# Sex Variations by Linear Measurements of Palatal Bones and Skull Base Using 3D Reconstructed Computed Tomographic Scan among Iraqi Sample

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## ABSTRACT

**Background:** The skull base and the hard palate contain many anatomical features that make them rich in information which are useful in sex differentiation; in addition to that they have the ability to resist the hardest environmental conditions that support them in making sex differentiation. Three dimensional computed tomographic techniques has important role in differentiation between sex since it offers images with very accurate data and details of all anatomical structures with high resolution. This study was made to study sex variations among Iraqi sample by craniometric linear measurements of the hard palate and the skull base using 3D reconstructed Computed Tomographic scan.

**Materials and methods:** This study composed of 100 Iraqi subjects (50 male and 50 female) aged between 20-59 years. The sample collected from patients attending Al-Shaheed Ghazi hospital in Baghdad city to for spiral CT scanner. The craniometrical linear measurements of the hard palate and the skull base in this study were including: Maxillo-Alveolar Breadth, Maxillo-Alveolar Length, the distance between incisive foramen and greater palatine foramen (right and left), the distance between the incisor foramen and B point (the median point located at the anterior area of the magnum foramen), the distance between the incisor foramen and the anterior root of the mastoid notch on both sides (right and left), Maxillo-Alveolar Index and size of Palate. All these measurements were done by (mm) unit.

**Results**: The statistical analysis of linear measurements of the hard palate and the skull base showed that the mean values of all measurements were significantly higher in males than females except for Maxillo-Alveolar Index was not significant and also showed that the size of the palate was the best indicator for sex variation and making the diagnosis of male with accuracy 93.3%. The age had none significant effect on these measurements.

**Conclusion:** Three dimensional Computed Tomographic scanners is the best diagnostic tool for sex variation by the craniometrical linear measurements for the anatomical landmarks points of the hard palate and the skull base.

**Key words:** Sex variations, 3D reconstructed computed tomography, palatal bones, skull base. **(J Bagh Coll Dentistry 2016; 28(4):82-88)**

## INTRODUCTION

Sexual dimorphism has been defined as the systematic variation in form between subjects of different sex in the same species. In spite of any human being can distinguish the variations by appearance, but it's stated that human beings have comparatively lower level of dimorphism when compared to other species.. Some of the other factors influencing the dimorphism among humans can be height, weight, hair, face, muscles (more among men than women) [(1)].

The identification of an individual through sex determination is very important since many skeletal features vary by sex [(2)].

Although the sex is best evaluated from the pelvis but the skull also provides a number of very good sex indicators and is usually better preserved [(3)].

Human skulls of adult individuals are consisting from a set of bones which have more information that can be used in sexual dimorphism [(4)].

The skulls of males had significantly, heavier, thicker and larger bones in addition to having greater cranial capacity, whereas the skull of females tend to be smaller and smoother [(4,5)].

The determination of sex can be made from isolated bony pieces such as the frontal, temporal bone, in orbit and in jaw, by calculating of general cranial dimensions and measuring the angles among craniometrics points [(6,7)].

When the sexual dimorphism of individual bones of the skeleton had been studied, these bones should be the most resistant and protected from damage. This will help in determination of sex in a higher accuracy determination. Bony and dental structures of the palate often are preserved even in the face of serious bodily damage at or following death [(2)].

Male proportions of the skull tend to be larger than their female, so the establishment of the sex differentiation parameter, based on anatomic points present when the skull base is visualized, since the male palate is larger than the female's [(8, 9)].

The cranial base is considered to be the most durable region of the skull and is known to be the best sexually dimorphic [(10,11)].

Computed Tomographic scanner is a machine that composed from an X-ray tube that

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responsible for emission of a finely collimated, fan-shaped x-ray beam directed through a patient to a series of scintillationdetectors or ionization chambers and thesedetectors measure the number of photons that exitthe patient. This information can be used to produce a cross-sectional image of the patient [12,13]. 3D-CT imaging has been considered to be more efficient and accurate in determining the linear measurements between anatomical points [14,15].

## MATERIALS AND METHODS

A prospective study composed of 100 Iraqi subjects (50 male and 50 female) aged between 20-59 years were analyzed. The sample collected from patients attending Al-Shaheed Ghazi hospital in Baghdad city to have spiral CT of the brain and paranasal sinus for different diagnostic purpose from November 2014 to April 2015.

The study sample divided into four groups as shown in table 1.

**Table 1: The distributions of sample according to age and sex**

| Groups | Age range | Male | Female |
|---|---|---|---|
| **A** | 20-29 | 15 | 15 |
| **B** | 30-39 | 15 | 15 |
| **C** | 40-49 | 14 | 14 |
| **D** | 50-59 | 6 | 6 |
| **Total** | | 50 | 50 |

Any subjects with physical damage, apparent deformity, abnormalities and severe systemic diseases that affect bone metabolism are excluded, also any subjects having missing maxillary central incisors and maxillary second molars are excluded from this study.

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

Patients were asked to remove all accessories like: ear rings, necklaces, hairpins and hearing aids before the exposure, then patient asked to lay down in supine position on the CT examination table and his head positioned on head set.

Three dimensional reconstructed computed tomographic images of palatal bones and skull base are analyzed in linear measurements between bony anatomical landmarks and all these linear measurements were done on axial section by (mm) unit.

The bony landmarks points were including [16, 17]:-

1. Alveolon A: The point locates where the mid-sagittal plane crosses a straight line drawn from the posterior margins of the alveolar processes of the maxilla.
2. Prosthion P: The point locates on the most anterior of the alveolar border of the maxilla in the mid-sagittal plane between the central incisors.
3. Incisor point (incisive foramen) IF: The central point located in the hard palate between the maxillary central incisors from the lingual borders of the alveolar processes.
4. Greater palatine foramen GPF: is the point locates at the palatine bones from the posterolateral region and there are two foramen (left and right) each one locates in palatine bone.
5. Basion B: The median point locates at the inferior surface of the skull at the most anterior border of the magnum foramen.
6.Mastoid point MP: The point locates on anterior root of mastoid notch; which is on the medial side of the mastoid process

The linear measurements between landmarks points:

1. Maxillo-Alveolar Breadth (MAB): The maximum breadth of the maxilla across thealveolar borders that measured on the lateral surfaces at the area of the maxillary second molars as shown in fig (1)
2. Maxillo-Alveolar Length (MAL): The direct distance from prosthion to alveolon. Line is measured from prosthion point to the middle of the straight line drawn across the posterior borders of the alveolar processes of the two sides (alveolon), in the mid-sagittal as shown in fig (2).
3. Incisive foramen - greater palatine foramen (IF-GPF): The distance between incisive foramen and greater palatine foramen (right and left)as shown in fig (3).
4. Incisive Foramen-Basion (IF-B): Distance between the incisive foramen and the Basion point the median point located at the anterior area of the magnum foramen) as shown in fig (4).
5. Incisive Foramen- mastoid Notch (IF-MN): Distance between the incisive foramen and the anterior root of the mastoid notch on both sides (right and left) as shown in fig (5).
6. Maxillo-Alveolar Index MAI: resulted from division of maxilla-alveolar breadth on maxilla-alveolar length then multiply by 100[18].
Maxilo-Alveolar Index= MAB/ MAL * 100
7. Size of Palate: resulted from multiplication of Maxillo-Alveolar Breadth and Maxillo-Alveolar Length then divided on 100[19].
Size of palate= MAL * MAB/100

**Statistical Analyses**

Data were translated into a computerized database structure. An expert statistical advice was sought for. Statistical analyses were computer assisted using SPSS version 21 (Statistical Package for Social Sciences). The linear measurements of the palatals bones and the base of the skull were described by mean, SD (standard deviation) and SE (standard error), and the parametric statistical tests of significance were used.

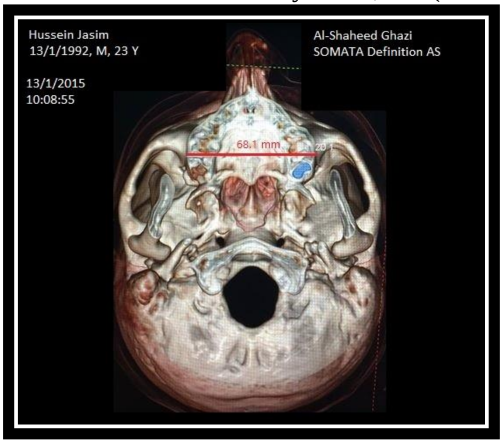


**Figure 1: 3D reconstructed axial view of CT image showing of Maxillo-Alveolar Breadth.**

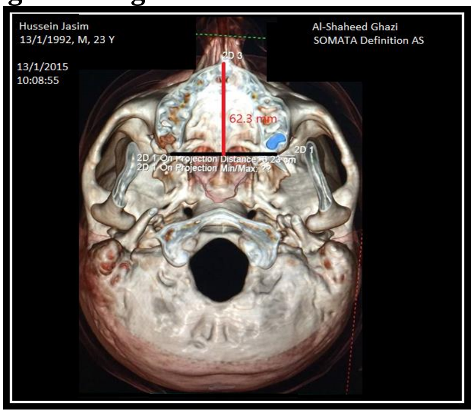


**Figure 2: 3D reconstructed axial view of CT image showing of Maxillo-Alveolar Length**

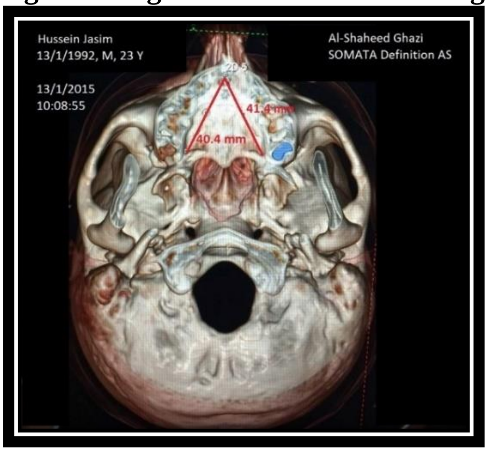


**Figure 3: 3D reconstructed axial view of CT image showing of Incisive foramen - greater palatine foramen (right and left)**


**Figure 4: 3D reconstructed axial view of CT image showing of Incisive-Basion line**

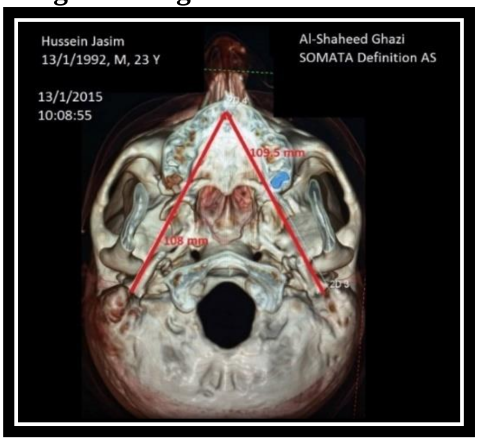


**Figure 5: 3D reconstructed axial view of CT image showing of Incisive- mastoid line (right and left)**

# RESULTS

**The sex differences in means of linear measurements between anatomical landmarks of hard palate and skull base:**

The mean values of all the linear measurements of the palatals bones and the base of the skull were higher among males than that among females and were statically significant p <0.001 excepted for Maxillo-Alveolar Index that was non-significant p = 0.17.

All the linear measurements have strong effect ofsexual differentiation (Cohen's d) excepted for Maxillo-Alveolar Index weak effect as shown in tables

**Table 2: The gender difference in mean of Maxillo-Alveolar Breadth**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (57.6 - 66.9) | (62.9 - 72.6) | 4.7 | 2.18 | 0.001 | 7.6 |
| **Mean** | 62 | 66.7 | | | | |
| **SD** | 2.3 | 2 | | | | |
| **SE** | 0.32 | 0.28 | | | | |
| **N** | 50 | 50 | | | | |

**Table 3: The gender difference in mean of Maxillo-Alveolar Length**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (47.7 - 57.9) | (53.2 - 62.7) | 4.7 | 1.17 | 0.001 | 8.9 |
| **Mean** | 52.8 | 57.5 | | | | |
| **SD** | 2.8 | 2.7 | | | | |
| **SE** | 0.4 | 0.38 | | | | |
| **N** | 50 | 50 | | | | |

**Table 4: The gender difference in mean of Incisive Foramen-Basion**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (76.7 - 90.9) | (84 - 95.3) | 5.4 | 2.1 | 0.001 | 6.4 |
| **Mean** | 84.2 | 89.6 | | | | |
| **SD** | 2.9 | 2.2 | | | | |
| **SE** | 0.42 | 0.32 | | | | |
| **N** | 50 | 50 | | | | |

**Table 5: The gender difference in mean of size of palate**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (28.1 – 37.4) | (34.5 – 45.5) | 5.7 | 2.24 | 0.001 | 17.4 |
| **Mean** | 32.7 | 38.4 | | | | |
| **SD** | 2.6 | 2.5 | | | | |
| **SE** | 0.37 | 0.36 | | | | |
| **N** | 50 | 50 | | | | |

**Table 6: The gender difference in mean of Maxillo-Alveolar Index**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (106.3 - 128.5) | (103.1 - 124.4) | -1.4 | -0.27 | 0.17 (NS) | -1.2 |
| **Mean** | 117.6 | 116.2 | | | | |
| **SD** | 5.3 | 4.9 | | | | |
| **SE** | 0.74 | 0.69 | | | | |
| **N** | 50 | 50 | | | | |

**Table 7: The gender difference in mean of Incisive Foramen- Greater Palatine Foramen**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (36.7 - 43.9) | (39.3 - 49.7) | 2.4 | 1.26 | 0.001 | 5.9 |
| **Mean** | 41 | 43.4 | | | | |
| **SD** | 1.8 | 2 | | | | |
| **SE** | 0.25 | 0.28 | | | | |
| **N** | 50 | 50 | | | | |

**Table 8: The gender difference in mean of Incisive Foramen- Mastoid Notch**

| | Genders | | Difference in means | Cohen's d | p-value | Sexual dimorphism |
|---|---|---|---|---|---|---|
| | Females | Males | | | | |
| **Range** | (95.3 - 109.3) | (103.9 - 117.9) | 5.4 | 1.72 | 0.001 | 5.6 |
| **Mean** | 103.6 | 109.2 | | | | |
| **SD** | 3.3 | 3.2 | | | | |
| **SE** | 0.46 | 0.45 | | | | |
| **N** | 50 | 50 | | | | |

**Multiple logistic regression model for the probability of being male**

The multiple logistic regression model was used to predict the probability of being a male gender based on selected skull measurements. A forward step slection algorithm was used to select only those measurements that significantly contributed to the predictive power of the logistic model.

Only 2 variables, namely “Maxillo-Alveolar Breadth” and “Incisive Foramen-Basion length” were enough to provide an overall accuracy of 94% for gender prediction, for each one mm increase in “Maxillo-Alveolar Breadth” the probability of being a male gender is increased by 4.9 times after adjusting (controlling) for the confounding effect of “Incisive Foramen-Basion length” measurement.

Similarly for each one mm increase in “Incisive Foramen-Basion length” the probability of being a male gender is increased by 3.5 times after adjusting (controlling) for the confounding effect of “Maxillo-Alveolar Breadth”, as shown in table 10.

**Table 10: Multiple logistic regression model for the probability of being male (forward selection algorithm)**

| | Partial OR | 95% OR | P |
|---|---|---|---|
| **Maxillo-Alveolar Breadth** | 4.9 | 1.9-12.5 | 0.001 |
| **Incisive Foramen-Basion** | 3.5 | 1.6-7.8 | 0.002 |

Overall predictive accuracy = 94%
P (Model) <0.001
Power=-212.596 + (1.588 * MAB) + (1.261 * IF_B)
Calculated probability for being a male=e (power)/ [1+e (power)]

**Discriminant analysis results of sex variation by linear measurements of palatal bones and skull base:**

All the linear measurements of the palatal bones and the skull base were used together in discriminant model to differentiate between females and males. The resulting equation was statistically significant (P (Model) <0.001) with overall prediction accuracy 93% and Wilks' Lambda=0.365. The resulting discriminant score (D score) from using the equation could be used in predicting gender If D>0 male is expected, while a negative value indicates a female gender. The more extreme is the value of discriminant score (D) in a positive direction the more probable is a prediction of male gender. In this discriminant model Maxillo-Alveolar Breadth was the best discriminating variable then Incisive Foramen-Basion.

**The validity of selected linear measurements in predicting male sex:**

Receiver operating characteristic analysis (ROC) was used to evaluate the validity of various tested linear measurements in predicting male sex variation from female. As shown in table (3.15) and among the computed tomographic linear measurements it was found that size of palate was the first value with the highest validity in predicting male sex with (ROC area = 0.955)as shown in table 11.

**Table 11: ROC area for selected linear measurements in predicting male sex**

| Variables | ROC area | P |
|---|---|---|
| **Size of Palate** | 0.955 | <0.001 |
| **Maxillo-Alveolar Breadth** | 0.951 | <0.001 |
| **Incisive Foramen-Basion** | 0.949 | <0.001 |
| **Incisive Foramen- Mastoid Notch** | 0.899 | <0.001 |
| **Maxillo-Alveolar Length** | 0.889 | <0.001 |
| **Incisive Foramen-GPF** | 0.834 | <0.001 |
| **Maxillo-Alveolar Index** | 0.586 | 0.14[NS] |

There was no statistical significance difference in the mean values of the all selected linear measurements between all age groups, so there was no effect of age on these measurements for males and females

## DISCUSSION

Sexually dimorphic characters of the skeleton having a fundamental importance in constructing a biological profile from unidentified human's bony remains, thus the skull exhibiting prominent sexually dimorphic features that are reliable indicators of sex evaluation in cases where a complete skeleton have been available for differentiation [20,21].

The palate is considered to be an essential region of the skull and composed from two horizontal plates of palatal bone and two palatal processes of maxilla, all of which are connected together by a suture [23,24], thus the palate is a significant indicator for the sex variation [22,23].

Multi slices computed tomography represents the latest revolution in CT technology and breakthrough in forensic medicine. It has transformed CT from a transaxial cross-sectional technique (conventional CT) into a truly three-dimensional imaging modality (3D-CT) with a different clinical applications mainly in musculoskeletal imaging [24], in addition to that 3D-CT allows studying of the anatomic structures and macroscopic content of the body while preserving the integrity of the human remains and also the images are very similar and nearest to the original images of the bone shape that require to be measured, in any axis and in rapid manner [25].

Since 3D CT images have importance role in quantitative and qualitative analysis the present study 3D Reconstructed Computed Tomography was used to assess sex variation through selected measurements calculated between anatomical points of hard palate and between hard palate and skull base for Iraqi population, thus this process offers better information about craniofacial complex to be recognized and computer workstations permit better visualization, details and segmentation that allow evaluation of volume, area, angular and linear measurements that can be obtained by calipers, simple rulers and other specific tools [26,27].

In the current study, the means of the linear measurements were significantly higher in males than that in females and it was found that among all these measurements the size of palate had the strongest effect in sex variation (Cohen's d) and the sexual dimorphism was the highest among all measurements.

Sumati et al. [2] found that the size of palate is the best predictor for sex determination among the hard palate variables and the size of palate alone correctly classified 70.0% of the cases which is equivalent to the correct classification rate of all hard palate variables.

Larnach and Freedman [28] stated that the size of palate among the seven characters of the skulls showed maximum contrast between the sexes, and concluded that the value of size of palate is important for sex determination.

For Maxillo-Alveolar Breadth and Maxillo-Alveolar Length the mean values were significantly higher in males than that for females and both of them had strong effect of Cohen's d, this had agreement with results of other studies [29,30].

The mean value for Maxilla-Alveolar Index was not statistically significant, although it was higher in females than males but the difference in means was very little, so this index was not used in sex determination, this result come in accordance with result of study done by Patel and Manmohan [31].

In the present study, the multiple logistic regression model was used to predict the probability of being a male gender based on selected hard palate and skull linear measurements, thus a forward step selection algorithm was used to select only those measurements that significantly contributed to the predictive power of the logistic model and the model selected between all these measurements only two variables, namely “Maxillo-Alveolar Breadth” and “Incisive Foramen-Basion length” were enough to provide an overall accuracy of 94% for sex prediction .

Laisse et al. [32] made study on hard palate and used logistic regression models for sex determination, that select Incisive Foramen-Basion as the highest expression of sexual dimorphism with an accuracy rate of 63%.

Sumati et al. [2] used multiple logistic regressions in their study of hard palate for sex identification and found that the palate breadth was the best sex predictor with accuracy 66.7%.

The results of the present study showed that the hard palate and in relation to skull base exhibits good anatomic variations between sexes thus all the linear measurements of the palatal bones and the skull base were used together in discriminant model to differentiate between females and males and the resulting equation was statistically significant with overall prediction accuracy 93% and Wilks' Lambda=0.365. In this discriminant model Maxillo-Alveolar Breadth was the best discriminating variable then Incisive Foramen-Basion.

Maria et al. [33] made study about the role of the shape and the size of the hard palate and the cranial base in sex determination and used discriminant function analysis in the study with accuracy 90.4% for cranial base, and 74.8% for palate and Wilk’s lambda = 0.842

Receiver operating characteristic analysis (ROC) was used to evaluate the validity of various tested linear measurements in predicting male sex variation from female as it was shown. And among the computed tomographic linear measurements it was found that the size of palate was the first value with the highest validity in predicting male sex while Maxillo-Alveolar

Index was the last value and it had no significant role in sex determination.

Variation in the percentage of accuracy between the two studies could be related to different race and different sample size, also craniofacial growth may be influenced by environment, nutrition and genetic factors [34].

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