Validity of 3D Reconstructed Computed Tomographic Image in Using Craniometrical Measurements of the Skull for Sex Differentiation (An Iraqi Study)

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ABSTRACT

Background: The skull offers a high resistance of adverse environmental conditions over time, resulting in the greater stability of the dimorphic features as compared to other skeletal bony pieces. Sex determination of human skeletal considered an initial step in its identification. The present study is undertaken to evaluate the validity of 3D reconstructed computed tomographic images in sex differentiation by using craniometrical measurements at various parts of the skull.

Materials and Method: 3D reconstructed computed tomographic scanning of 100 Iraqi subject, (50 males and 50 females) were analyzed with their age range from20-70 years old. Craniometrical linear measurements were located and marked on both side of the 3D skull images.

Results: For the all parameters measured for sexes the mean value for Male had significantly greater than females 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 mastoid triangle was found the best variable in sex differentiation (ROC area =0.97 for unilateral skull measurements and 0.98 for bilateral measurements).while EU-EU was found to be the least one.

Conclusion: 3D reconstructed Computed tomography scanning is a good diagnostic method for analyzing the craniometrical measurements of sex determination. sex differentiation for isolated part of the skull when only the fragmentary crania is available, could be achieved and the highest accuracy in sex determination can be obtained whether part or complete skull available.

Keyword: Sex determination, 3D reconstructed computed tomography, mastoid process, sexual dimorphism. (J Bagh Coll Dentistry 2015; 27(4):72-77).

INTRODUCTION

Human identification is one of the major and most important tasks of Forensic Medicine and Dentistry. The identification of a deceased individual holds social, economic and legal repercussions. Soft tissues are commonly no longer present, due to carbonization, trauma or advanced decomposition. In those cases, forensic anthropology serves an important role in human identification [(1,2)].

Before puberty, it is virtually impossible to diagnose sex by visual examination of the human skull. After this period, as a result of hormone action, distinctive sexual characteristics become more apparent, male muscles gain mass and power, and bones begin to exhibit significant differences between sexes[(3)]. However, there is no single male skull trait that identifies a skull as being male or female. Rather, it is a set of traits that determine one sex or the other[(4,5)]. The skull is a very useful alternative to determine sex in the absence of the pelvis because of its prominent morphological differences between the two sexes, attributed to different genetic makeup as well as the acquired changes that occur during pubertal growth and it has a high resistance to adverse environmental conditions over time, resulting in the greater stability of the dimorphic features as compared to other skeletal bone pieces[(6,7)].

The highest accuracy in sex determination is achieved when the complete skeleton is available; it is often difficult to identify sex in fragmented remains, as no isolated characteristic of any particular bone can perfectly determine the sex of a skeleton. Therefore, it becomes essential then to observe the sex-specific characteristics from as many bones as possible[(8)]. In many such instances, attempts have been made for sex assessment from isolated part of the skull when only fragmentary remains are available, instead of, complete skeletons for forensic identification. Henceforth, individual parts of the skull like mastoid process, zygomatic bone, glabella region, hard palate, basal region, occipital condyle, foramen magnum or some other parts have been analyzed by few researchers for sex determination[(9-14)].

3D-CT imaging has been proven to be more accurate in determining measurements than imaging performed directly on CT slices and 2D-CT image reconstruction [(15)].

The present study was done to evaluate the validity of 3D reconstructed computed tomographic image in sex differentiation by craniometrical measurements at various parts of the skull.

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MATERIALS AND METHODS

For this prospective study, total 100 Iraqi adults, comprising of 50 males and 50 females, their ages ranging between (20-70) years old were attending to Neuroscience Hospital in Baghdad city taking CT scans for different diagnostic purpose from November 2013 to April 2014.

The total study sample divided into the following groups according to different ranges of age selected as shown in table1.

Table (1): Distribution of Participating Patients According to Age and Gender

Groups	Age rage	Male	Female
1	20-29	7	8
2	30-39	11	14
3	40-49	6	10
4	50-59	10	8
5	60-69	16	10
Total		50	50

The crania having any pathological lesions affecting the examined area, fracture, or maxillofacial deformities, as well as those subjects with signs of gross facial asymmetry.

The examination was performed on multi-slice spiral tomography scanner (The Siemens somatom definition AS), and the patients were prepared for the exposure by asking them to remove any spectacles, hearing aids, and personal jewelry such as ear rings, necklaces, and hairpins. The patient positioned supine on the CT examination table and the patient's head positioned in the head rest. The measurement was done by advanced post processing techniques using 3D reconstructed computed tomographic scans; the selected craniometrical points were identified and marked on the both sides of the skulls , the craniometrical points are: Porion (PO-superior point of the external auditory meatus), Mastoidale (MS - lower tip of the mastoid process), Asterion (AS –the meeting point of the lambdoid, occipitomastoid and parietomastoid sutures), Glabella (G-The most anterior point in the midsagittal plane, between the supraorbital tori), Inion (I-The most prominent projection of the occipital bone at the most posterioinferior point of the external occipital protuberance), Zygion (ZY-The lateral point on the zygomatic bone that marks the greatest bizygomatic diameter), Euryon (EU-The lateral point on the parietal bone that marks the greater transverse diameter of the skull), Frankfurt Horizontal plane—(FH plane): line connecting the Porion (superior point of the external auditory meatus) with the Orbitale (lowest point of bony orbit)[16,17].

The Linear Measurements between the Previous Points:

(1) Porion-mastoidal length (PO -MS): It is the straight distance between porion and mastoidal, (right and left).

(2) Asterion-Mastoidale length (AS-MS): It is the straight distance between Asterion and Mastoidale, (right and left).

(3) Perpendicular distance from mastoidal to Frankfort plane (MS-FH): It is the length of the mastoid is measured from a point on the Frankfort plane vertically downwards to the tip of the mastoid process

(4) Glabella-Inion (G-I): The distance between the most anterior points on frontal midline to the most prominent projection of occipital bone.

(5) Zygion- Zygion (ZY-ZY): Greatest bizagomatic.

(6) Euryon- Euryon (EU-EU): Lateral point on the parietal bone which make the greatest transverse diameter of the skull [16, 17].

A triangle was designed at mastoid process region from the 2 linear measurements (PO-MS) and (AS-MS) with the third line drawn between (PO) and (AS) as shown in figure 1, all linear measurements were made on both sides of the skull for each CT image and the area of demarcated triangle for right and left side of the skull was calculated using (Heron's formula) as the following:

S= the sum of three linear measurements

Heron's formula (H), with sides of triangle a, b&c

$H= \sqrt{(s(s-a)(s-b)(s-c))}$

$S= ((a+b+c))/2$

The total triangular area was calculated by the sum of these two measurements. All measurements were made with cm unit[18] figure 1 3D reconstructed frontal view of female CT image of skull showing mastoid triangle area.

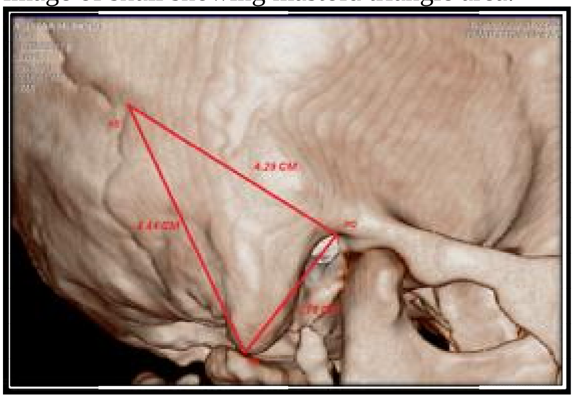

Figure (1): 3D Reconstructed Frontal View of Female CT Image of Skull Showing Mastoid Triangle Area.

Statistical Analysis:

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).

RESULTS

The presented study was stratified into 2 parts; the first part used the measurements of one side of the skull as a sampling unit. The justification for such strategy is the absence of statistically significant differences between right and left sides of linear craniometrical measurements. In addition a researcher in forensic medicine may be confronted with a situation in which one side of the skull is available for evaluation when gender discrimination is required, this part called “unilateral craniometrical measurements analysis”

The second part is called “bilateral craniometrical measurements analysis”. The assumption in this part was the availability of both sides of the skull intact. Since no important differences existence between right and left side measurements one can use the mean of both right and left sides as representative for both sides’ measurements. Some of the measurements had no right and left side for example (ZY-ZY, EU-EU, and total mastoid area) therefore they are single measurements representing the skull. For all linear measurements, no statistically differences is observed between right and left side of the skull.

Unilateral and Bilateral Craniometrical Measurements for the Skull Stratified by Gender:

The mean values and standard deviation for the five selected linear measurements of the anatomical landmarks in both male and females showed a highly significant differences between male and female (p<0.001). All the measurements demonstrated in tables (2, 3).

Table (2): The Gender Differences in Mean of Unilateral Measurements

variables	Gender		Differences in mean	Gender dimorphism	Cohen’s d	P
	Female N(100)	Male N(100)				
	Mean					
(MSFH)	2.65	3.11	0.46	17.4	1.44	<0.001
(GI)	17.09	18.26	1.17	6.8	1.67	<0.001
(PO-MS)	2.8	3.3	0.50	17.9	1.79	<0.001
(AS-MS)	4.6	5.33	0.73	15.9	1.97	<0.001
Mastoid triangle	5.99	8.05	2.06	34.4	2.71	<0.001

Table (3): The Gender Differences in Mean of by Bilateral Measurements

variables	Gender		Differences in mean	Gender dimorphism	Cohen’s d	P
	Female N(50)	Male N(50)				
	mean					
MSFH	2.65	3.11	0.46	17.4	1.48	<0.001
(GI)	17.09	18.27	1.18	6.9	1.69	<0.001
(PO-MS)	2.8	3.3	0.50	17.9	1.92	<0.001
(AS-MS)	4.6	5.33	0.73	15.9	2.28	<0.001
Mastoid triangle	11.97	16.09	4.12	34.4	2.99	<0.001
(ZY-ZY)	12.2	13.17	0.97	8	2.06	<0.001
(EU-EU)	13.66	14.2	0.54	4	1.13	<0.001

The Validity of Unilateral and Bilateral Selected Measurements in Predicting Male Sex:

Receiver operating characteristic analysis (ROC) was used to assess the validity of different tested measurements in predicting male sex differentiating from female. Among the computed tomographic measurements, as shown in table (4) area of mastoid triangle was associated with the highest validity in the context of gender identification (Roc area =0.972 cm),(AS-MS) ranked second in its validity when used as a test for differentiating male from female. (ROC area=0.925cm), followed by (PO-MS), (ROC area =0.916 cm). (GI) and (MSFH) were the least valid in predicting a male gender (ROC area =0.879 and 0.852 cm respectively) although their validity is still height. While for bilateral selected parameters, as shown in table (4), area of mastoid triangle was associated with the highest validity in the context of gender identification (Roc area =0.985 cm). (AS-MS) and (ZY-ZY) ranked second in there's validity when used as a test for differentiating male from female (ROC area=0.947cm and 0.924) respectively followed by (PO-MS), (ROC area =0.919 cm). Followed by (GI) (ROC=.0883), (MSFH) and (EU-EU) were the least valid in predicting a male gender (ROC area =0.867 and 0.774 cm respectively) although their validity is still height.

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

Table (4): ROC Area for Selected Parameters when Used as Test to Predict Male Gender Differentiating them From Female.

	Variables	ROC	P
Unilateral measurements	(MSFH)	0.852	<0.001
	(G-I)	0.879	<0.001
	(PO-MS)	0.916	<0.001
	(AS-MS)	0.925	<0.001
	Area of mastoid triangle	0.972	<0.001
bilateral measurements	(MSFH)	0.867	<0.001
	(G-I)	0.833	<0.001
	(PO-MS)	0.919	<0.001
	(AS-MS)	0.947	<0.001
	Area of mastoid triangle	0.985	<0.001
	(ZY-ZY)	0.924	<0.001
	(EU-EU)	0.774	<0.001

DISCUSSION

Human identification consists of a series of steps to individualize individuals and establish their identity [14]. In this respect, forensic anthropology plays an important role in reconstructing the biological profile, taking into consideration its four main components, ancestry, age, stature and sex [19, 20]. These factors can be determinants in a unique subject or a large number of unidentified corpses and skeletal remains. Such as the case of mass disasters, where correct sex identification reduces the pool of possible missing persons to just 50% of the population [21,22].

There are clear limitations in using simple linear measurements to describe the morphology of a complex three-dimensional object as the cranium. But it has used extensively as it is less problematic in statistical analysis[23]. Spiral CT has brought new technology with faster scan times, allowing an improvement in 3D reconstruction with better detail and visualization of anatomical structures when compared with conventional CT. The value of computer graphics in manipulative craniofacial images and the importance of 3DCT images in quantitative and qualitative analysis, a process which provides more information about the craniofacial complex is Cleary recognized. Computer graphics technology and current workstations allow better visualization and segmentation that enable assessment of volume, area, linear and angular measurements [24,25].

The current study relied on 3D reconstructed image based on spiral CT. There is No Iraqi literature on the use of 3D reconstructed image of cranium in sex determination was retrieved, making the current work the first of its kind to be explored on Iraqi subjects.

The variability in the dimensions of the skulls can be explained by reason of that the cranial size determination is multifactorial and influenced by epigenetics factors of high variability among populations, geographical regions, socioeconomic strata, and so on[26]. Craniofacial growth like mastoid region, zygomatic process and the ridges of occipital bone are influenced by nutrition, environment and genetic factors [27].

Dayal and Bidoms[28] stated that sex estimation can be accomplished using either morphological or metric methodologies. Statistical methods utilizing metric traits are becoming more popular, with most of bones having been subjected to linear discriminant classification.

In the current study, the mean of both unilateral and bilateral craniometrical linear measurements for males were significantly higher than that for female .The gender effect on these tested linear measurements ranged from strong to very strong effect when evaluated by Cohen's for effect size, this may be attributed to the fact that females reach skeletal maturity two years earlier than males allowing for longer growth period in males, and also to genetic and hormonal factors[29-32].

Among all the measurements used in the current study, for both unilateral and bilateral craniometrical linear measurements, the mastoid area was the most important in gender dimorphism, being associated with the highest effect size estimated by Cohen's. Sukumar et, al.,[33] adopt area of mastoid triangle in sex discrimination in their study where done on a sample of 30 adults males and 30 adult female lining subjects using 3D reconstructed image of spiral CT, the found of mastoid triangle area was significantly in males compared to females.

The Mastoid region is one of the slowest and later growing regions of cranium and such regions show higher degree of sexual dimorphism in adulthood. Moreover, the differences in size of the mastoid process between sexes could be attributed to the variable duration of growth in males and females, along with relatively greater development of the mastoid process in males in response to stronger muscle action of the sternocleidomastoideus, splenius capitis (the posterior belly of the digastric muscle), and longissimus capitis. Also, these muscles are attached over a relatively larger area in males[7, 34].

For (ZY-ZY) we noticed that the mean values of male significantly higher than for females in both unilateral and bi, with a very strong effect of (Cohen's d), followed the total mastoid area, while the (EU-EU) had the lowest value of (Cohen's d) among other variable but still strong. Bizygomatic width reflects growth at maxilla and orbital region in lateral direction. Extended growth in male causes the malars to be large and the zygomatic arch to be displaced more laterally than the corresponding structures in the female Thus males have definitely larger Bizygomatic width, thus providing robustness in male facial skeleton [7], while For (MSFH) and (GI) we noticed that the mean values of male was significantly higher than for females, with a very strong effect of (Cohen's d) in both unilateral and bilateral craniometrical linear measurements,

The Validity of Selected Measurements in Predicting Male Sex:

The use of ROC curve to find out an optimal cut off point for discriminant of sex (for classification of male and female) in each variable and comparing the performance of each variable using its (AUC) is helpful in determination of sex specially in classes of fragmentary crania (unilateral measurements)[8].

From our finding, we notice that the use of bilateral measurements is associated with a very small increase in validity of gender discrimination. The increase in ROC area observe when substituting a unilateral for bilateral measurements is almost negligible not exceeding 1%.

The mastoid triangle was defined by 3sides, namely PO-MS and MS-AS, and PO-AS. The PO-MS and AS-MS were associated with the highest validity in sex determination among the 3 sides of mastoid triangle (ROC area =0.919 and 0.947 respectively) this finding was agreed with Sukumar et, al.,[33] were use the Heron's formula. It was found that measuring the mastoid area using Heron's formula improved the prediction accuracy of gender to an almost perfect test (ROC area =0.97 for unilateral skull measurements and 0.98 for bilateral method).

Similar finding reporting by Saini et, al.,[35] studied 138 North Indian adult crania and they found that (PO-MS) and (AS-MS) were the two mastoid triangle sides associated with the most effective single measurement with highest validity (ROC area of 0.787 and 0.798 respectively). (ZY-ZY) ranked a good test in there validity when used as a test for differentiating male from female with accuracy of 86%. Followed by (GI) and (MSFH) with 84% and 80% accuracy, while the (EU-EU) ranked as fair test and the least valid in predicting a male gender with71% accuracy.

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