PALATINE BONE ANALYSIS FOR SEXING HUMAN CRANIA: A COMPUTED TOMOGRAPHY STUDY OF 500 EGYPTIANS FROM MINIA GOVERNORATE.

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ABSTRACT:

Introduction & objectives: The preliminary phase in the forensic investigation is sex determination. The hard palate attained significance in sexing cranium due to its nature, which is resistant and secluded location, especially in cases of burns and explosions, so the objective of this study is the analysis of palatine MDCT imaging for sexual dimorphism in a sample from the Egyptian population using the following measurements TPVD-M2, O-SNP, PWPA, and AWPA.

Results: The results showed that there is a slight increase in measurements of males than females, but only PWPA and O-SNP had significant differences between both. Single regression analysis showed a low accuracy of O-SNP and PWPA (55 % & 58 %) respectively, using multiple discriminant function analysis didn't increase the accuracy as it reported an accuracy of 55.4%. ROC curve analysis for male sex prediction reported an accuracy of 58% with O-SNP and 59.4% with PAWA.

Conclusion: In conclusion, palatine measurements obtained from CT images have a low value in sex determination in an Egyptian sample from the Minia governorate.

Keywords: sex determination, anthropology, palate, MDCT.

INTRODUCTION

The hard palate is the bony part that separates both cavities; oral and nasal; created by the fusion of the palatine processes of maxillae bone and the transverse plates of palatine bones connected by a suture called cruciform **(Alves et al., 2019)**. In human remains, the hard palate is usually well preserved since the structures of the cranium and face have the advantage of being hard tissue, which cannot be destructed easily to an excellent extent **(Adel et al., 2019).** It too has a few and distinctive anatomical focuses which help in conducting basic and repeatable estimations **(Tomaszewska et al., 2014).**

Sex determination of unknown remains is considered as the primary and the most vital step in forensic investigations with the pelvis and the cranium being the foremost reliable sex determinants as it could exclude half of the population **(Sweilum et al., 2017)**. This process becomes challenging in cases of burns and

explosions or when the bodies were exposed to various environmental conditions for a time which resulted in the distortion of the soft tissue **(Tomaszewska et al., 2014)**, moreover sexing intact skeleton is easier and more accurate than fragmented or part of a bone **(Saleh et al., 2019)**.

Multi-Detector Computerized Tomography (MDCT) has picked up significantly over the final decade as a noninvasive apparatus for performing legal examinations like sex, stature, and age estimation as well as injuries analysis. MDCT imaging moreover spares time and exertion since it doesn't require time-consuming maceration of the deceased, is nondestructive, and empowers examination of enormous datasets from variable populations within a brief time **(Clemente et al., 2017).**

Different populations have variable anatomical features which attributed to different sexual characteristics, therefore it is necessary to investigate each population-related standard **(Elgazzar et al., 2016)**, up to our knowledge there are not any similar studies investigated using MDCT imaging of palate in sex determination in Egyptian population, so this study is aimed toward analysis of palatine MDCT imaging for sexual dimorphism in a sample from Egyptian population.

PATIENTS & METHODS:

The following work was done at the radiology department, the **i**nformation was analyzed for 500 patients (250 male and 250 female), with ages ranging from 18 to 73 years from May 2019 to May 2020. All members were subjected to cranial MDCT due to various causes. Any patient with pathological or traumatic defect inside the hard palate and non - Egyptians were excluded from this study.

Cranial MDCT imaging was done using PHILIPS 16 multi-slice computed tomography (Flex, Healthcare, Netherland), examination convention utilizing a 64- 0.5 mm area collimation scanner with 400 ms/rotation speed, box range of 450 - 500, the thickness of section is 0.80 mm, time of section is 1.60 seconds, standard pitch figure is 0.641, 0.5 mm as reconstruction interval. and all time of exposure is 6.949 seconds. Every scan was gotten with a tube voltage of 120 kV and 399 mAs. Axial cuts were taken on the brain and cranium, also, coronal and sagittal pictures were created and used to get the consequent measures according to **(Tomaszewska et al., 2014):**

-TPVD-M2: is the total depth vault of the palate at the extent of the second molar (M2) (figure 1).

-AWPA: is the anterior breadth of the arch of the palate at the extent of 1st premolar (PM1) (figure 2).

-PWPA: is the posterior breadth of the arch of the palate at the extent of M2 (figure 2).

-O-SNP: the Orale-spina nasalis posterior distance O: Orale, SNP: spina nasalis posterior (figure 3).

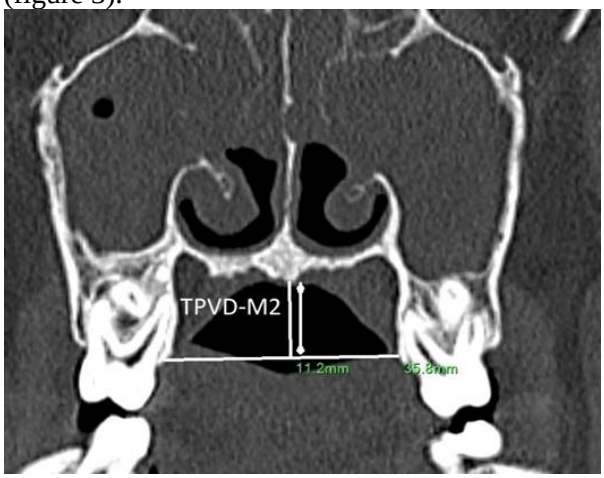

Figure (1): TPVD-M2 distance, Total palatal vault depth at the level of the second Molar.

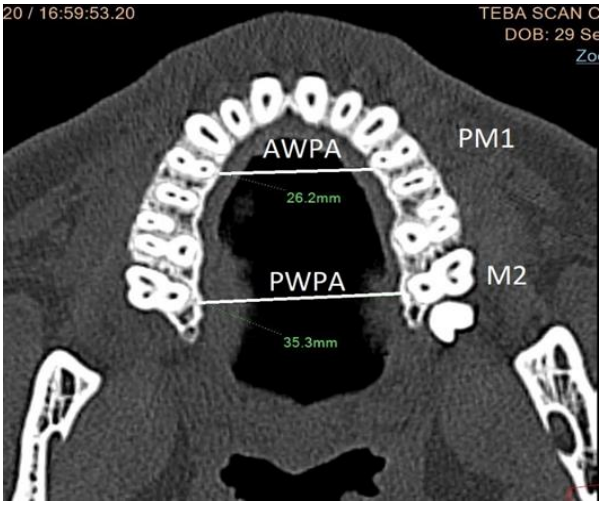

Figure (2): AWPA: anterior width of the palatal arch at the level of 1st premolar PM1. PWPA: posterior width of the palatal arch at the level of 2nd molar M2.

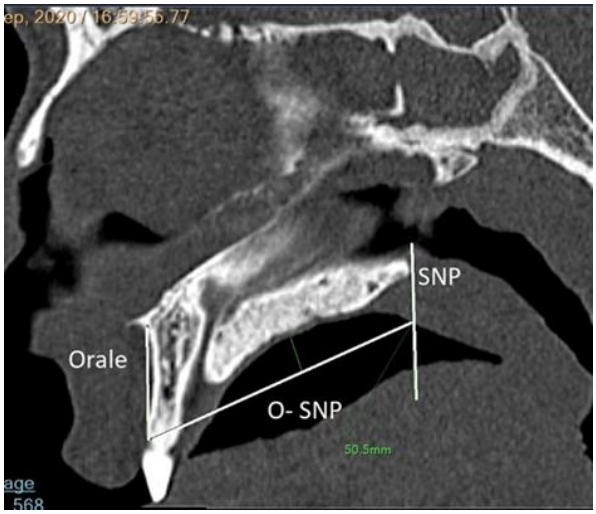

Figure (3): O-SNP: the Orale-spina nasalis; posterior distance Orale SNP: spina nasalis posterior.

The measures of 20 MDCT images selected randomly were repeated by both second and the third co-author.

The obtained data were entered for statistical analysis by Statistical Package for Social Sciences software program (SPSS 24). Descriptive statistics; mean, standard deviation, and range; were done for the numerical data. Independent-samples t-test was used for parametric quantitative data analysis in-between both groups.

Both intraobserver and interobserver errors were assessed by the relative technical error of measurement (rTEM) and coefficient of reliability (R). rTEM ranges are accepted for intraobserver errors if <1.5% in beginner

anthropometrist and if <2.0% for interobserver errors. R-value is that the proportion of the variance between subjects that is free from measures errors, if > 0.75, it is precise.

Simple and multiple discriminant functional analyses were done to extract the equations for predicting the sex by palatal measures and their accuracy. Receiver operating characteristic; (ROC) curves; were administered to point out the cutoff point, the area under the curve (AUC), sensitivity, specificity, positive predictive value, negative predictive value, and the accuracy of the used palatal measures in male prediction.

Ethical considerations:

This study was done after the endorsement of the local medical ethical committee (No. 700:12/2020) and written consent was taken from the patients.

RESULTS:

The mean age of included cases was (36.1± 12.4) years. The estimations appeared slight increase in males than females except TPVD with a significant difference in both PWPA and O-SNP as described in table (1).

The Intraobserver precisions of palatal measures were rTEM (1.22%–1.03%) which less than 1.5% and R (0.989–0.998) which is more than 0.95, and interobserver precisions were rTEM (1.86%–1.53%) which less than 2.0%, and R (0.975–0.997) which is more than 0.95 as shown in Table 2.

Table (1): -Independent samples t test of Palatal Measurements in Males (n = 250 Cases) and Females (n = 250 Cases).

		Male	**Female**	**P**
		N=250	**N=250**	**value**
O-SNP	**Range**	(2.6-5.9)	(2.9-5.5)	0.001*
	Mean ± SD	4.3±0.8	4±0.7	
AWPA	**Range**	(2-5.4)	(2-4)	0.366
	Mean ± SD	2.8±0.5	2.9±0.4	
PWPA	**Range**	(3-4.6)	(3.1-4.5)	0.002*
	Mean ± SD	3.7±0.4	3.6±0.3	
TPVD-M2	**Range**	(0.8-2)	(0.7-2)	0.369
	Mean ± SD	1.5±0.3	1.5±0.3	

***: Significant difference at P value < 0.05**

Table (2): Intraobserver and Interobserver of rTEMs (%) and Coefficient of Reliability (R) for all Palatal Measurement (n = 20 Cases)

	Intra-observer		Inter-observer	
	R	rTEM	R	rTEM
O-SNP	0.991	1.13	0.984	1.53
AWPA	0.995	1.03	0.986	1.74
PWPA	0.989	1.19	0.975	1.86
TPVD	0.998	1.22	0.997	1.66

Table (3) showed sex prediction by simple discriminant functional analysis, which revealed that the equation used O-SNP had an accuracy of 55 %, and the equation used PWPA had an accuracy of 58 %. While multiple discriminant functional analysis equations using both diameters reported an accuracy of 55.4% (table 4). Receiver Operating Characteristic (ROC) function analysis is employed for male sex prediction, which revealed that using O- SNP had an accuracy of (58%) and sensitivity (54.4%) and PAWA had low accuracy (59.4%) and sensitivity (51.2%) (Table 5).

Table (3): Simple Discriminant Functional Analysis for Sex Determination.

		Wilk's lambda	**P value**	**Constant**	**Coefficient**	**Sectioning point**	**Cross validated Accuracy (%)**		
							In males	**In females**	**Total**
O-SNP		0.978	**0.001***	-5.51	1.33	0	46	64	55
PWPA		0.980	**0.002***	-10.6	2.89	0	52.8	63.2	58

-Discriminant score = constant + (coefficient x measure), If the discriminant score > sectioning point → male. If the discriminant score < sectioning point → female

Table (4): Multiple Discriminant Functional Analysis for Sex Determination

	Wilk's lambda	P value	Constant	Coefficient	Sectioning point	Cross validated Accuracy (%)		
						In males	In females	Total
O-SNP	0.963	**<0.001***	-10.84	0.93	0	54.4	56.4	55.4
PWPA				1.9				

Discriminant score = constant + (coefficient x measure), If the discriminant score > sectioning point male. If the discriminant score < sectioning point → female.

Table (5): ROC For prediction of male sex.

	O-SNP	PWPA
Optimal cutoff point	**> 4.01**	**> 3.74**
AUC	**0.585**	**0.580**
95% CI	**0.540-0.628**	**0.535-0.623**
P value	**<0.001***	**0.002***
Sensitivity	**54.4**	**51.2**
Specificity	**61.6**	**67.6**
PPV	**58.6**	**61.2**
NPV	**57.5**	**58.1**
Accuracy	**58**	**59.4**

AUC: Area under the curve**; CI:** Confidence interval**; PPV:** Positive Predictive value**; NPV:** Negative Predictive value**; *:** Significant level at P value < 0.05**.**

DISCUSSION

Sexual dimorphism is the full differences in size, shape, and behavior between males and females in the form of primary and secondary sexual characteristics **(Kotb et al., 2016)**, it is the most important aspect of variation between males and females, so, sex determination of the unidentified remains is required before, age, stature, and ancestry with skull and pelvis are considered the most sexually dimorphic bones in human body **(Cappellaab et al., 2020).**

Sex determination can be investigated by morphological or metric methods **(Hussein et al., 2016)**. The morphological method depends on visual evaluation, it allows rapid evaluation but needs high experience, the interobserver agreement is highly variable and statistical analysis is not possible. On the other hand, the metric method depends on the measurement of variable angles, breadths, and lengths which is more objective and statistical analysis can be made based on the obtained numerical data. So, metric researches have been carried out in different populations using various techniques and parameters. The most common and recent used imaging methods which gained great attendance are magnetic resonance imaging (MRI) and MDCT **(Gündogdu & Kebapçı, 2019).**

This research aimed to investigate sex by specific palatal dimensions using MDCT images. The present work included 500 patients (250 males and 250 females), with age ranging from 18 to 73 years old from May 2019 to May 2020 at the Radiology Department in our Hospital. Patients with any palatal defect either pathological or traumatic or non-Egyptians were excluded from the study.

The studied measures were the total depth of palatal vault which is at the extent of the M2 (TPVD-M2), the anterior breadth of the arch of the palate at the

extent of PM1 (AWPA), posterior breadth of the arch of the palate at the extent of M2 (PWPA), and the Oral-Spina Nasalis Posterior diameter (O-SNP).

The results of this study revealed that the measurements were slightly higher in males than females except for TPVD-M2 which is nearly equal among males and females this contradicts with **(Tomaszewska et al., 2014)** and **(Mustafa et al., 2019)** who reported that all measures were higher in males than females, also our study differs from **(Qurashi et al., 2020)** who reported that means of anterior arch length was higher in females than in males.

The range of measurements within the current sample was smaller than that of the Polish **(Tomaszewska et al., 2014)** and Yemeni **(Al-Zubair, 2015)** samples, however,

the means of our measurements are higher than the study of **(Jacob et al., 2016)** in dry skulls of South Indians.

In this study, the PWPA and the O-SNP had significant differences (p= 0.002 & 0.001 respectively), while the AWPA and the TPVD-M2 measurements were insignificant (p = 0.366 and 0.369 respectively) and these results disagree with (Tomaszewska et al., 2014) who stated that all the measurements had significant differences among both sexes ($p < 0.0001$).

In the same line, **(Qurashi et al., 2020)** revealed that males have significantly high values regarding total arch length and palatal width. However, anterior arch length did not show a significant difference among males and females.

Regarding simple discriminant analysis, these results revealed that the O-SNP had an accuracy of 55 % and PWPA had an accuracy of 58 %. While the accuracy was 55.4% by using multiple discriminant. Our accuracy is lower than **(Tomaszewska et al., 2014)** who reported reliability of 68.35% with O-SNP distance alone which increased to 78.37% by multiple discriminant function analysis using depth of the right greater palatine canal (GPC), the O-SNP, and the AWPA, this disagreement may be attributed to using GPC which is not evaluated in our study and larger sample size in the study of **(Tomaszewska et al., 2014)**.

Regarding ROC curve analysis for male sex prediction, the results showed accuracy and AUC of O-SNP is 58% & 0.585 respectively and for PWPA is 59.4% & 0.585 respectively, these results are less than results of **(Mankapure et al., 2017)** who studied maxillary arch depth and palatal depth in Marathwada region, India and revealed that AUC for maxillary arch depth was 0.7621.

This disparity within the results is attributed to different races, genetic and environmental factors as well as the sample size **(Al-Zubair, 2015)**. This is illustrated in table (6) which showed a comparison between different studies of different populations.

These results showed little intraobserver and interobserver deviations (<2 %) and consequently proved the reliability of the virtual estimations, this is considered an accepted range of error in forensic anthropology **(Hishmat et al., 2015).**

Up to our knowledge, little data were reviewed about these used measurements and their value in sex determination.

Table (6): Comparison of different studies investigated sexual dimorphism in palate.

Study	Race	method	Measurements used	Accuracy
Our study	Egyptian	MDCT	-total palatal vault depth -anterior breadth of the palatal arch -posterior breadth of the palatal arch -Oral-spina nasalis posterior diameter	Single regression analysis O-SNP 55%, PWPA 58 % -multiple regression analysis (55.4%%). -ROC curve: accuracy and AUC of O-SNP is 58% & 0.580 and for PWPA is 59.4% & 0.585.
Tomaszewska et al., 2014	Polish	MDCT	orale-spina nasalis posterior, anterior width of the palatal arch, posterior width of the palatal arch, greater palatine canal, total palatal vault depth, palatine index	-Single regression analysis (68.35%) -multiple regression analysis (78.37%)
Al-Zubair 2015	Yemeni	cast	intercanine distance*, interpremolar distance*, inter–first molar distance*, inter–second molar distance*, anterior arch length, molar-vertical distance*, total arch length, palatal length*, width*, depth*.	Not evaluated

Jacob et al., 2016	South Indian	Dry skull	maximum length of hard palate*, maximum width of hard palate* and palatine index	Not evaluated
Mustafa et al., 2019	north Jordan	cast	Length*, width*, and depth* of the hard palate	Not evaluated
Mankapure et al., 2017	Marathwada region, India	cast	maxillary arch depth* & palatal depth	Evaluated by ROC curve AUC for maxillary arch depth was 0.7621
Qurashi et al., 2020	Kashmiri population	Maxillary cast	anterior arch length, total arch length* and palatal width*	Not evaluated

CONCLUSION

It is concluded based on the present results that the diameters used for the current study are of little help in sex discrimination in the Egyptians due to the low accuracy of the measurements. The measurements that gave a significant difference among males and females were PWPA & O-SNP with an accuracy of 58% and 55%, respectively.

RECOMMENDATIONS

We recommend further studies of other palatal measurements other than those used, increase the tested sample in the hope to reach a good result, and test the reliability of these results.

LIST OF ABBREVIATIONS:

TPVD-M2 distance: Total palatal vault depth at the level of the second Molar; **AWPA:** anterior breadth of the palatal arch at the level of 1st premolar PM1; **PWPA:** posterior breadth of the palatal arch at the level of 2nd molar M2; **O-SNP:** the Orale-Spina Nasalis Posterior diameter O: Orale, SNP: Spina Nasalis Posterior; **GPC**: greater palatine canal; **AUC:** Area under the curve; **CI:** Confidence interval; **PPV:** Positive Predictive Value; **NPV:** Negative Predictive Value; **rTEM:** relative technical error of measurement; **R:** the coefficient of reliability; **MDCT:** Multi-detector computed tomography; **MRI:** magnetic resonance imaging.

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الملخص العربي

تحليل عظم الحنك لتحديد جنس الجمجمة البشرية: دراسة تصوير مقطعي ل 500 مصري من محافظة المنيا

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***مدرس الطب الشرعي والسموم الاكلينيكية- كلية طب- جامعة المنيا**

****مدرس الاشعة التشخيصية- كلية طب- جامعة المنيا**

الملخص: ان تحديد الجنس هو المرحلة الأولية في التحقيق الجنائي. اكتسب الحنك الصلب أهمية في تحديد جنس الجمجمة بسبب طبيعتها المقاومة والمكان المنعزل خاصة في حالات الحروق والانفجارات ، لذا فإن الهدف من هذه الدراسة هو تحليل التصوير الحنكي المقطعي ثلاثي الابعاد من أجل إزدواج الشكل الجنسي في عينة من السكان المصريين باستخدام ما يلي من قياسات TPVD-M2 و O-SNP و PWPA و AWPA.

أظهرت النتائج أن هناك زيادة طفيفة في قياسات الذكور مقارنة بالإناث ولكن فقط PWPA و O-SNP كان لهما فرق ذات دلالة احصائية بين الذكور والاناث. أظهر تحليل الانحدار الفردي دقة منخفضة لـ O-SNP و PWPA 55٪ و 58٪ على التوالي ، باستخدام تحليل الانحدار المتعدد لم يزيد الدقة عن 55.4٪. أفاد تحليل منحنى ROC للتنبؤ بجنس الذكور بدقة 58 ٪ مع O-SNP و 59.4 ٪ مع PAWA.

ولكن من النتائج نستخلص أن القياسات المأخوذة من الصور المقطعية لعظم الحنك لها قيمة منخفضة في تحديد الجنس في عينة من المصريين في محافظة المنيا.

الكلمات المفتاحية: تحديد الجنس ، الأنثروبولوجيا ، الحنك ، تصوير مقطعي متعدد المقاطع.