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Assessment of Age and Sex Through Measuring of Maxillary Sinus using Cone Beam Computed Tomography in an Egyptian Sample

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Abstract

Identification is an important issue in forensic medicine for ethical, humanitarian, official, statistical and legal purposes. Maxillary sinus is the largest one of paranasal sinuses, that can be used for age and sex identification through variation in its dimensions. The current study aimed to determine the accuracy and reliability of maxillary sinus for personal identification (age and sex) through morphometric analysis using Cone Beam Computed Tomography (CBCT). The present study was of prospective and retrospective nature, including CBCT images of 50 subjects using Planmeca proface machine. Maxillary sinus height, width and depth were measured using Romexis software, then volume was calculated according to an equation. Maxillary sinus measurements were found to be of higher values on the right side than the left one, and in cases of age >40 years than in those of age ≤40 years, and also of higher values in male than those of female. For age identification, volume of left maxillary sinus was proved to have the highest ability. While, for sex identification, height and width of both sides and volume of right side have a high ability. However, volume of the left maxillary sinus showed moderate ability for sex identification. Predictive formulae were initiated through maxillary sinus measurements to detect age and sex, such formulae showed 70.0 % and 90.0 % level of accuracy respectively. Maxillary sinus can be used as an authentic and reliable tool for age and sex identification.

Keywords: Maxillary sinus, CBCT, Identification, Age, Sex.

1. Introduction

Identification of living or deceased individual is based on the theory that, every person is unique. In the field of forensic medicine, fingerprint, dental, genetic, anthropological or radiological examination can be used to scientifically identify human remains [1]. Age estimation can be conducted based on

growing skeleton, degenerative changes of the skeleton or developing dentition [2]. Sex determination using skeletal remains presents a significant challenge to forensic experts, especially when only the body fragments are recovered. Forensic dentists can help other experts to identify sex of the remains using skull and teeth [3]. Maxillary sinus is the earliest and the largest developed one of paranasal sinuses, it is present in the body of the maxilla [4]. It has been revealed that, maxillary sinus remains intact although the skull and other bones may be extensively disfigured. Consequently, the maxillary sinuses measurements in CT scans can be utilized for determination of age and gender when other methods are inconclusive [5]. Maxillary sinus varies widely in shape, size, and position not only in different individuals but also in both sides of the same individual. As a result, the dimensions of the maxillary sinus vary greatly depending on the gender and ethnic groups [6]. When Cone Beam Computed Tomography (CBCT) was introduced, the drawbacks of computed tomography (CT) have been eliminated. CBCT can visualize and provide accurate information about teeth and surrounding complex anatomical structures, as it is recognized by rapid volumetric image acquisition with high resolution and low radiation dose level. Because of these advantages, CBCT is a reliable tool for identification in forensic medicine [7]. The current study was aiming to determine the accuracy and reliability of maxillary sinus for personal identification (age and sex) through morphometric analysis using Cone Beam Computed Tomography (CBCT).

2. Subjects and Methods

The present study was carried out on 50 Egyptian adults of both sexes (25 male and 25 female) of age group 21–75 years, they were selected for the study by simple sampling from the patients attending to Faculty of Dentistry for girls, Al-Azhar University, also, from patients attending to a private radio-dental center in Cairo during the period from April,2019 to August 2020. Cases were chosen according to the following inclusion criteria; ages above 20 years, Egyptian in origin, high quality reconstructed images of bilateral maxillary sinuses. Cases with facial trauma, acquired facial deformity, previous plastic or reconstructive facial surgery, facial congenital anomalies, apparent sino-nasal pathology, low quality images not covering the entire extent of the sinuses were excluded. The study was conducted according to declaration of Helsinki, [8]. The study protocol was revised for approval by the research Ethics Committee of Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt. For prospective study, written informed consent was obtained for each case after explaining the importance of the work to them. While for retrospective study, written consent was obtained from the manager of the private radio-dental center. The used apparatus of CBCT was Planmeca proface machine, version 5.3.4.39 -3D module planmeca finland helsinki field of view 20*17*20 height*width*length voxel size 200-micron reconstruction, as shown in Figure 1. The selected cases were classified into 2 groups; first group: includes 37 individuals aged from (21 to 40) years and second group: includes 13 individuals aged > 40 years. For all cases, CBCT was performed, then radiographs were stored with patients' details incorporated; all radiographs were interpreted using Romexis software. Height, width and depth of maxillary sinus were performed according to Gopal and Paul, [9]; Bangi et al., [10]. In addition, volume of maxillary sinus was calculated according to Sathyathas et al., [5].

2.1 Height (superior-inferior diameter) of maxillary sinus:

It is defined as the longest distance from the lowest point of the sinus floor to the

highest point of the sinus roof (measured in the coronal view) as shown in Figure 2.

Figure 1. Planmeca proface machine.

2.2 Width (mediolateral diameter) of maxillary sinus:

It is defined as the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the maxillary sinus (measured in the coronal view) as shown in Figure 3.

Figure 2. CBCT image (coronal view) showing maxillary sinus height.

2.3 Depth (anteroposterior diameter) of maxillary sinus:

It is defined as the longest distance from the most anterior point to the most posterior point (measured in the axial view) as shown in Figure 4.

Figure 3. CBCT image (coronal view) showing maxillary sinus width.

2.4 Volume of maxillary sinus:

It was calculated using the following equation: volume = (height × depth × width) × 0.52.

- Paired t-test was used for comparison of mean values of measurements between right and left maxillary sinuses.
- For age determination, Student's t-test was used for comparison of mean measurements of maxillary sinuses between group I (cases ≤40 years) and group II (cases of age >40 years) of both right and left sides.
- For sex determination, Student's t-test was used for comparison of mean measurements of maxillary sinus between male and female of both right and left sides.

- Receiver operating characteristic curve (ROC) was used to determine the diagnostic performance and ability of the different measurements of the maxillary sinus to identify age and sex.
- Logistic regression analysis was used to compute predictive formulae to identify age and sex from different measurements of maxillary sinus.

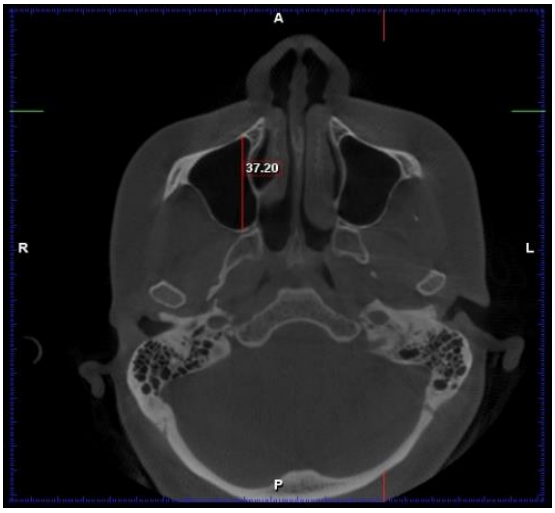

Figure 4. CBCT image (axial view) showing maxillary sinus depth.

3. Results

As regards comparison of right and left maxillary sinus measurements; Paired t-test revealed that, the mean values of height, width and volume of the right maxillary sinus were significantly higher than those of the left one (Table 1).

As regards age determination through comparison of maxillary sinus measurements; Student t-test showed that, the mean values of height, width and volume of the maxillary sinus of both right and left sides in cases of age ≤40 were significantly of lower values than in those of age >40 (Table 2).

As regards age determination through Receiver operating characteristic (ROC) curve analysis using maxillary sinus measurements; it was revealed that, maxillary sinus height of both right and left sides, left maxillary sinus width and right maxillary sinus volume had a moderate ability to predict age (cases of age ≤40 years and those of age >40 years). While the highest ability was encountered with the volume of left maxillary sinus. A limited ability for age prediction was met with width of right maxillary sinus (Table 3) & (Figure 5).

As regards age prediction through maxillary sinus measurements; a predictive formula was initiated through maxillary sinus measurements using logistic regression analysis ($-0.707 + (0.003*HT) – (0.006*W) +(3.04x10^{-5} *V)$), such a predictive formula showed 70.0 % accuracy for age prediction (Table 4).

As regards sex determination through comparison of maxillary sinus measurements; Student t-test showed that, the mean values of height, width and volume of male maxillary sinus of both right and left sides were significantly of higher values than those of the female maxillary sinus (Table 5).

As regards sex determination through ROC curve analysis using maxillary sinus measurements; it was revealed that, height and width of both right and left sides and volume of right maxillary sinus had a high ability to detect the sex, while the volume of the left maxillary sinus had a moderate ability (Table 6) & (Figure 6).

As regards sex prediction through maxillary sinus measurements; a predictive formula was performed through the measurements using logistic regression analysis ($-5.909 +(0.121*HT) +(0.136*W) – (4.08x10^{-5}*V)$), such formula showed high level of accuracy for sex prediction represented by 90.0 % (Table 7).

Table (1). Comparative statistics for right and left maxillary sinus measurements in both groups of the study (n=50) using Paired t-test, data are expressed as Means ± SD (Standard Deviation).

Maxillary sinus measurement	Right	Left	t-value	p-value
Height	34.05 ± 3.43	33.0 ± 3.45	2.610*	0.012*
Width	27.90 ± 2.55	27.06 ± 2.83	2.508*	0.016*
Volume	34887.0 ± 7044.3	32917.8 ± 7509.9	2.994*	0.004*

t: Paired t-test, p: p value for comparing between right and left, *: Statistically significant at p ≤ 0.05

Table (2). Age determination through comparative statistics for cases of group I (n=37) and group II (n=13) as regards both right and left maxillary sinus measurements using Student t-test, data are expressed as Means ± SD (Standard Deviation).

Maxillary sinus measurement	Age in years		t-value	p-value
	Group I (≤40) (n=37)	Group II (>40) (n=13)		
Height				
Right	**33.39 ± 3.45**	**35.92 ± 2.68**	**2.397***	**0.020***
Left	**32.19 ± 3.44**	**35.28 ± 2.36**	**2.997***	**0.004***
Width				
Right	**27.43 ± 2.59**	**29.22 ± 2.0**	**2.255***	**0.029***
Left	**26.48 ± 2.93**	**28.73 ± 1.69**	**2.618***	**0.012***
Volume				
Right	**33160.4 ± 6619.0**	**39801.3 ± 5986.2**	**3.185***	**0.003***
Left	**30884.9 ± 7054.4**	**38703.8 ± 5655.8**	**3.602***	**0.001***

t: Student t-test, p: p value for comparing between ≤40 and >40, *: Statistically significant at p ≤ 0.05

Table (3). Age determination through descriptive statistics and results of ROC curve analysis (sensitivity and specificity) for both right and left maxillary sinus measurements in cases of group I (n=37) and group II (n=13).

Maxillary sinus measurement	AUC	P	95% CI	Cut off	Sensitivity	Specificity	PPV	NPV
Height								
Right	**0.726**	**0.016***	**0.579 – 0.872**	**>34.3**	**69.23**	**54.05**	**34.6**	**83.3**
Left	**0.786**	**0.002***	**0.651 – 0.920**	**>32.3#**	**92.31**	**56.76**	**42.9**	**95.5**
Width								
Right	**0.667**	**0.075**	**0.511 – 0.824**	**>28**	**61.54**	**64.86**	**38.1**	**82.8**
Left	**0.792**	**0.002***	**0.666 – 0.918**	**>27#**	**92.31**	**62.16**	**46.2**	**95.8**
Volume								
Right	**0.792**	**0.002***	**0.668 – 0.917**	**>32519.4**	**92.31**	**56.76**	**42.9**	**95.5**
Left	**0.857**	**<0.001***	**0.749 – 0.964**	**>35665.9#**	**76.92**	**83.78**	**62.5**	**91.2**

AUC: Area under a curve (AUC 5-7= limited ability, AUC 7-8= moderate ability, AUC >8 = high ability), P value: Probability value, CI: Confidence intervals, PPV: Positive predictive value, NPV: Negative predictive value, *: Statistically significant at p ≤ 0.05, #Cut off was chosen according to Youden index.

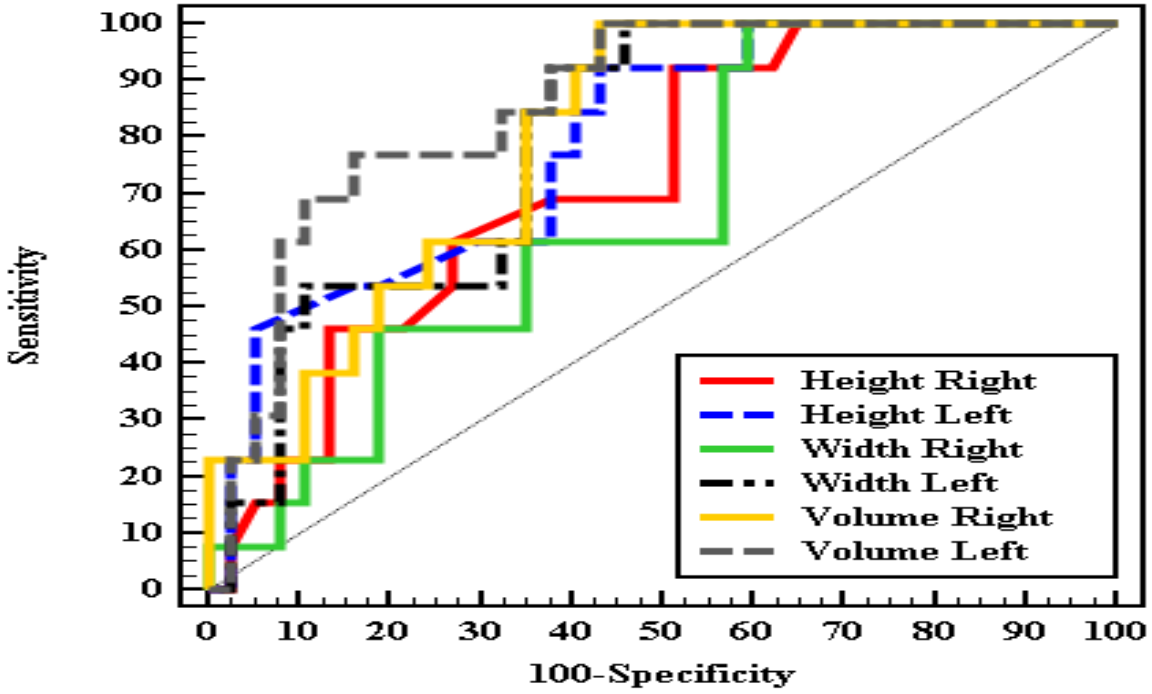

Figure (5): Age determination through ROC curve for both right and left maxillary sinus measurements in cases of group I (n=37) and group II (n=13).

Table (4). Multivariate analysis for the maxillary sinus parameters as predictors to age in group I (n=13) and group II (n=13).

	Age						
	R^2	P	Predict formula	#Cutoff	Sens.	Spec.	Acc.
Average maxillary sinus	0.216	0.010*	-0.707 + (0.003*HT) – (0.006*W) +($3.04x10^{-5}$ *V)	0.251	92.31	62.16	70.0

R^2: Coefficient of determination, P: p value for the model, *: Statistically significant at p ≤ 0.05, Sen.: Sensitivity, Spec.: Specificity, Acc.: Accuracy, HT: Height, W: Width, V: Volume, #: If more than cut off indicates age >40 years.

Table (5). Sex determination through comparative statistics for male cases (n=25) and female cases (n=25) as regards both right and left maxillary sinus measurements using Student t-test, data are expressed as Means ± SD (Standard Deviation).

Maxillary sinus measurement	Sex		t-value	p-value
	Male (n=25)	Female (n=25)		
Height				
Right	36.27 ± 2.83	31.83 ± 2.39	5.996*	<0.001*
Left	34.83 ± 2.66	31.16 ± 3.20	4.414*	<0.001*
Width				
Right	29.51 ± 1.93	26.28 ± 2.04	5.764*	<0.001*
Left	28.40 ± 2.90	25.73 ± 2.05	3.757*	<0.001*
Volume				
Right	39411.3 ± 6095.4	30362.7 ± 4638.4	5.907*	<0.001*
Left	36653.6 ± 7627.0	29182.0 ± 5282.1	4.027*	<0.001*

t: Student t-test, p: p value for comparing between male and female, *: Statistically significant at p ≤ 0.05.

Table (6). Sex determination through descriptive statistics and results of ROC curve analysis (sensitivity and specificity) for both right and left maxillary sinus measurements to predict male cases (n=25) and female cases (n=25).

Maxillary sinus measurement	AUC	P	95% CI	Cut off	Sensitivity	Specificity	PPV	NPV
Height								
Right	0.886	<0.001*	0.786 – 0.985	>33.7#	92.0	80.0	82.1	90.9
Left	0.840	<0.001*	0.722 – 0.958	>33.7#	76.0	88.0	86.4	78.6
Width								
Right	0.866	<0.001*	0.768 – 0.963	>27.5#	92.0	68.0	74.2	89.5
Left	0.818	<0.001*	0.698 – 0.937	>27.9#	68.0	92.0	89.5	74.2
Volume								
Right	0.886	<0.001*	0.795 – 0.978	>35145#	76.0	92.0	90.5	79.3
Left	0.797	<0.001*	0.670 – 0.924	>33264#	72.0	84.0	81.8	75.0

AUC: Area under a curve (AUC 5-7= limited ability, AUC 7-8= moderate ability, AUC >8 = high ability), P value: Probability value, CI: Confidence intervals, PPV: Positive predictive value, NPV: Negative predictive value, *: Statistically significant at p ≤ 0.05, #Cut off was chosen according to Youden index.

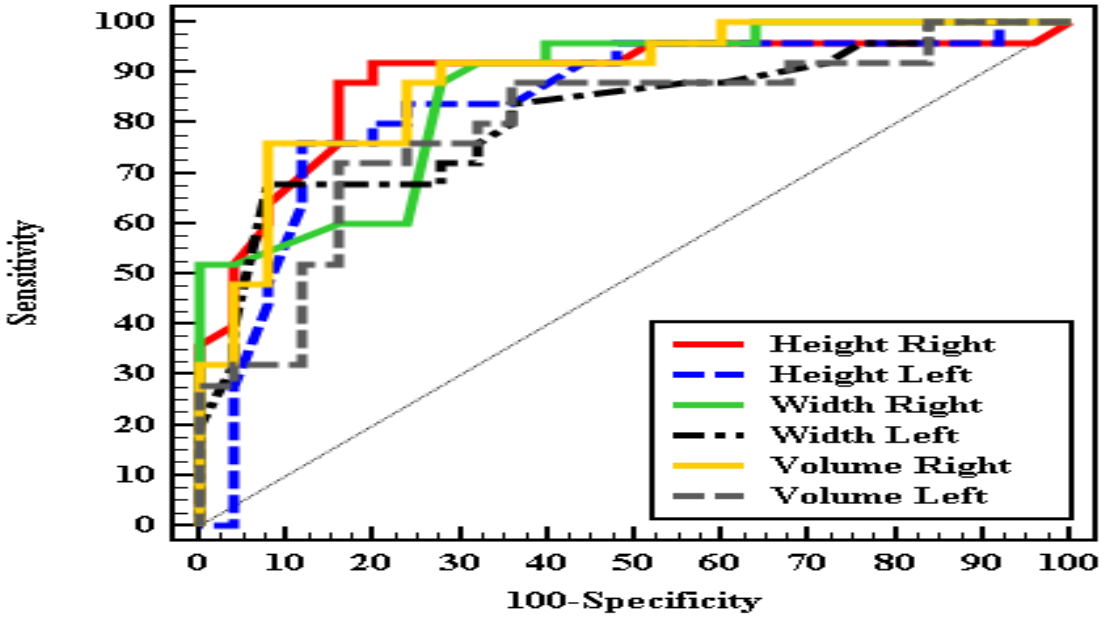

Figure (6): Sex determination through ROC curve for both right and left maxillary sinus measurements in male cases (n=25) and female cases (n=25).

Table (7). Multivariate analysis for the maxillary sinus parameters as predictors to sex in both groups (I&II) of the study (n=50).

	Sex						
	R^2	P	Predictive formula	#Cutoff	Sens.	Spec.	Acc.
Average maxillary sinus	0.555	<0.001*	-5.909 +(0.121*HT) +(0.136*W) – ($4.08x10^{-5}$*V)	0.358	96.0	84.0	90.0

R^2: Coefficient of determination, P: p value for the model, *: Statistically significant at p ≤ 0.05, Sen.: Sensitivity, Spec.: Specificity, Acc.: Accuracy, HT: Height, W: Width, V: Volume, #: If more than cut off indicates sex is male.

4. Discussion

Human beings are born with identities and have the right to die with their identities. Identification of a dead body may be essential in circumstances of abrupt and unexpected fatalities such as fires, explosions, accidents involving different modes of transportation, criminal actions, or mutilated or decomposed mortal remains which frequently necessitate great medico-legal expertise [11]. Maxillary sinus radiography has been used for identification of remains, as maxillary sinus varies greatly among individuals, its measurements can be used for determination of age and gender especially if other methods are inconclusive [5]. The current study is aiming to determine the accuracy and reliability of maxillary sinus for personal identification (age and sex) through morphometric analysis using Cone Beam Computed Tomography (CBCT). In the current study, measurements of right maxillary sinus were higher than those of left one, which agreed with Prabhat et al., [12] but disagreed with Ariji et al., [13], Demir et al., [14] and Belgin et al., [15] who found no significant difference between the right and left maxillary sinus volume. The different results can be explained by Rani et al., [16] who stated that, maxillary sinus dimensions show a wide range in different studies that may reflect the influential effects such as human variability and triggering of pneumatization. In the present study, it was found that, measurements of both right and left maxillary sinuses in cases of age ≤40 years were of lower values than those of age >40 years, which agreed with Abd-alla and Mahdi [17] who explained that the maxillary sinus reaches its full growth at the age (50-59) years if it fails to reach it in the stage of (40-49) years. The above-mentioned result disagreed with Ariji et al., [13], Takahashi et al., [18] and Belgin et al., [15] who observed that, maxillary sinus size decreases with age. The decrease of maxillary sinus dimensions with age progression can be explained by the opinion of Rani et al., [16] who reported that, the paranasal sinus anatomy varies from person to person, the main characteristic of these structures (paranasal sinuses) is being pneumatic. Environmental conditions, past infections and genetic diseases can affect the process of pneumatization of paranasal sinuses. In addition, the result of current work disagreed with Luz et al., [19] and Najem et al., [20] who found no difference in maxillary sinus dimensions between cases younger and older than 40 years of age. Regarding age identification, the present study proved that height of both right and left maxillary sinuses, width of left maxillary sinus and volume of right maxillary sinus had a moderate ability to detect age. However, the highest ability for age prediction was encountered with the volume of left maxillary sinus, so it is the best discriminator of age. While limited ability was met with width of right maxillary sinus. In the present study, maxillary sinus showed 70.0 % accuracy to predict age. So, maxillary sinus could be used in age identification, this found agreement with the result of Rani et al., [16]. Regarding sex identification, the current study revealed that, measurements of both right and left maxillary sinuses in male was of higher values than in female, which agreed with Fernandes [21], Teke et al., [22], Vidya et al., [23], Azhar et al., [24] Prabhat et al., [12] and Belgin et al., [15] who found that, maxillary sinus dimensions were higher in male. The greater size of maxillary sinus in male can be probably due to sex-specific differences in body composition, nutrition, energetic intake and genetics [22]. The previous finding encountered in the present work concerning the size of maxillary sinus as being larger in male could find interpretation by Samhitha et al., [25] who stated that, male needs a larger airway, which begins with the nose and nasopharynx. In other words, physiological changes in nasal cavity size and shape occur as a direct result of respiration-related

needs, such as warming and humidifying inhaled air. As the maxillary sinus occupies the remaining space within the naso-maxillary complex, it also increases in size. The above-mentioned results concerning sex disagreed with Ariji et al., [13] and Najem et al., [20] who found no difference between male and female in maxillary sinus dimensions. Also, the result of the present study disagreed with Urooge and Patil [7] who showed a statistically non-significant difference between male and female on both the right and left sides of maxillary sinus with respect to the maxillary sinus depth, height, area, volume and perimeter, however, they reported that, female showed a statistically significant higher values for left maxillary sinus width only. So, they concluded that, maxillary sinus width can be used as an aid in forensic anthropology for sex determination.

Regarding sex identification, the present study proved that height, width of both right and left maxillary sinuses and volume of right maxillary sinus had a high ability to detect the sex, while the volume of the left maxillary sinus had a moderate ability. The result of the present study disagreed with Uthman et al., [26]; Amin and Hassan [27] who found that, the maxillary sinus height was the best discriminator that could be used to study sexual dimorphism, and disagreed with Sharma et al., [28] who reported the maxillary sinus depth to be the best sex discriminator. Also, the current result disagreed with Azhar et al., [24] who stated that, left maxillary sinus width was the best sex discriminator.

In the present study, maxillary sinus showed high level of accuracy reached 90.0 % for sex prediction, while, other studies showed lower level of accuracy as those of Teke et al., [22] who found the accuracy to be less than 70%, Uthman et al., [26] found an overall accuracy of 71.6%, Sharma et al., [28] found the overall accuracy to be 67.03%, Azhar et al., [24] found the accuracy to be 71% in female and 56.1% in male (overall accuracy = 63.9%). In addition, Prabhat et al., [12] observed that, the accuracy of the right maxillary sinus (80.0%) was more than that of the left one (73.3%), when the measurements of both right and the left maxillary sinuses were accounted together, the accuracy rate increased to 83.3%.

5. Conclusion

Maxillary sinus measurements (height, width and volume) using Cone Beam Computed Tomography (CBCT) are reliable tool for personal identification (age and sex), they could be used in formulation of predictive formula that showed high level of accuracy; 70.0 % for age and 90.0 % for sex prediction.

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