justice and prevent similar acts [5]. With the appearance of CBCT that showed superior details to diagnose cranial traumas, the number of radiographic scans requested by medical forensic personals had increased dramatically to aid in human identification by comparing scans of important anatomies of skull [6,7]. The X-ray production systems are divided according their corresponding shape of input radiation into: Fan shaped computed tomography (CT) and Cone shaped CBCT .CBCT was the first to be used specifically for head and neck regions [5]**.**

Kharoshah, Magdy Abdel Azim, Osama Almadani, Sherien Salah Ghaleb, Mamdouh Kamal Zaki, and Yasser Ahmed Abdel Fattah assessed human type by a series of anthropometric measurements on mandibular CBCT scans that were (ramus length, gonion−gnathion length, minimum ramus breadth, gonial angle) from reconstructed sagittal view. Bicondylar breadth, and bigonial breadth from 3D axial view [7]. Another study achieved its measurements on certain structures that present different anatomical variations such as inferior alveolar canal and mental and mandibular foramina to detect sex related characters [5]**.**

The aim of this retrospective study was to identify sex of humans in Egypt using anthropometric measurements on mandibular CBCT scans by creating a formula with predictive variables and compare the values between sexes.

2. MATERIALS AND METHODS

This retrospective study included 120 CBCT scans collected from the database of patients affiliated to Oral radiology department, Ain shams university from January 2016 to December 2016 . The study was approved by the research ethical committee of Faculty of Dentistry, Ain Shams University.

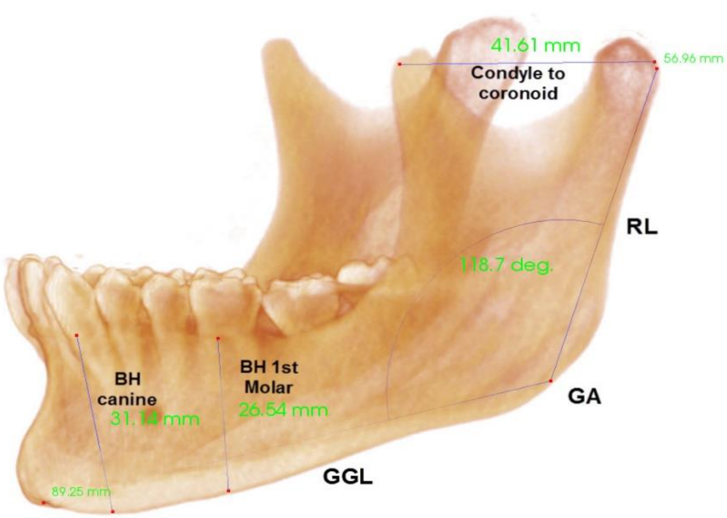
The scans were obtained from I-Cat scanner (Imaging Sciences, Hatfield, PA, USA) under fixed parameters (120 KVP, 37 mA, and 0.25 μm in 26.9 seconds) with amorphous silicon flat panel detector. Field of View (FOV) was adjusted separately for each human mandible.

The inclusion criteria included both sexes of adult patients (60 males and 60 female), dentate patients, and aged between 20 and 60 years. Previous traumatic or pathological fractures in jaw region. Recent or past expansile intra bony lesion and any skeletal anomaly or periodontal disease in jaws were excluded.

i. Tomographic measurements:

Tomographic measurements were made using volume render (VR) screen of Invivo dental software version 5.2 (Anatomage Inc., San Jose, CA). The system is run from Intel Core i5 CPU at 2.2 GHz with 8GB RAM, Windows 8.1, and 1920 x 1080 resolution liquid crystal display. The observers primarily detected the 3D locations of gonion (A), gnathion (B) and condylion (C). The gonion is the most lateral, caudal and posterior point on the external mandibular angle. The gnathion is the most anterior lower point on the curve of the chin. The condylion is the most postro-superior point of the mandibular condyle.

Then, eight different measurements were taken to detect the human sex [6,7]. The first six measurements were obtained from 3D sagittal view and they were ramus length (RL) , gonial angle (GA) , gonion gnathion Length (GGL), body height at canine area (BH canine) , body height at 1^{st} molar area (BH 1^{st} molar) , and distance from most posterior point of condyle to most anterior point of coronoid (Condyle to Coronoid) ***(Fig. 1)*** . While the 7^{th} and 8^{th} measurements were gained from 3D axial view and they were bi-gonial breadth (BigBr), bi-condylar breadth (BicBr) ***(Fig. 2).***



(Fig. 1): 3D sagittal view shows: (RL) ramus length (56.9 mm) ; (GA) gonial angle (118.7°) ; (GGL) gonion-gnathion length (89.2 mm) ; (BH canine) body height at canine (31.1mm) ; (BH 1^{st} molar) body height at first molar (26.5 mm) ; and (Condyle to coronoid) distance from condylar head to coronoid process (41.6 mm).

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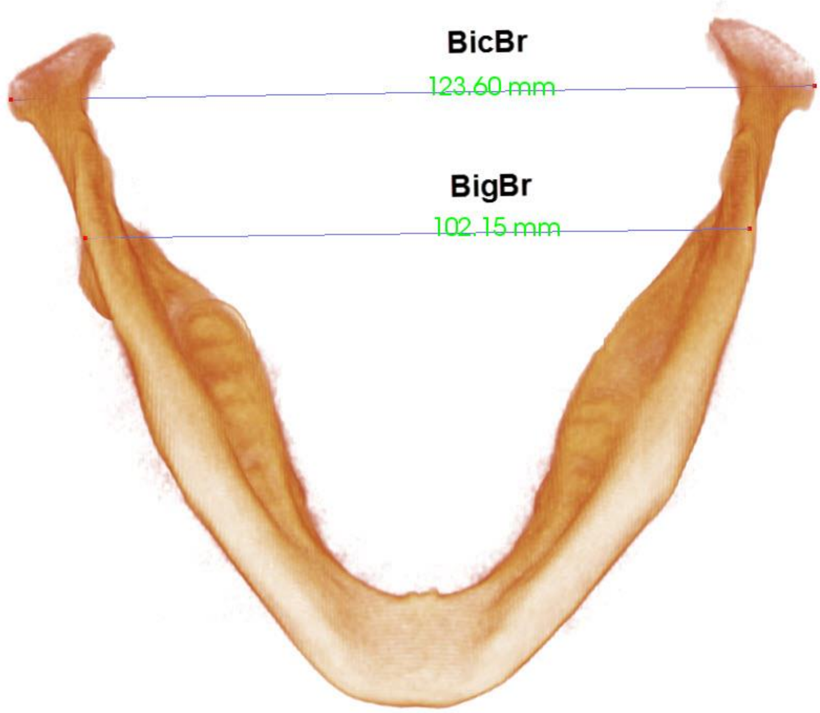

(Fig. 2): 3D axial view shows: (BicBr) bicondylar breadth (123.6 mm); (BigBr) bigonial breadth (102.1 mm).

The distance between (A) and (C) points is (RL). The junction of the posterior and lower borders of the mandible forms (GA). The distance between (A) and (B) points is (GGL) , and the distance from most posterior part of condylar head to most anterior area of Coronoid Process is (condyle to coronoid). The distance from the inferior border of mandible to the neck of canine forms (BH canine) while (BH 1st molar) is from lower border of mandible to the top of inter-septal bone. (BigBr) is determined by the most lateral points of both gonia. (BicBr) is between most outer points of head of condyles.

The scans were selected and assessed by two Oro maxillofacial radiologists with four years' experience and both were calibrated prior conducting the experiment. After 14 days, Values were measured again.

ii. Statistical analysis:

Data was analyzed by SPSS software (statistical package for social science) (version 25 for Windows; SPSS, IBM). Intra - inter observers' reliability were assessed by intra-inter class co-relation coefficient (ICC). A one-way analysis of variance (ANOVA) test suitable for experiments with a factor and repeated measures was used. Logistic regression (LR) analysis with stepwise variables selection was done to choose the most effective variables and use them in a formula. A significance level of 5% was used for all statistical tests. Discriminant function analysis was done to confirm this formula. Pearson co-relation coefficient (PCC) was also used to clarify the relation between measurements and age variable.

3. RESULTS

- **ICC:**

It showed high intra-observer reliability, its range (.760 -1.000) .Also, a high inter-reviewer degree of agreement was found and its range was (.905 1.000)

- **ANOVA:**

It was done to detect significance between measurement and sex variable .There were differences in all scales except GGL. Significant values were found to be higher for male sex except GA. ***(Table 1)***

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Table (1): The significance of each measurement in relation to sex variable by ANOVA test

Measurement	Sex	Mean		Sum of Squares	df	Mean Square	F	Sig.	Statistical significance
RL	Female	51.470	Between Groups	1716.120	1	1716.120	62.413	.000	Significant
	Male	59.033	Within Groups	3244.539	118	27.496			
			Total	4960.660	119				
GGL	Female	80.727	Between Groups	28.421	1	28.421	1.063	.305	Not Significant
	Male	81.700	Within Groups	3155.297	118	26.740			
			Total	3183.719	119				
GA	Female	122.023	Between Groups	246.247	1	246.247	7.322	.008	Significant
	Male	119.158	Within Groups	3968.373	118	33.630			
			Total	4214.620	119				
BH Canine	Female	28.103	Between Groups	235.760	1	235.760	30.498	.000	Significant
	Male	30.907	Within Groups	912.177	118	7.730			
			Total	1147.937	119				
BH 1st Molar	Female	23.253	Between Groups	263.737	1	263.737	29.950	.000	Significant
	Male	26.218	Within Groups	1039.099	118	8.806			
			Total	1302.836	119				
Condyle to coronoid	Female	34.640	Between Groups	643.570	1	643.570	57.962	.000	Significant
	Male	39.272	Within Groups	1310.186	118	11.103			
			Total	1953.756	119				
BicBr	Female	112.820	Between Groups	1358.787	1	1358.787	33.980	.000	Significant
	Male	119.550	Within Groups	4718.606	118	39.988			
			Total	6077.393	119				
BigBr	Female	87.652	Between Groups	2055.924	1	2055.924	37.336	.000	Significant
	Male	95.930	Within Groups	6497.696	118	55.065			
			Total	8553.620	119				

- **LR:**

This analysis method was used to reach sexual identification by including seven measurements .Most predictive measurements were achieved using full sample. (LR) analysis produced coefficients for each measurement included in our study and a constant ***(table 2).***

Table (2): Logistic Regression co-officiants used to calculate Logit Pi from the most significant measurements

Measurements	B	S.E.	Wald	df	Sig.	Exp(B)
RL	.196	.054	12.972	1	.000	1.217
BH Canine	.260	.113	5.336	1	.021	1.297
condyle to coronoid	.301	.094	10.325	1	.001	1.351
BigBr	.102	.036	7.903	1	.005	1.107
Constant	-38.865-	6.979	31.014	1	.000	.000

To use this information to assess human sex, a logit must be first obtained using

$$Logit\ (p_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n$$

Logit value could be used for male sex (PM) probability calculation using equation

$$P(M) = \frac{e^{Logit\ (p_i)}}{(1 + e^{Logit\ (p_i)})}$$

Female sex probability is simply $P(F) = 1 - P(M)$

In practice, if PM > 0.5, then the most likely sex is male, and if PM < 0.5, the most likely sex is female. The more PM is close to 1, the higher the chance person is male.

The overall accuracy was (85.8%).

- **Discriminant function:**

It was performed by obtaining discriminant function co-officiants

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n$$

By substituting in the equation by information in ***(table 3)***

Table (3): Discriminant Function Coefficients

Measurements	Function
	1
RL	.100
BH Canine	.104
condyle to coronoid	.148
BigBr	.049
(Constant)	-18.581-

We obtain

$$Y_i = -18.581 + .100 \times RL + .104\text{BH Canine} + .148\text{Condyle 2 Coronoid} + .049\text{BiGonial}$$

Positive value means male individual. It succeeded in sex classification with (85.8%) confirming results obtained from (LR).

- **PCC:**

It was made between measurements and age variable. Weak significance was detected except BicBr, its CC was (.263*) at level of significance (0.05) ***(table 4).***

Table (4): Pearson Correlation Coefficients representing relation between measurements and age

Male		**Female**	
Measurement	**Correlation coefficient**	**Measurement**	**Correlation coefficient**
RL	.102	RL	.116
GGL	-.022-	GGL	.042
GA	-.153-	GA	-.092-
BH Canine	-.006-	BH Canine	.017
BH 1st Molar	.166	BH 1st Molar	.122
condyle to coronoid	.243	condyle to coronoid	.177
BicBr	.117	BicBr	.263*
BigBr	.210	BigBr	-.046-

*. Correlation is significant at the 0.05 level (2-tailed

4. DISCUSSION

Forensic medicine was one of the medical branches that reflected a demanding role in the court of justice. This branch always tried to build database about sex, age, time, way of morbidity, and many other characteristics of the human being that might reveal the nature of the human corps [8]. Sexual Prediction was one of the basic parameters used for identification of missing or severely deteriorated personnel. According to Miracle and Mukherji**,** Skull bones had the privilege of being very dense and were hardly destructible [9]. Thus they could be of high diagnostic value**.**

In the current study we tried to describe an anthropometric approach in Egyptians using eight mandibular CBCT measurements in an equation to estimate sex. The former equation could be applied by manual substitution of the resultant measurements or it could be integrated in a 3rd party software to be calculated automatically.

Our study of sexual dimorphism used 120 scans ranged from 20 to 60 years old. The study conducted by Kharoshah, Magdy Abdel Azim, Osama Almadani, Sherien Salah Ghaleb, Mamdouh Kamal Zaki, and Yasser Ahmed Abdel Fattah also used the full mandibular projections of 330 African individuals ranging from 6 to 60 years [6] .While Gamba TDO, Alves MC and Haiter-Neto used the mandibular scans of 159 collected from a Brazilian population ranging from 18 to 60 years old [7]. Such age range was selected because all skull bones had reached almost complete puberty with minimal growth changes.

Mandible was selected in our study as the skull bone of choice due to its high density according to Gamba TDO, Alves MC and Haiter-Neto [7] .Other skull bones were used for the purpose of sexual prediction as described by Iscan [1] who used 3D reconstructed CT images of the curvature of the best fit-circle of the greater sciatic notch and Marques JAM, Musse J de O, Gois BC, Galvão LCC, Paranhos LR who used maxillary frontal sinuses [4]. Another study conducted by Holland [9] used victims' cranial base for dimorphism.

Measurements included in our study following Gamba TDO, Alves MC, and Haiter-Neto's protocol for eight different mandibular measurements [7]. Those were ramus length (RL) , gonial angle (GA) , gonion gnathion Length (GGL) , bi-gonial breadth (BigBr) , bi-condylar breadth (BicBr) , body height at canine area (BH canine) , body height at 1st molar area (BH 1st molar) , and distance from most posterior point of condyle to most anterior point of coronoid (Condyle to Coronoid).

The last three measurements of the current study (BH canine, BH 1st molar, and distance from Condyle to coronoid) were added to this research as a new entity in response to the fact that there is a difference between males and females in musculature. That would reflect on the degree of skeletal growth and development in a way that allowed us to markedly differentiate between sexes.

Kharoshah MAA, Almadani O, Ghaleb SS, Zaki MK, Fattah YAA used six mandibular measurements that were (RL) ,(GA) , minimum ramus breadth (MRBr) , (GGL) ,(BigBr) ,and (BicBr) on Africans for sexual identification [6]. Similarly, the study conducted by Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK used a specific mandibular ramus measurements namely coronoid height, projective height, condylar height, and maximum breadth and minimum breadth of ramus on Brazilians [2]. Also, (MRBr) was excluded from current study because it proved dimorphism in one out of the two analysis tests used in their studies which meant weak significance. [6,7]

The CBCT imaging technique was used according to Gamba T de O, Alves MC, Haiter-Neto [5] in the current study due to its unique capabilities of reconstructing a 3D volume with no magnification and minimum distortion as described by Miracle AC, Mukherji SK [10]. Scans of CBCT were produced through harmonious steps unlike spiral CT used by Kharoshah, Magdy Abdel Azim, Osama Almadani, Sherien Salah Ghaleb, Mamdouh Kamal Zaki, and Yasser Ahmed Abdel Fattah which exposed the patients to higher radiation doses over longer times in a relatively inconvenient acquisition procedure and high cost compared to CBCT [6].

Invivo Dental software was used in our study as a reliable software for measurement in accordance to Weissheimer A, Menezes LM De, Sameshima GT, Enciso R, Pham J, Grauer D [12] who compared six different software programs regarding accuracy of 3D analysis of upper airways. Similarly, Alves MC, and Haiter-Neto [7] used Ondemand software to assess his measurements while Kharoshah MAA, Almadani O, Ghaleb SS, Zaki MK, Fattah YAA used Siemens machine's software to perform his anthropometric measurements [6]**.**

The accuracy rate in our study on Egyptian population was found to be (85.8%) with a false rate of (13.3%) in males and (15%) in females. The study conducted by Kharoshah [6] found an accuracy of 83.9% for sexual dimorphism (applied on six mandibular measurements) . False identification of males was 16.4% versus 15.8% in females. Similarly, Gamba [7] performed his anthropometric measurements and found an accuracy of (89%). Such fluctuations in results between our study and the other studies were due to difference in populations, observers, imaging techniques and software programs.

Results obtained using maxillary sinus analysis by Marques JAM, Musse J de O, Gois BC, Galvão LCC, Paranhos LR [4] had achieved an accuracy rate of 73.9% in sexual dimorphism. In 2012, Gamba T de O, Alves MC, Haiter-Neto [5] detected the reproducibility of the foramen magnum and other skeletal measurements in sexual dimorphism and found an accuracy rate of 90.7% for males and 73.3% for females**.**

5. CONCLUSION

CBCT technology is an accurate imaging technique for sexual dimorphism. Invivo dental software is a reliable program for linear and angular measurements as the intra and inter observer reliability of the selected measurements showed high degree of agreement as they ranged from.760 to 1.000 and from .905 to 1.000 respectively. The measurements were overall higher in males than females, except GGL which showed no statistical significance between males and females. Logistic regression analysis was used to select the measurements RL, BH canine, distance from condyle to coronoid, and BigBr. Combining the four variables, the resultant equation was $P(M) = \frac{e^{Logit\,(p_i)}}{(1+e^{Logit\,(p_i)})}$

The Success rate of sex determination using the equation was 86.7% for males and 85% for females. The overall percentage of accuracy of sexual determination was 85.8%.

Hence, the formula developed in this study can be used as a valid tool for sexual dimorphism. Further studies are needed on larger groups and different people to add extra valuable data and aid forensic personals executing justice as nowadays our countries faced lots of terroristic attacks that reflected the need of forensic odontology to add remarkable finger prints

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