EVALUATION OF SELECTED MANDIBULAR MEASUREMENTS IN SEX IDENTIFICATION BY USING CONE BEAM COMPUTED TOMOGRAPHY IN A SAMPLE OF EGYPTIAN POPULATION

Alaa Mahmoud Helmy[1], Nancy Shalaby[1], Asmaa Youssry Aabdallah[2], Sahar M. Moustafa[3]

[1] *Department of Forensic Medicine and Clinical Toxicology, Faculty of Medicine, Damietta University, Egypt.*

[2] *Department of Oral Radiology, Faculty of Dentistry, Suez Canal University, Egypt.*

[3] *Department of Forensic Medicine and Clinical Toxicology, Faculty of Medicine, Suez Canal University, Egypt.*

ABSTRACT

Background: Sexual dimorphism is crucial for person identification, distinguishing males from females. The mandible, the most dimorphic skull bone, is easily imagined using Cone Beam Computed Tomography (CBCT). Skeletal structures vary among populations, requiring specific standards for accuracy. **Aim of the work:** To provide a reliable method and accurate determination for sex identification. **Subjects and methods:** The study comprised 260 full skull CBCT radiographs, it was carried out in Oral Radiology Department at Faculty of Dentistry in Suez Canal University (SCU), twelve parameters were measured, maximum ramus length (Max. RL), mandibular base length (MBL), gonial angle (GA), body height at mental foramen (BHMF), maximum ramus breadth (Max. RB), minimum ramus breadth (Min. RB), mandibular notch breadth (MNB), mandibular length projection (MLP), bi-coronoid breadth (BCB), bi- mental length (BML), bi- gonial breadth (BGB) and bi- condylar breadth (BCoB). **Results:** Males were significantly larger in all measurements except for the gonial angle which was larger in females. Using receiver operating characteristics (ROC) analysis, BGB followed by BCB and BCoB provided sex discrimination accuracy of 76.16% and 73.46% respectively. 90% of the males and 89.2% of the females were properly identified by the binary logistic regression (BLR) model, yielding an overall classification accuracy of 89.6%. The regression formula yielded an accuracy of 89.23%, specificity of 88.46% and sensitivity of 90%. **Conclusion and recommendations:** Mandible measurements can be used to correctly detect a person's sex, and it is an excellent bone for forensic examination.

Keywords: *Sex, mandibular bone, Cone Beam Computed Tomography, bi-gonial breadth, bi-coronoid breadth, gonial angle.*

Corresponding author: *Dr. Alaa Mahmoud Helmy*
Email: alaa.helmy@du.edu.eg
ORCID: 0009-0000-1945-3841

INTRODUCTION

Identification of skeletal remains is crucial for forensic anthropologists particularly in cases of mass disaster and high intensity explosions ***(Blau et al., 2021)***. Sexual dimorphism is one of the major criteria of person identification and represents a set of morphologic traits which differentiate between males from females ***(Pokala et al., 2023)***. In cadavers with severe degree of decomposition, burns or disfigurement, identification from tissue typing and Deoxyribonucleic acid (DNA) profiling turns into a major challenge, and in these circumstances, bone turns into a more trustworthy tool for identification ***(Nugroho, 2022)***. The pelvic bones and skull are considered the most significant indications of sexual dimorphism ***(Kurniawan et al., 2023)***. Although osseous structures of the skull like foramen magnum, frontal and maxillary sinuses, have been used to determine gender, there is less likelihood of these structures being preserved after death ***(Küchler et al., 2024)***.

The mandible is a (U) shaped bone, which is the only movable bone in the skull. It has three main parts, the body, the two rami and the process. It shows morphological changes related to size and remodeling during human growth. It has been found that there is a strong correlation between the chronological age and mandible morphology, especially that of the ramus. Additionally, ancestry and genetic factors are believed to modify bone age validation for chronological age determination ***(Okiriamu et al., 2023)***.

The mandible is essential for determining sex in both living and deceased individuals and can do so with a high degree of accuracy because of its high degree of sexual dimorphism in terms of size and shape ***(Liu et al., 2018; Baghdadi and Pani, 2012)***. Due to the ease of imaging of the mandible, this bone is considered as an important tool in identification through radiology ***(Hussein et al., 2023)***. The bone thickness and size of the female skeleton are smaller than those of the male attributed to sex, nutrition, and physical activity. Due to the fact that males and females' masticatory forces differ, mandibular dimorphism is shown to be influenced by the relative development of the masticatory muscles, including their size, strength, and angulation ***(Van der wel et al., 2023)***.

The most prevalent sex estimation techniques fall into one of two categories: metric or morphologic, while metric approaches offer a higher level of accuracy ***(Bulut et al., 2019; Cappella et al., 2020)***. Sexual dimorphism varies by population, the model that has been proven to work for one population may not work for another and it essential to study population-specific characteristics ***(Jerković et al., 2023; Dakhli and El-Dahab, 2020)***.

In order to develop models and equations that help with sex identification using osteometric measures, many statistical techniques, such as binary logistic regression (BLR) and discriminant function analysis (DFA) can be used ***(Hamdan et al., 2023)***.

However, because sexual dimorphism varies by population, the model that has been proven to work for one population may not work for another ***(Jerković et al., 2023)***.CBCT is a recent introduced three-dimensional (3D) imaging method that offers quick scan durations, high- resolution pictures, bone quality assessment, minimal nerve damage, non-intrusive equipment, a single scan for all purposes, and a dosage reduction that is 96% less than that of traditional Computed Tomography (CT) ***(Issrani et al., 2022)***. Moreover, the introduction of CBCT imaging in the management of patients has been more accurate in osteometric analysis. So, sexual dimorphism by using CBCT images have some advantages more than conventional osteometric methods ***(Köse and Bulut, 2022)***.

THE AIM OF THE WORK

The current study aimed to assess the reliability of sex identification using CBCT, assessing the mandibular measurements differences between both sex in a sample of Egyptian population and to develop a formula with potential dimorphic variables utilizing measurements of anatomic mandibular landmarks on CBCT images.

SUBJECTS AND METHODS

The sample size was calculated using the following formula: $n = 2\left[\frac{(Z_{\alpha/2} + Z_{\beta})*\sigma}{\mu_1 - \mu_2}\right]^2$ ***(Dawson and Trapp, 2004)***

Where:

n= is sample size required. Z $\alpha/2$ = 1.96 (The critical value that divides the central 95% of the Z distribution from the 5% in the tail). $Z\beta$ = 0.84 (The critical value that separates the lower 20% of the Z distribution from the upper 80%). σ = 4.3 (The estimate of the standard deviation) ***(Albalawi et al., 2019)***. $\mu1$= 47.7 (Mean linear distance from the right gonion to left gonion among males) ***(Albalawi et al., 2019)***. $\mu2$ = 46.6 (Mean linear distance from the right gonion to left gonion among females) ***(Albalawi et al., 2019)***. According to the previous calculations, 260 radiographs of patients were required. Simple random sampling was used from archived radiographs of patients attending the Oral Radiology Department, Faculty of Dentistry, SCU, with full complement of teeth in mandible (except to wisdom tooth), radiographs with any bony lesions leading to variation in morphology of mandible as fracture or malunion of the mandible, bone diseases, previous orthodontic treatment, orthognathic surgery, severe developmental anomalies or massive head trauma or surgery were excluded from the previous archived patients records as they may affect in the results. The archived radiographs of patients were divided into two groups (males and females). The sample was chosen randomly equally from each group (n= 130 for each group) aged from 18 to 50 years old as females older than 50 years undergo physiological changes as osteopenia which will affect the mandibular measurements, All archived radiographs of patients were scanned with full skull CBCT for various purposes using scanora 3dx *(scanora 3dx, soredex, Finland)*. Field of view fixed for all images included in the present study for standardization at 240×165 mm used standard resolution mode. The operating parameters were 90 kVp, 10 mA and the effective exposure time was about 3.2 seconds. The voxel size was 0.5 mm using a flat panel detector. The radiographs were coded and presented to two independent observers.The CBCT measurements were achieved using on demand 3D application software *(on demand cybermed. co., Seoul, Korea)*, with the distance and angle measurement tools.

The cases were opened on Lenovo *(laptop-4159oqkr)* personal computer, then each case was opened by using DVR, then 3D views, for lengths, a ruler was used, and measurements were recorded in millimeters, angle was used, and was recorded in angles. Twelve parameters were measured **(Table 1)**, Max. RL, MBL, GA, BHMF, Max. RB, Min. RB, MNB and MLP were measured from lateral view, BCB and BML from anterior view**,** BGB and BCOB from basal view **(Figures 1, 2 and 3 respectively)**.

Table (1): list of mandibular measurements and definitions.

The measurement	Definition
Minimum ramus breadth (Min. RB)	The mandibular ramus's minimal breadth measured perpendicular to its height ***(Elsayed et al., 2021)***
Maximum ramus breadth (Max. RB)	The mandibular ramus's maximal breadth measured perpendicular to the ramus's height ***(Elsayed et al., 2021)***
Maximum ramus length (Max. RL)	The distance from gonion to the highest point on the mandibular condyle ***(Motawei et al., 2020)***
Mandibular base length (MBL)	The distance between gonion to ganathion ***(El- sherbiny et al., 2019)***
Gonial angle (GA)	Intersection between the line representing ramus length and the line representing the mandibular base ***(Kharoshah et al., 2010)***
Bi- gonial breadth (BGB)	Linear distance between right and left gonion ***(İlgüy et al., 2014)***
Bi- condylar breadth (BCOB)	Linear distance between right and left condylion ***(Abd Elsalam et al., 2019)***
Bi- coronoid breadth (BCB)	Distance between the highest points of the mandibular coronoid processes ***(Abd Elsalam et al., 2019)***
Bi- mental length (BML)	Linear distance between right and left mental foramen ***(Abd Elsalam et al., 2019)***
Body height at mental foramen (BHMF)	Distance from the alveolar process to the inferior border of the mandible at the level of the mental foramen ***(Abd Elsalam et al., 2019)***
Mandibular notch breadth (MNB)	Distance between the superior point of the condylar process and the superior point of the coronoid process ***(Lopez et al., 2017)***
Mandibular length Projection (MLP)	The Distance measured from pogonion to the perpendicular line that tangent the posterior part of the condylar processes ***(Lopez et al., 2017)***

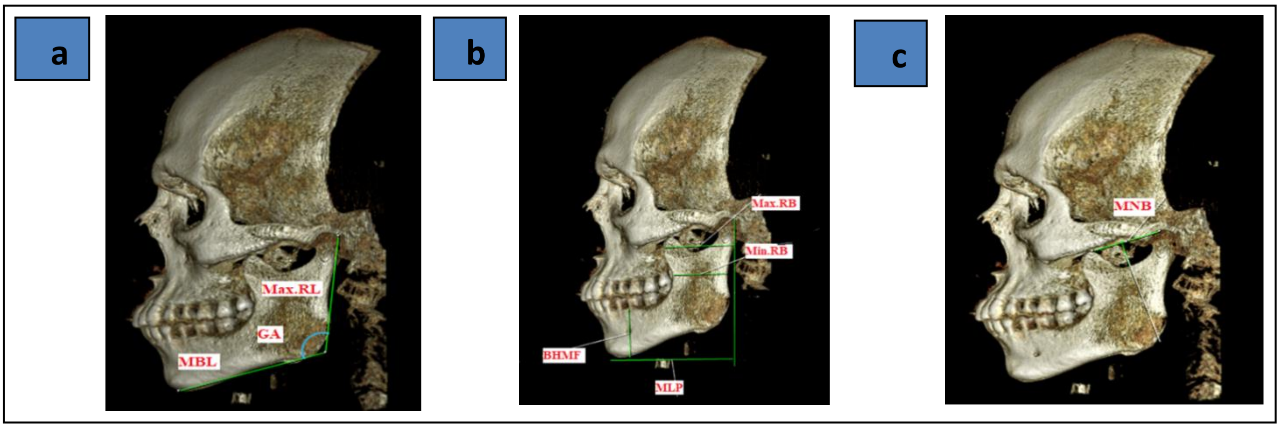

Figure (1): Lateral view full skull CBCT, a: Max. RL, maximum ramus length; GA, gonial angle; MBL: mandibular base length. b: Max. RB, maximum ramus breadth; Min. RB, minimum ramus breadth; MLP, mandibular length projection; BHMF, body height at mental foramen. c: MNB, mandibular notch breadth.

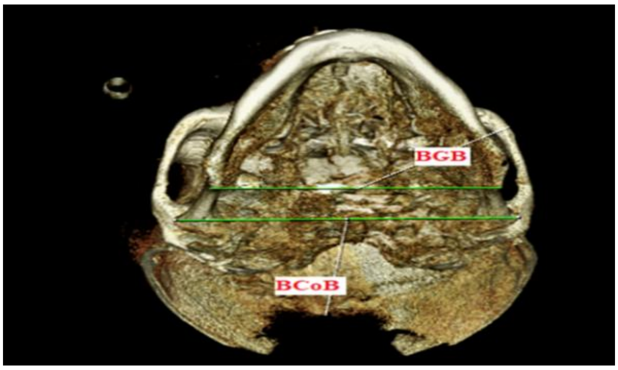

Figure (2): Basal view of full skull CBCT shows BGB, bi- gonial breadth; BCOB, bi- condylar breadth.

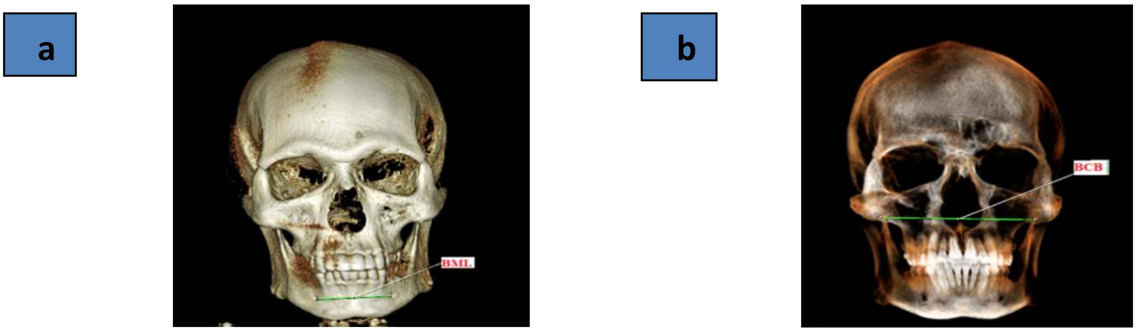

Figure (3): Anterior view of full skull CBCT, a: BML, bi- mental length, b: BCB, bi- coronoid breadth.

Statistical Analysis: SPSS version 25 (IBM Corporation, Chicago, USA) was used to analyze the data. The intra-observer reliability was evaluated using the Intraclass Correlation Coefficient (ICC) test. Mean and standard deviation (SD) were derived from the data. For parametric variables, the student t-test was used to determine the difference between the means of males and females' measurements. Using the ROC curve, sex was predicted based on the mandibular data that were measured. A sex prediction model was created using BLR analysis. A ROC curve was used to determine the resulting BLR formula's sensitivity, specificity and accuracy.

Ethical considerations: Approval from the research ethical committee, Faculty of Medicine, SCU *(Reference number: 5102)* was obtained before starting the study. Administrative approval from the department council of Oral Radiology Department of Faculty of Dentistry, SCU was obtained before starting the study. All data were considered confidential and anonymously conducted, and all samples were used in research only. The informed consent was waved as the study population was the archived radiographs of patients came to Oral Radiology Department of SCU Dentistry Hospital and performed full skull CBCT for any purpose.

RESULTS

The level of inter- and intra-observer error was acceptable with mostly excellent reliability. **Table (2)** showed that all mean values of the measurements were larger in males than in females except for GA mean was larger among females. The results showed that the mean values of the measurements of GA in females (123.3±5.27) were significantly greater than those in males (118.7±4.27), and the Max. RL mean values were significantly greater in males (62.28±6.39) than in females (55.0±5.38), and MBL mean values were greater in males (73.33±3.38) than in females (71.59±3.35), also the mean values of the measurements of BHMF in males (29.72±2.39) were significantly greater than in females (28.54±2.0), and the MNB mean values in males (33.06±4.87) were greater than in females (29.01±3.62), and the Max. RB mean values were significantly greater in males (41.12±5.17) than in females (38.83±3.05), and the Min. RB mean values in males (31.49 ± 3.32) were greater than in females (29.32±2.72), also the mean values of MLP were significantly greater in males (81.18±6.89) than in females (78.89±7.38), and the BGB mean values in males (95.51±7.26) were significantly greater than in those of females (85.73±6.26), the BCOB mean values of males (113.1±4.52) were greater than those in females (107.2±5.78), in addition the BCB mean values of males (95.66±4.43) were significantly greater than those in females (90.29 ± 4.38), and the BML mean values in males (48.42±2.47) were significantly greater than in females (46.25±2.88).

Table (3) describes the ROC curve analysis of the examined mandibular measures. ROC analysis shows the area under curve (AUC), best cut- off point values, sensitivity, specificity, and accuracy for all twelve studied measurements. AUC assesses how well a parameter can accurately distinguish between two groups (males and females). Max. RL, BGB, and BCB were shown to have the highest AUC which was interpreted as a good result (0.8≤AUC). The GA, MNB, BCOB and BML parameters were interpreted as fair result (0.7≤AUC). MBL, BHMF, Max. RB, Min. RB and MLP were interpreted as poor result (0.6 ≤ AUC). Cut off point of values typically divides the continuous results into categories like male or female. Male subjects were considered to have values more than the cut-off values for each variable except for GA. Female subjects were considered to have values equal to or less than the cut-off values except for GA. The highest sensitivity was for BGB (80%), the highest specificity for BGB was (72.31%) and the highest accuracy value for BGB was (76.16%) at a cut-off value of (>88.8 mm). The lowest sensitivity was for Max. RB and Min. RB (61.54%) at a cut value of (>39.4mm and >29.6mm respectively), the lowest specificity was for Min. RB (50%) at a cut value of (> 29.6mm) and the lowest accuracy was for Min. RB (55.7%) at a cut value of (> 29.6mm).

Table (4) shows simple logistic regression analysis of the mandibular measurements using the BLR formula. It includes the odds ratio (OR) for each variable, the regression beta coefficient (β), and the p-value based on the Wald statistic to assess the significance of each independent variable's individual logistic regression coefficient. Each of the analyzed mandibular measurements exhibited a statistically significant value when applied separately in a regression model. After the variables were entered into a backward stepwise regression.

Table (5) displays the best-fit model, only GA (OR= 0.774), Max. RL (OR= 1.216), MNB (OR= 1.229), Max. RB (OR= 0.707), BGB (OR= 1.205) and BCB (OR= 1.436) were selected in the analysis as GA, Max. RL, MNB, Max. RB, BGB and BCB had high statistically significance (p<0.001). The six variables (GA, Max. RL, MNB, Max. RB, BGB and BCB) were incorporated into the final equation that presented as follow:

$$P(sex) = \frac{1}{e^{(-0.257\,(GA) + 0.195\,(Max.\ RL) + 0.206(MNB) - 0.205\,(Max.\,RB) + 0.187\,(BGB) + 0.362\,(BCB) - 29.030}}$$

The formula will most likely predict a female sex when the estimated result is less than 0.5, and a male sex when the anticipated result is greater than or equal to 0.5.

Table (6) shows the accuracy of the model which tested those results. The resultant BLR model that includes the six independent variables (GA, Max. RL, MNB, Max. RB, BGB and BCB) was able to correctly classify 116 female subjects (116/130) as true females (89.2% of female cases). The model also was able to correctly classify 117 male (117/130) subjects as true males (90% of male cases). The overall accuracy to correct classification of gender was (89.6%).

Table (7) and **figure (4)** show the ROC curve which is used to evaluate the accuracy of the BLR model's resultant formula, AUC was interpreted as an excellent result (0.9 ≤ AUC). with an accuracy value of 89.23% at a cut-off point (0.5).

Figures (5 and 6) show different images of female and male cases with their measurements.

Table (2): Descriptive statistics and comparison of mandibular measurements between both genders.

Measurements	Male (n=130) Mean ± SD	Female (n=130) Mean ± SD	p-value
GA **(degree)**	118.7 ± 4.27	123.3 ± 5.27	**< 0.001 ǂ****
Max. RL **(mm)**	62.28 ± 6.39	55.0 ± 5.38	**< 0.001 ǂ****
MBL **(mm)**	73.33 ± 3.38	71.59 ± 3.35	**< 0.001 ǂ****
BHMF **(mm)**	29.72 ± 2.39	28.54 ± 2.0	**< 0.001 ǂ****
MNB **(mm)**	33.06 ± 4.87	29.01 ± 3.62	**< 0.001 ǂ****
Max. RB **(mm)**	41.12 ± 5.17	38.83 ± 3.05	**< 0.001 ǂ****
Min. RB **(mm)**	31.49 ± 3.32	29.32 ± 2.72	**< 0.001 ǂ****
MLP **(mm)**	81.18 ± 6.89	78.89 ± 7.38	**0.01 ǂ***
BGB **(mm)**	95.51 ± 7.26	85.73 ± 6.26	**< 0.001 ǂ****
BCOB **(mm)**	113.1 ± 4.52	107.2 ± 5.78	**< 0.001 ǂ****
BCB **(mm)**	95.66 ± 4.43	90.29 ± 4.38	**< 0.001 ǂ****
BML **(mm)**	48.42 ± 2.47	46.25 ± 2.88	**< 0.001 ǂ****

n: *number of each group* ***SD:*** *standard deviation* **: statistically significant (p<0.05)*
: high statistically significant (p<0.001)* ***ǂ: *student's t-test*

GA: gonial angle — *Max. RL: maximum ramus length* — *BML: bi- mental breadth*
BHMF: body height at mental foramen — *MNB: mandibular notch breadth* — *BGB: bi- gonial breadth*
Min. RB: minimum ramus breadth — *MLP: mandibular length projection* — *BCB: bi- coronoid breadth*
MBL: mandibular base length — *BCOB: bi- condylar breadth* — *Max. RB: maximum ramus breadth*

Table (3): Receiver Operating Characteristics analysis results of mandibular measurements for sex prediction.

Measurements (mm& degree)	AUC	Standard error	P-value	Cut-off (mm & degree)	Sensitivity (%)	Specificity (%)	Accuracy (%)
GA	0.740	0.030	**<0.001****	≤121.9	73.08	59.23	66.16
Max. RL	0.815	0.027	**<0.001****	>57.8	73.85	70	71.93
MBL	0.652	0.034	**<0.001****	>72.2	64.62	60.77	62.70
BHMF	0.663	0.034	**<0.001****	>29.2	63.85	60	61.93
MNB	0.746	0.030	**<0.001****	>29.3	75.38	60	67.69
Max. RB	0.641	0.035	**<0.001****	>39.4	61.54	55.38	58.46
Min. RB	0.678	0.034	**<0.001****	>29.6	61.54	50.0	55.77
MLP	0.672	0.034	**<0.001****	>80.8	70.77	60	63.9
BGB	0.845	0.023	**<0.001****	>88.8	80.0	72. 31	76.16
BCOB	0.769	0.029	**<0.001****	>109.7	76.92	58.46	73.46
BCB	0.803	0.027	**<0.001****	>91.9	76.92	70	73.46
BML	0.738	0.031	**<0.001****	>47.5	71.54	58.46	65.0

AUC: *area under curve* ***: high statistically significant (p<0.001)*

GA: gonial angle — *Max. RL: maximum ramus length* — *BML: bi- mental breadth*
BHMF: body height at mental foramen — *MNB: mandibular notch breadth* — *BGB: bi- gonial breadth*
Min. RB: minimum ramus breadth — *MLP: mandibular length projection* — *BCB: bi- coronoid breadth*
MBL: mandibular base length — *BCOB: bi- condylar breadth* — *Max. RB: maximum ramus breadth*

Table (4): Simple logistic regression analysis of each mandibular measurements for sex prediction.

Measurement	ß	p-value	Odds ratio	95% CI
GA	-0.212	**<0.001****	0.809	0.758– 0.864
Max. RL	0.244	**<0.001****	1.277	1.196 – 1.362
MBL	0.154	**<0.001****	1.167	1.080 – 1.260
BHMF	0.250	**<0.001****	1.284	1.137 – 1.450
MNB	0.219	**<0.001****	1.245	1.163 – 1.333
Max. RB	0.127	**<0.001****	1.136	1.068 – 1.207
Min. RB	0.230	**<0.001****	1.259	1.154 – 1.373
MLP	0.045	**0.011***	1.046	1.010 – 1.083
BGB	0.195	**<0.001****	1.215	1.160 – 1.274
BCOB	0.215	**<0.001****	1.240	1.168 – 1.316
BCB	0.281	**<0.001****	1.325	1.228 – 1.429
BML	0.313	**<0.001****	1.367	1.225 – 1.527

ß: *Beta coefficient* ***CI:*** *confidence interval* ****:*** *Statistically significant (p<0.05)* *****:*** *Highly statistically significant (p<0.001)*

GA: gonial angle — *Max. RL: maximum ramus length* — *BML: bi- mental breadth*
BHMF: body height at mental foramen — *MNB: mandibular notch breadth* — *BGB: bi- gonial breadth*
Min. RB: minimum ramus breadth — *MLP: mandibular length projection* — *BCB: bi- coronoid breadth*
MBL: mandibular base length — *BCOB: bi- condylar breadth* — *Max. RB: maximum ramus breadth*

Table (5): Best- fit multiple logistic regression analysis of the mandibular measurements for sex prediction.

Measurement	ß	p-value	Odds ratio	95% CI
GA	-0.257	**<0.001****	0.774	0.674 - 0.888
Max. RL	0.195	**<0.001****	1.216	1.095 - 1.349
MNB	0.206	**<0.001****	1.229	1.063 - 1.421
Max. RB	-0.205	**<0.001****	0.814	0.707 - 0.939
BGB	0.187	**<0.001****	1.205	1.101 - 1.318
BCB	0.362	**<0.001****	1.436	1.249 - 1.651
Constant	-29.030	**0.015***	0.0	-

*ß: Beta coefficient CI: confidence interval *: Statistically significant (p<0.05)*
***: Highly statistically significant (p<0.001)*
GA: gonial angle BCB: bi- coronoid breadth MNB: mandibular notch breadth
BGB: bi- gonial breadth Max. RL; maximum ramus length Max. RB: maximum ramus breadth

Table (6): Accuracy of multiple logistic regression model using mandibular measurements for sex prediction.

Observed	Predicted		
	Sex		Percentage correct (%)
	Female	Male	
Sex			
Female (n= 130)	116	14	89.2
Male (n= 130)	13	117	90.0
Overall percentage			**89.6**

n: total number of each group

Table (7): The accuracy of the resultant formula of binary logistic regression model using mandibular measurements for sex prediction.

Statistic	AUC	Standard error	p-value	Cut-off	Sensitivity (%)	Specificity (%)	Accuracy (%)
Mandibular measurements	0.969	0.008	**<0.001****	0.5	90	88.46	89.23

*AUC: Area under the curve ****:** Highly statistically significant (p<0.001)*

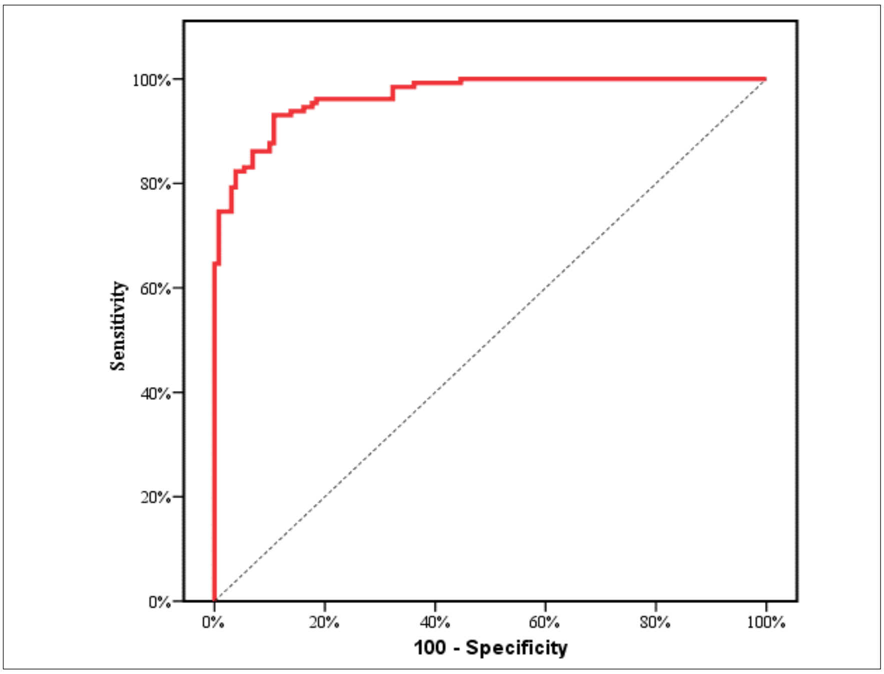

Figure (4): Receiver Operating Characteristics curve for Binary logistic regression model formula using mandibular measurements for sex prediction.

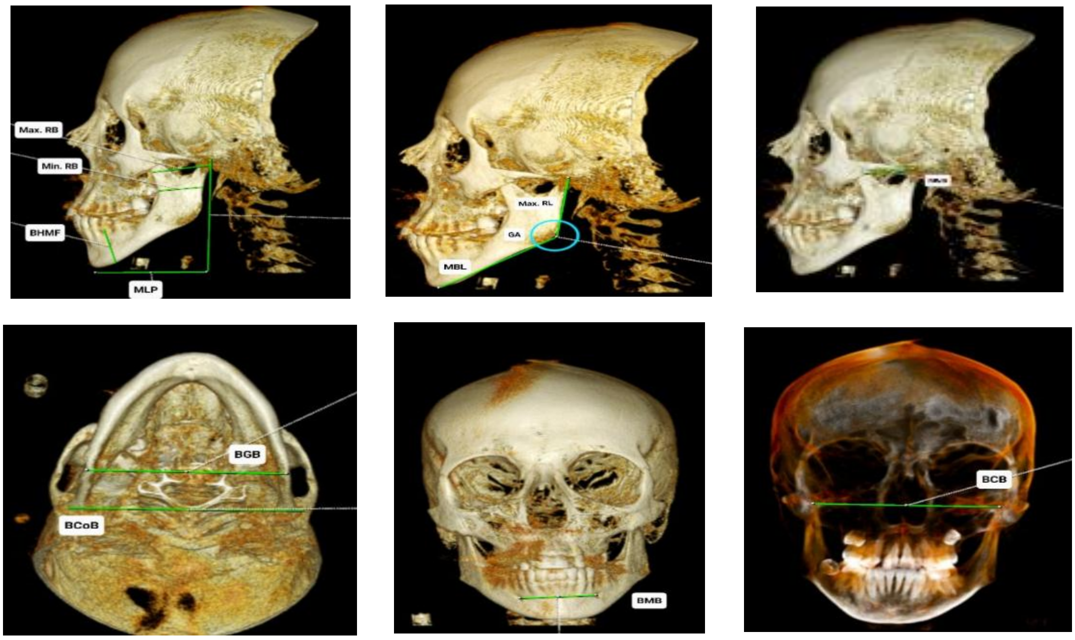

Figure (5): Full skull CBCT images of male case showing the following values,

GA: 114.3°	*BGB: 100.7 mm*	*MBL: 76.7 mm*	*Max. RL: 64.2 mm*
BHMF: 29.7 mm	*BCB: 90.5 mm*	*MLP: 81.6 mm*	*Max. RB: 45.7 mm*
BML: 48.7 mm	*BCOB: 111.7 mm*	*MNB: 35 mm*	*Min. RB: 35.3 mm*

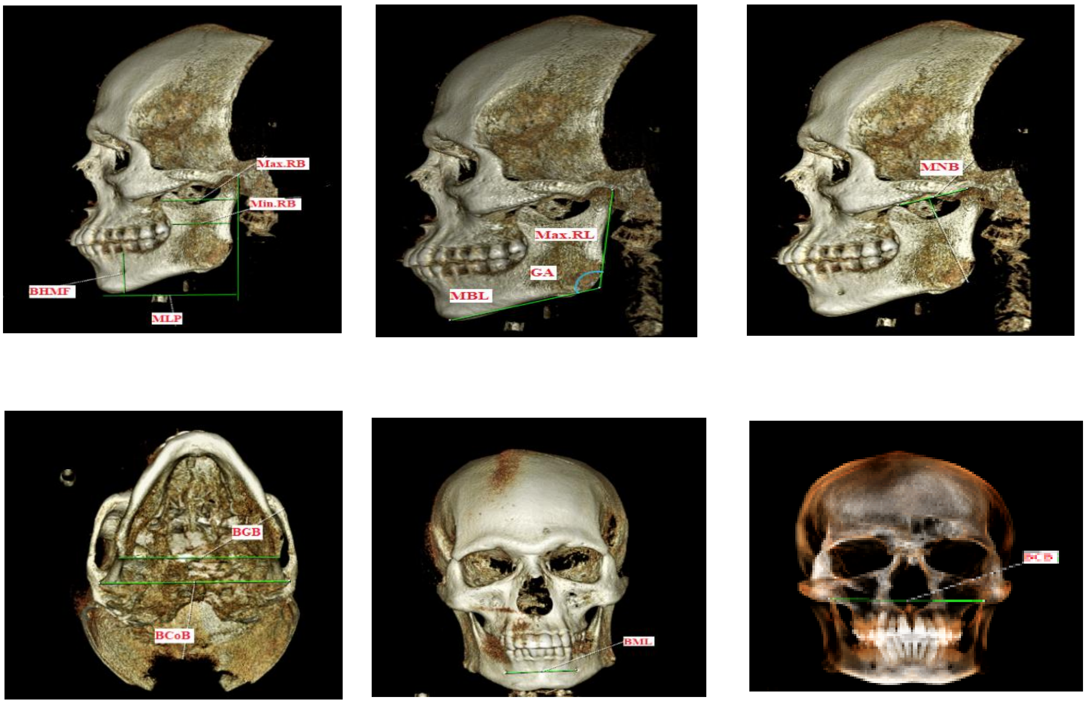

Figure (6): Full skull CBCT images of female case showing the following values,

GA: 132.5°	*BGB: 86.9 mm*	*MBL: 71 mm*	*Max. RL: 44.2 mm*
BHMF: 27.5 mm	*BCB: 91.5 mm*	*MLP: 64.8 mm*	*Max. RB: 34.6 mm*
BML:38.9 mm	*BCOB: 103.1 mm*	*MNB:25.9 mm*	*Min. RB: 26.2 mm*

DISCUSSION

One of the most important steps in proving the identity of the deceased is determining biological sex via anthropological study of human skeletal remains ***(Techataweewan et al., 2021)***. Researchers have utilized both dry bone and digital radiography techniques for sexual dimorphism ***(Ostovar Rad et al., 2020)***. The mandible is the largest and toughest facial bone, which is important for sexual dimorphism since it can resist harsh environmental circumstances ***(Senol et al., 2022)***. CBCT is regarded as a trustworthy, efficient, and relatively easy approach that has been utilized in sex identification ***(Jurić and Matijaš, 2023)***.

In the present study, all measurements between both genders were high statistically differences and can be used in estimation of sexual dimorphism. The mean of all measurements was higher in males than in females while GA mean was larger among females. ***Abd Elsalam et al. (2019)*** study was in agreement with the current study as, the mean values of the measurements of BGB, BCB, BCOB and BHMF showed significantly higher values in males than in females and the mean value of GA showed significant higher values in females than in males. These results were in accordance with ***Okkesim and Erhamza, (2020)*** study which conducted to measure the morphometric characteristics of the 3D mandible models in the Turkish population and to assess the efficacy of measurements in determining gender and reported that the mean values of Max. RB and Min. RB were larger in males than females and showed high statistically significantly difference between both groups. The present study was in agreement with a Japanese study as, the mean values of all parameters (BGB, BCB, BCOB, BHMF, Min. RB and Max. RH) except for GA were statistically significantly larger in males ***(Ostovar Rad et al., 2020)***.

Gillet et al., (2020) results revealed that mean values of BGB, BCB and ramus height (equal to Max. RL) were highly significant in males, these results were in accordance with the current study, and it showed that the mean values of GA had no significant difference between the two groups which opposes the present study. A recent study conducted in Turkey, males had statistically larger mean values of BGB, BCB, Max. RB, Min. RB and length of the body (equal to MBL) measurements than females, females had statically larger mean value of mandibular angle (equal to GA) than males, which comes in agreement with the results of the present study. The mean value of the height of mandibular body (equal to BHMF) had no statistical significance between two genders that oppose the current study ***(Kavak et al., 2023)***.

The current results are in a difference with an Indian study that showed the mean values of MBL, Max. RH and BGB were statistically significant larger in males than females and it agrees with the current study. But it disagrees with GA, BCB and Min. RB which had not statistically significance difference between two groups and higher in males ***(Rao et al., 2021)***. A recent study revealed that Max. RB showed highly significantly difference between mean values of both groups and being largely in males than females that comes in agreement with the current study. However, it disagrees with the current study in that the mean values of Min. RB were larger in males but not statistically significant ***(Ingaleshwar et al., 2023)***.

In India, a digital orthopantomography study was conducted on 40 males and 40 females between ages 18 to 50 years old. Five parameters were measured. It revealed that the mean value of projective height of ramus (equal to MLP) had statically significant difference between both genders and larger in males ($p < 0.05$). Max. RB and Min. RB mean values were not significantly difference and larger in male which disagree with the current study ***(Chalkoo et al., 2019)***. The males bone longer and broader than female ones, Testosterone is the major gonadal androgen in males, it promotes bone growth and inhibits bone loss ***(Callewaert et al., 2010)***, and estrogen increase results in epiphyseal fusion and the termination of longitudinal growth and reduces osteoclast activity and enhances osteoclast apoptosis ***(Sabag et al., 2019)***.

The effect of masticatory power on the morphology of mandibular ramus on the mandibular base is greatly make the difference in GA between two genders, the female GA (with low masticatory muscles power) is more obtuse than male GA (with powerful mastication muscles which make traction power on the mandibular ramus toward the mandibular base) ***(Albalawi et al., 2019)***.

(ROC) curves were created for a direct comparison of the sex prediction of each measurement. The present study showed that all measurements had a high degree of diagnostic value for discriminating sex (0.5<AUC<1.0). The parameter with the highest diagnostic accuracy for discriminating sex was BGB (76.16%) followed by BCB and BCOB (73.46%) and Max. RL (71.93%). ***Dong et al. (2015)*** study reported that the BCOB and maximum ramus height (equal to Max. RL) had the highest accuracy rates of 78.3 % and 76.8%, respectively by using univariate Discriminant Functional Analysis, which were slightly higher than those of the current study (73.64% and 71.93%, respectively). However, the accuracy rate of BGB and GA in the aforementioned study were 71.4% and 61.1% respectively which were lower than the accuracy rate of BGB and GA in the present study (76.16% and 66.16%).

Dabaghi and Bagheri. (2020) results revealed that the parameter with the highest accuracy using the ROC curve was ramus height (equal to Max. RL) with accuracy of 84.6% which is higher than the current study (71.93%) followed by BHMF of accuracy 83.8% which is higher than the current study (61.93%) and BCOB with the same accuracy rate of 73.5% to the present study (73.46%).

Additionally, ***Alias et al. (2018)*** in Malysia employed univariate Discriminant Function Analysis and reported that the BGB provided the highest prediction rate of 78.5% which can be considered close to the BGB result of the present study (76.16%) where the BGB provided the highest prediction rate. In the current study, a model for sex prediction based on mandibular measures was created using BLR. The prediction of sex using the BLR model, based on GA, Max. RL, MNB, Max. RB, BGB and BCB which had high statistically significance in backward stepwise regression analysis. The prediction model could correctly classify 90% of males and 89.2% of females with an overall accuracy of 89.6%. Finally, the accuracy of the resultant formula from the BLR model was tested using ROC curve. The formula demonstrates an accuracy rate of 89.23%, with 90% sensitivity and 88.46% specificity. A study conducted in Egypt on mandible by Stepwise Discriminant Function Analysis on BCB, MBL and Max. RL the accuracy rate for sex discrimination was 82.7% for males, 76% for females, and an overall percentage of 79.4% ***(Dakhli and Abu El- Dahab, 2020)***.

El- Sherbiny et al. (2019) results reported that the accuracy rate with stepwise DFA of coronoid height, mandibular notch depth, mandibular canal length and BCB was 76.1% for males, 76.2% for females with an overall accuracy of 76% and had the same result in being equally predict sex in both groups. ***Moustafa, (2014)*** demonstrated that GA, BCOB, MBL and Max. RL collectively produced a whole accuracy of 84.95% and could correctly identify males in 84.7% and females in 85.2% cases by using stepwise DFA of the mandible among Saudi subjects. ***Verma et al., (2020)*** reported that the Discriminant Function Analysis of mandibular parameters achieved 78.4% sex estimation accuracy for males, 76.8% for females and 77.6% in total from a model accompanying Max. RL, Max. RB and GA. ***Kurniawan et al., (2023)*** study revealed that sex prediction accuracy from Max. RL and symphysis height (not included in the current study) was about 82.5% in total using DFA and can correctly identify 94.3% in females and 63.6 in males. Sexual classification accuracy for the human mandible ranged from 56.3% to 99% ***(Alves et al., 2022)***. The vast majority of studies showed accuracy levels above 70% ***(Villanueva et al., 2017)***.

Diverse accuracy rates might be attributed to various demographics represented in each study's sample as well as various statistical methods ***(Krenn et al., 2022)***. Different statistical methods, sample size, anatomical and radiographic techniques, research variables, and ethnic differences in the population under investigation might all be factors in the variance shown in different studies ***(Agarwal et al., 2021)***.

The current study found that the mandibular measurements significantly differ between male and female by using Cone Beam Computerized Tomography. The mandibular parameters' ability to accurately determine sex may vary among communities, hence the research population must be taken into consideration while selecting the optimum parameters ***(Alves et al., 2022)***.

Limitations of the study: Egypt's population is large and diversified; therefore, the present study's sample size and its focus on recruiting individuals from a single geographic area are viewed as its limitations. Based on anthropometric techniques, sex identification is ethnicity-specific and population-specific, depending on a variety of genetic and environmental variables. Therefore, the results of the present study cannot be generalized to other populations.

CONCLUSION

The recent study concluded that mandible measurements can be used to correctly detect a person's sex, and it is an excellent bone for forensic examination. The means of all measurements were higher in males than in females except for GA mean which was larger among females. BGB was the most valuable parameter for discriminating between both sexes with 76.16% accuracy. An effective logistic regression model was constructed, with an 89.6% total accuracy rate. The ROC curve was used to examine the accuracy of the BLR resultant formula, which revealed an accuracy rate of 89.23%. The derived formula is population specific and cannot be generalized to other populations.

RECOMMENDATIONS

The present study recommended a larger sample size for future studies to determine the mandibular accuracy in sex identification. In order to improve the precision of sex identification based on the mandible, more radiometric characteristics from the mandible should be evaluated. Testing the metric approach and equation produced from the current study in various geographic places in Egypt to see if it can be applied to Egyptians as a whole for sex prediction. Due to the significant variance that may exist between various population groups, such as differences in profession and ethnicity that may alter the skeleton and, as a result, bone measurements, further research is required to produce a group-specific standard for identification. Additionally, there is a critical need for increased understanding of the identifying power of CBCT scans within Egyptian and forensic communities because it is a practical and non-invasive mean of identifying people.

REFERENCES

1. **Abd Elsalam, G. S.; El-Shal, O. and Shaaban, A., (2019):** Evaluation of different mandibular measurements by cone beam computed tomography as a forensic age and gender determination tools. *Al- Azhar Dent. J. Girls, 6(4): 445–452.*
2. **Agarwal, H. K.; Setia, P. S. and Pandey, S., (2021):** Virtual determination of sex: estimating cut off value of digital metric traits of foramen magnum on three-dimensional computed tomography with receiver operating characteristic and logistic regression analysis. *J. Forensic Sci. Med., 7(1):1-8.*
3. **Albalawi, A. S.; Alam, M. K.; Vundavalli, S. et al. (2019):** Mandible: An indicator for sex determination–A three-dimensional cone-beam computed tomography study. *Contemp. Clin. Dent.,10(1): 69.*
4. **Alias, A.; Ibrahim, A. N. M.; Bakar, S. N. A. et al., (2018):** Morphometric analysis of coronoid process of mandible by CT in the Malaysian population: An important step for determination of sex. *J. Dent. Sci. Res. Ther.,5(1):1-8.*
5. **Alves, N.; Ceballos, F.; Muñoz, L. et al., (2022):** Estimación sexual mediante análisis métrico del ángulo de la mandíbula y de la rama mandibular: Revisión sistemática. *Int. J. Morphol.,40(4):883-894.*
6. **Baghdadi, Z. D. and Pani, S. C. (2012):** Accuracy of population-specific Demirjian curves in the estimation of dental age of Saudi children. *Int. J. ped. Dent.,22(2): 125–113*
7. **Blau, S.; Graham, J.; Smythe, L. et al., (2021):** Human identification: a review of methods employed within an Australian coronial death investigation system. *Int. J. Legal Med.,135(1):375–385.*
8. **Bulut, O.; Freudenstein, N.; Hekimoglu, B. et al., (2019):** Dilemma of gonial angle in sex determination: sexually dimorphic or not? *Am. J. Forensic Med. Pathol.,40(4):361–365.*
9. **Callewaert, F.; Venken, K.; Kopchick, J. J. et al., (2010):** Sexual dimorphism in cortical

bone size and strength but not density is determined by independent and time-specific actions of sex steroids and IGF-1: evidence from pubertal mouse models. *J. Bone Min. Res.,25(3):617-626.*

10.**Cappella, A.; Gibelli, D.; Vitale, A. et al., (2020):** Preliminary study on sexual dimorphism of metric traits of cranium and mandible in a modern Italian skeletal population and review of population literature. *Legal Med.,44:101695.*

11.**Chalkoo, A. H.; Maqbool, S. and Wani, B. A. (2019):** Radiographic evaluation of sexual dimorphism in mandibular ramus: A digital orthopantomography study. *Int. J. App. Dent. Sci.,5(1):163–166.*

12.**Dabaghi, A. and Bagheri, A. (2020):** Mandibular ramus sexual dimorphism using panoramic radiography. *Avicenna J. Dent. Res.,12(3):97-102.*

13.**Dakhli, I. and El- Dahab, O. A. (2020):** Sexual differentiation based on mandibular parameters utilizing cone beam computed tomography of a sample of Egyptian population. *Int. Arch. Integ. Med.,7(5):24–31.*

14.**Dawson, B. and Trapp, R. (2004):** Basic and Clinical Biostatistics. 4th ed. *United States of America: McGraw-Hill.*

15.**Dong, H.; Deng, M.; Wang, W. et al., (2015):** Sexual dimorphism of the mandible in a contemporary Chinese Han population. *Forensic Sci. Int.,255(2):9-15.*

16.**Elsayed, R. M.; Hilal, M. A.; Mahmoud, H. M. et al., (2021):** Determination of sex from various measurements of mandibular ramus and mental foramen relations using digital panoramic imaging in a sample of Sohag governorate population. *Egy. J. Forensic Sci. App. Toxicol.,21(1):95–113.*

17.**El- sherbiny, M.; El-shafey, M.; Hend, M. et al., (2019):** Sexual dimorphism of mandibular ramus in an Egyptian sample: A radiographic study. *Med. J. Cairo Univ., 87: 645–651.*

18.**Gillet, C.; Costa-Mendes, L.; Rérolle, C. et al., (2020):** Sex estimation in the cranium and mandible: A multislice computed tomography (MSCT) study using anthropometric and geometric morphometry methods. *Int. J. Legal Med.134:823-832.*

19.**Hamdan, S. N. S. M.; Rahmat, R. A. A.; Razak, F. A. et al. (2023):** Sex estimation of Malaysian sub-adults using craniometrics: A computed tomography study. *Legal Med.,64(1):102275.*

20.**Hussein, S.; Mohamed, N. A. and Amer, M. I., (2023):** Accuracy of various parameters of the mandible for sex determination by cone beam computed tomography (retrospective study). *Egy. Dent. J., 69(3): 1887-1892.*

21.**İlgüy, D.; İlgüy, M.; Ersan, N. et al., (2014):** Measurements of the foramen magnum and mandible in relation to sex using CBCT. *J. Forensic Sci.,59(3):601–605.*

22.**Ingaleshwar, P.; Bhosale, S.; Nimbulkar, G. et al. (2023):** Mandibular ramus-An indicator for gender determination: A digital panoramic study in Bagalkot population. *J. Oral Maxillofac. Pathol.,27(1):66.*

23. **Issrani, R.; Prabhu, N.; Sghaireen, M. G. et al. (2022):** Cone-beam computed tomography: A new tool on the horizon for forensic dentistry. *Int. J. Environ. Res. Public Health, 19(9):5352.*

24.**Jerković, I.; Ljubić, T.; Bardić, L. et al., (2023):** Application of palmar digital intertriradial distances for sex classification from palmprints: A preliminary study. *Aust. J. Forensic Sci.,55(1):34-45.*

25.**Jurić, B. and Matijaš, T., (2023):** The role of CBCT in the field of dental implantology. Radiološki vjesnik. *Radiol. Radiot. Nukl. Med.*

26.**Kavak, V.; Pilmane, M.; Kazoka, D. et al., (2023):** Anthropometric evaluation of mandibular characteristics in the medieval Kurdish population of Girê Kortikê: Sex-based variations and comparative analysis. *Trans. Res. Anat.,32(1):100255.*

27.**Kharoshah, M. A. A.; Almadani, O.; Ghaleb, S. S. et al. (2010):** Sexual dimorphism of the mandible in a modern Egyptian population. *J. Forensic Legal Med.,17(4): 213–215.*

28.**Köse, E. and Bulut, D. G. (2022):** The use of hyoid bone dimensions in age and sex estimation in a Turkish population: a cone-beam computed tomography study. *Folia Morphol.,81(1), pp. 183–189.*

29.**Krenn, V. A., Webb, N. M., Fornai, C. et al., (2022).** Sex classification using the human sacrum: Geometric morphometrics versus conventional approaches. *Plos One,17(4): e0264770.*

30.**Küchler, E. C.; Kirschneck, C.; Marañón-Vásquez. et al. (2024):** Mandibular and dental measurements for sex determination using machine learning. *Sci. Rep.,14(1): 9587.*

31. **Kurniawan, A.; Sosiawan, A.; Nurrahman, T. F. et al. (2023):** Predicting sex from panoramic radiographs using mandibular morphometric analysis in Surabaya, Indonesia. *Bull. Int. Assoc., Paleodontol.,17(1):32-40.*
32. **Liu, Y., Wang, R.; Baur, D. A. et al. (2018):** A finite element analysis of the stress distribution to the mandible from impact forces with various orientations of third molars. *J. Zhejiang Univ. Sci.,19(1): 38–48.*
33. **Lopez, T. T.; Michel- Crosato, E.; Benedicto, E. de N. et al. (2017):** Accuracy of mandibular measurements of sexual dimorphism using stabilizer equipment. *Braz. Oral Res.31(1):1–7.*
34. **Moustafa, S. (2014):** Sexual dimorphism of selected mandibular anthropometric parameters in saudi population sample: Application in forensic identification. *Ain Shams J. Forensic Med. Clin. Toxicol., 23(2):43-49.*
35. **Motawei, S. M.; Helaly, A. M. N.; Aboelmaaty, W. M. et al. (2020):** Length of the ramus of the mandible as an indicator of chronological age and sex: A study in a group of Egyptians. *Forensic Sci. Int. Rep.,2(1):66–69.*
36. **Nugroho, N. A. (2022):** Identification of bone skeleton in old well. *Smart Med. J.,5(3):169-173.*
37. **Okiriamu, A.; Butt, F.; Opondo, F. et al. (2023):** Morphology and variant anatomy of the mandibular canal in a kenyan population: A cone-beam computed tomography study. *Craniomaxillofac. Res. Innov.,8(1):1-12.*
38. **Okkesim, A. and Erhamza, T. S. (2020):** Assessment of mandibular ramus for sex determination: Retrospective study. *J. Oral Biol. Craniofac. Res.,10(4):569–572.*
39. **Ostovar Rad, F.; Javanshir, B.; Nemati, S. et al. (2020):** Evaluation of sexual dimorphism with mandibular parameters by digital panoramic radiography. *Open Dent. J.,14(1):1-10.*
40. **Pokala, A.; Ravali, M.; Gowda, B. G. et al. (2023):** Determination of gender by radiographic analysis of mental foramen in computed tomography. *J. Ind. Acad. Oral Med. Radiol.,35(2):255-257*
41. **Rao, K.; Shetty, M.; Nayak, U. K. et al. (2021):** Estimation of sexual dimorphism of the mandible in coastal Karnataka and Kerala populations using cone beam computed tomography. *J. Health Alli. Sci. Nitte Univ.,12(02):106-112.*
42. **Sabag, E.; Halperin, E.; Liron, T. et al. (2019):** Hormone-Independent sexual dimorphism in the regulation of bone resorption by krox20. *J. Bone Min. Res., 34(12):2277-2286.*
43. **Senol, G. B.; Tuncer, M. K.; Nalcaci, N. et al. (2022):** Role of mandibular anatomical structures in sexual dimorphism in Turkish population: A radiomorphometric CBCT study. *J. Forensic Odonto-Stomatol.,40(1): 53-64.*
44. **Techataweewan, N.; Hefner, J. T.; Freas, L. et al. (2021):** Metric sexual dimorphism of the skull in Thailand. *Forensic Sci. Int. Rep.,4:100236.*
45. **Van der Wel, H.; Qiu, B.; Spijkervet, F. K. et al. (2023):** Morphological variation of the mandible in the orthognathic population: A morphological study using statistical shape modelling. *J. Person. Med.,13(5):854.*
46. **Verma, P.; Mahajan, P.; Puri, A. et al. (2020):** Gender determination by morphometric analysis of mandibular ramus in sriganganagar population: A digital panoramic study. Indian Journal of Dental Research, 31(3), p.444.
47. **Villanueva, E. Á.; Garmendia, A. M.; Torres, G. et al. (2017):** Gender assessment using the mandible in the Mexican population. *Span. J. Legal Med.,43(4):146-154.*

تقييم استخدام قياسات مختارة للفك السفلي في الاستعراف على الجنس باستخدام التصوير المقطعي ذو الحزمة المخروطية في عينة من المصريين.

آلاء محمود حلمي[1]، نانسي شلبي[1]، أسماء يسري عبد الله[2]،سحر محمد مصطفى[3]
[1] *قسم الطب الشرعي والسموم الإكلينيكية ، كلية الطب، جامعة دمياط، مصر.*
[2] *قسم أشعة الفم، كلية طب الأسنان، جامعة قناة السويس ، مصر.*
[3] *قسم الطب الشرعي والسموم الإكلينيكية، كلية الطب، جامعة قناة السويس ، مصر.*

الملخص العربى

المقدمة: يعتبر ازدواج الشكل الجنسي أمرا بالغ الأهمية لتحديد هوية الشخص، وتمييز الذكور عن الإناث. يمكن بسهولة تصوير الفك السفلي، وهو عظمة الجمجمة الأكثر تميزا بين الجنسين، باستخدام التصوير المقطعي المحوسب بالشعاع المخروطي وهي طريقة تصوير ثلاثية الأبعاد توفر صور عالية الدقة وتقليل الجرعة الاشعاعية المنبعثة بنسبة ٩٦٪ مقارنة بالتصوير المقطعي التقليدي. تختلف الهياكل العظمية بين السكان، وتتطلب معايير محددة للدقة. تركز هذه الدراسة على التعرف الجنسي من عظم الفك السفلي في عينة من السكان المصريين.

الهدف من الدراسة: الى تمكين تحديد الجنس عن طريق بعض قياسات الفك السفلي المختارة وتطوير نموذج لتحديد الجنس في عينة من السكان المصريين.

طريقة الدراسة: تعد هذه الدراسة تحليلية مقطعية التصميم حيث أجريت الدراسة على ٢٦٠ صورة مقطعية ذو الحزمة المخروطية المؤرشفة لمشاركين مصريين بالغين (١٣٠ ذكرًا و١٣٠ أنثى) أجروا صورة مقطعية كاملة ذي الحزمة المخروطية للجمجمة بقسم أشعة الفم بمستشفى كلية طب الأسنان بمحافظة الإسماعيلية وتراوحت أعمارهم بين ١٨ إلى ٥٠ سنة (مع اكتمال أسنانهم باستثناء ضرس العقل). تم دراسة اثنتي عشر قياسا للفك السفلي لكل صورة مؤرشفة لتحديد الفروقات بين الجنسيين.

النتائج: جميع القياسات بين الجنسين كانت ذات فروق احصائية عالية ما عدا الطول الإسقاطي لعظمة الفك كان ذو فرق احصائي، وكان متوسط جميع القياسات أعلى عند الذكور منه عند الإناث بينما كان متوسط زاوية الفك أكبر عند الإناث. بالإضافة كان لقياس العرض بين زاويتي الفك أعلى معدل دقة (الى أي مدى القياس يستطيع التنبؤ بالجنس) في التنبؤ بالجنس (٧٦.١٦٪) متبوعا بالعرض بين الناتئين اللقميين والعرض بين الناتئين الإكلينيكيين (٧٢.٧٪) ثم أقصى طول للرأد (٧١.٩٣٪). أيضا قد أظهرت النسبة الكلية للانحدار اللوجستي الثنائي للتنبؤ بشكل صحيح للجنس ٨٩.٦٪ بنسبة بلغت ٨٩.٢٪ للإناث و٩٠٪ للذكور وتم التنبؤ بجنسهم بشكل صحيح. وقد أظهرت معادلة الانحدار معدل دقة ٨٩.٢٣٪ ومعدل حساسية ٩٠٪ ومعدل نوعية ٨٨.٤٦٪.
الخلاصة: خلصت هذه الدراسة أن بعض القياسات المختارة من الفك السفلي أظهرت اختلافات ذات دلالة احصائية بين الذكور والاناث ويمكن ان تكون مفيدة لتحديد الجنس في حالات الطب الشرعي.