Original Article

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The Radio-Morphometric Analysis of Maxillary Sinus Dimensions in Pediatric Population: A CBCT Study

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Abstract

Objectives: The objective of the present study is to determine the age on the basis ofbizygomatic distance, intermaxillary distance, antero-posterior diameter and maxillary sinus width.The bizygomatic distance and maxillary sinus width is also studied as dimorphic tool in relation to gender determination. *Materials and Methods:* This is prospective study of 151 study subjects which was carried out in Department of oral medicine and radiology using Carestream 9000cc Cone beam computed tomography(CBCT) machine. All the measurements were taken from series of axial sections of cone beam computed tomography (CBCT) of head and paranasal sinuses (PNS) images using DICOM viewer. *Results*: The study population consists of 151 study subjects aged between 6 and 17 years having49.7% male and 50.3% females.The maxillary sinus width in right side of male and female was statistically significant (p<0.05). The mean maxillary sinus width in right side is higher in males (25.6 mm)than females(23.9mm).Maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width were significantly associated in all age groups(P<.005). On the basis of strong positive correlation shown by pearson correlation, it was concluded that age plays an important role in determination of maxillary sinus width, maxillary sinus height, intermaxillary distance and bizygomatic width. The mathematical equations derived from linear regression analysis helps in age determination. However age prediction by maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width was strongly significant i.e on the basis of above parametrs age can be predicted with high accuracy. *Conclusion:* As maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width was strongly significant (P value<.05). It was concluded that in paediatric population, all the maxillary parameters can be used as strong dimorphic tool for sex determination by cone beam computed tomography.

Keywords: Maxillary Sinus; Bizygomatic Distance; Intermaxillary Distance; Cone Beam Computed Tomography; Sex Determination.

Introduction

Forensic identification by its inherent nature is a multidisciplinary team effort depending on positive identification methodologies as well as supposition or exclusionary approaches. However typical identification methods may be indecisive, especially when certain extreme post-mortem alterations have occurred [1]. In spite of the leaps in medical breakthroughs, modern technology, investigations and its holistic application in forensics, identification of remnants of skeletal and decomposing parts of humans remains challenging. Forensic odontology aids personal identification through theprocesses of comparative dental identification, post mortemprofiling from dental records, identification from dental DNA etc [2]. Sexual dimorphism is one of its integral aspects as it is one of the initial steps in personal identification of an unknown cadaver thus narrowing down the diagnosis toward a correct possibility. Since, most bones that are conventionally used for sex determination (pelvis, skull & long bones etc.) are often recovered either in a fragmented,

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incomplete or commingled state especially in catastrophes like explosions, warfare, natural calamities, and other mass disasters like aircraft crashes, identification and sex determination are not easily achievable tasks [3]. It has thus become important to use denser bones that are often recovered intact. e.g. the maxillary sinus and thus alternate areas of the skeleton to be researched for sex estimation [1]. It has been reported that zygomatic bones and maxillary sinus remains intact although the skull and other bones may be badly disfigured in victims who are incinerated [1,4]. Comparison of ante mortem and post-mortem medical records, such as dental documents, plays an important role in the identification of corpses. However, typical identification methods may be inconclusive, especially when certain extreme post-mortem changes have developed [5]. Although development and progress in various diagnostic methods, but still identification of remnants of skeletal and decomposing parts of human is one of the most difficult skills in forensic medicine. Gender and age estimation is also considering an importantproblem in the identification of unknown skull [6]. Because most bones that are conventionally used for sex determination (skull, pelvis & long bones etc.) are often recovered either in a fragmented or incomplete state, it has become necessary to use denser bones that are often recovered intact, eg. the maxillary sinus [7]. Therefore it is important for alternate areas of the skeleton to be researched for gender estimation. It has been reported that zygomatic bones & maxillary sinus remains intact although the skull & other bones may be badly disfigured in victims. Establishing identification is necessary for unknown deceased person in homicide, suicide, accident, mass disasters, and for culprits hiding their identity [8]. The size and shape of, maxillary sinus remains intact although other bones may be badly disfi gured in victims who are incinerated and therefore, the maxillary sinuses can be used for identifi cation [8]. It has been reported that the gender can be determined with an accuracy of 100% if entire skeleton is available. 98% accuracy can be achieved from the pelvis and the skull, 95% from only or the pelvis and the long bones, 90-95% from both the skull and the long bones and 80-90% from long bones only [9,10]. Forensic pathologists may be asked to identify the ethnic group and gender of a cranium of unknown origin [11]. Forensic personal identification is a fundamental topic of forensic sciences and technologies to identify live subjects, recently deceased bodies and human remains often at a crime scene by using several appropriate techniques. It has been reported that computerized tomography is a suitable imaging method in the identification of unknown human remains and presents a lot of advantages as compared with conventional radiographs [12].The volumes of maxillary sinuses are of interest to surgeons operating endoscopically as variation in maxillary sinus volume. Other surgical disciplines, such as dentistry, maxillafacial surgery may benefit from this information [13].

A primary component of any skeletal analysis is determination of age and sex. Identiûcation of the individual from skeletal remnants and decomposing parts of human is one of the most difûcult skills in forensic medicine in spite of rapid progress in various diagnostic methods. Gender and age estimation is considered as an important problem in the identiûcation of unknown skull [14]. Gender determination is an important step in identification in forensic medicine. In most of cases forensic anthropologists receive an incomplete skeleton therefore it is important for alternate areas of the skeleton to be researched for sex estimation. Because most bones that are conventionally used for sex determination (skull, pelvis and long bones etc.) are often recovered either in a fragmented or incomplete state, it has become necessary to use bones that are often recovered intact e.g. the maxilla. It has been reported that maxillary sinus remains intact although the skull and other bones may be badly disfigured in victims who are incinerated and therefore maxillary air sinus can be used for identiûcation. Next to the pelvis, the skull is the most easily sexed portionof the skeleton, but the determination of sex from the skull is not reliable until after puberty [15]. Skull requires the most frequent sexing in medico legal cases. It appears to be the main reliable bone exhibiting sexually dimorphic traits, because skull has a high resistance to adverse environmental conditions over time, resulting in the greater stability of dimorphic features as compared to other skeletal bony pieces [16]. Traditionally, radiology has been limited in its applications to forensic medicine in the ûeld of identiûcation. Visual in- spection, anatomic measurement and precise measurement of bone dimensions often exceed radiologic contribution, particularly where identiûcation of skeletal remains is required. The most helpful area of the body for comparison radiography is the cranium [17]. Measurements of the maxillary sinuses in computerized tomography (CT) scans can be used for determination of age and gender when other methods are inconclusive [18,19]. Maxillary sinus dimensions measurements are valuable in studying sexual dimorphism. They tend to stabilize after second decade of life and the radiographic images could provide adequate measurements for maxillary sinuses that cannot be approached by other means. Hence, morphometric analysis of maxillary sinuses can assist in gender determination [20]. It has been reported that computerized tomography is a suitable imaging method in the identiûcation of unknown human remains and presents a lot of advantages as compared with conventional radiographs [21]. CT scans are an excellent imaging modality used to evaluate the sino-nasal cavities as they provide three-dimensional information and an accurate assessment of the paranasal air sinuses. Till date no study has been conducted on paediatric population using CBCT to study the maxillary sinus width, maxillary sinus height, intermaxillary distance and bizygomatic widthand their role in age determination. So in light of scarcity of literature on maxillary sinus width, maxillary sinus height, intermaxillary distance and bizygomatic width on paediatric population,this study has been taken in account.

Materials and Methods

This is prospective study of 151 study subjects which was carried out in Department of Oral medicine and Radiology using Carestream 9000cc Cone beam computed tomography (CBCT) machine. The study population consists of 75 male and 76 females. The CBCT scans of patients who came for other diagnostic purposes are used in this study. All the measurements were taken from series of axial sections of Cone beam computed tomography (CBCT) of head and paranasal sinuses (PNS) images using DICOM viewer. An informed consent was obtained from each patient. All those patients having maxillary sinus pathology, trauma, facial asymmetry is excluded from study.

Methodology

The study subjects were scanned with 9000cc Carestream cone beam computed tomography machine. All measurements of bizygomatic distance, intermaxillary distance, anterior-posterior diameter and maxillary sinus width were made directly on the console computer using Trophy Dicom Ink software programme (inbuilt software) having measuring tools from axial sections of head and paranasal sinuses.

The Measurements were Done as Follows

1. On axial images the bizygomatic distance was measured and is defined as the maximum distance between the most prominent points on the right and left zygomatic arches (Figure 1).
2. The Intermaxillary distance was also measured on axial reconstructed image by measuring the maximum distance between medial walls of right & left maxillary air sinuses (Figure 2).
3. The Antero-Posterior dimension was measured on axial section by measuring the longest distance antero-posteriorly from the most anterior point to the most posterior point (Figure 3).
4. The width was measured on axial reconstructed image by measuring the longest distance perpendicular from the medial wall of the sinus to the outermost point of lateral wall of the lateral process of the maxillary sinus (Figure 3).

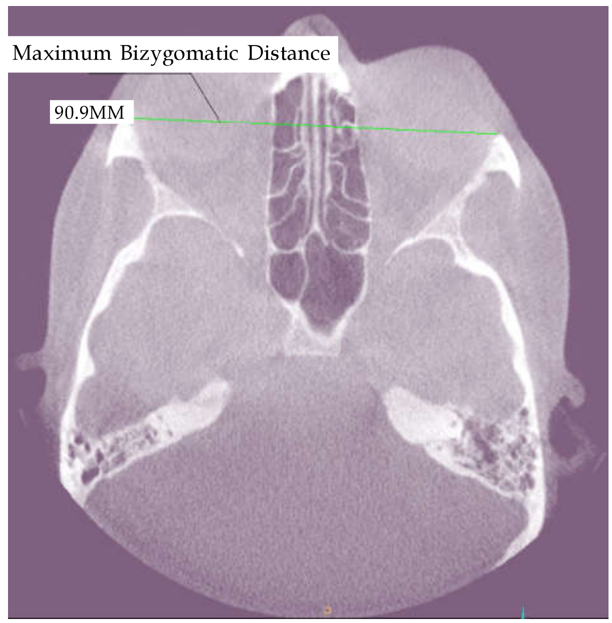


Fig. 1: CBCT (Axial sections) showing Bizygomatic distance

Fig. 2: CBCT (Axial sections) showing Intermaxillary distance

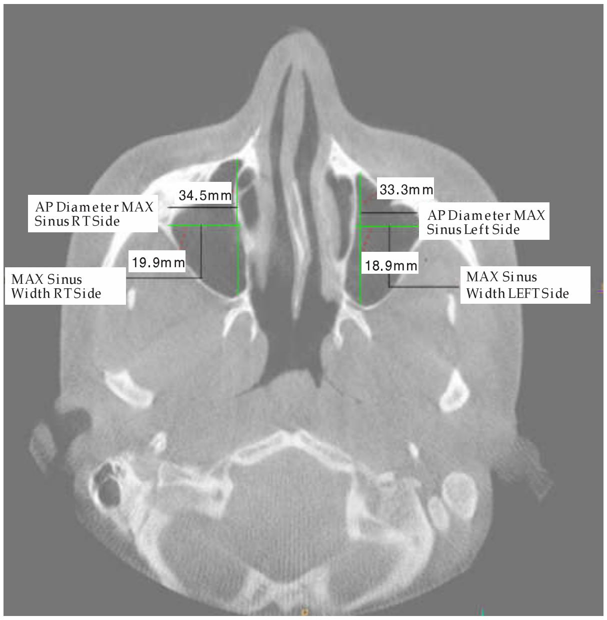


Fig. 3: CBCT (Axial section) showing right and left maxillary sinus anetro-posterior diameter and maxillary sinus width (right and left)

Statistical Analysis

Categorical variables will be presented in number and percentage (%) and continuous variables will be presented as mean and SD. Quantitative variables will be compared using Unpaired t-test between two groups and ANOVA test between three groups.

Pearson correlation coefficients were used to determine the relationship between two scale parameters while correlation was defined as a measure of the strength of a linear relationship between two variables.

A p value of <0.05 will be considered statistically significant. The data is analyzed by using Statistical Package for Social Sciences (SPSS) version 21.0.

Results

The study population consists of 151 study subjects aged between 6 and 17 years with a mean age of 11.81±3.271 years (Table 1). Majority of the study subjects belonged to 9 to 11 years (Table 2). The study population have 49.7% male and 50.3% females (Table 3). Using unpaired t test, the study parameters are studied in male and female population. The maxillary sinus width in right side of male and female was statistically significant (p<0.05). The mean maxillary sinus width in right side of was higher in males (25.6 mm) than females (23.9mm) (Table 4). The one way ANOVA test is applied in age groups to find the association between age and study parameters. The study parameters i.e. Maxillary sinus width (right & left), Maxillary sinus height (right & left), Intermaxillary distance and Bizygomatic width were significantly associated in all age groups (P<.005). (Table 5).

The Pearson Correlation between age and maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width demonstrates a highly significant positive relation (Table 6). On the basis of strong positive correlation between Maxillary sinus width (right & left), Maxillary sinus height (right & left), Intermaxillary distance and Bizygomatic width and age it was concluded that age plays an important role in determination of Maxillary sinus width,

Table 1:

	N	Minimum	Maximum	Mean	Std. Deviation
Age	151	6	17	11.81	3.271

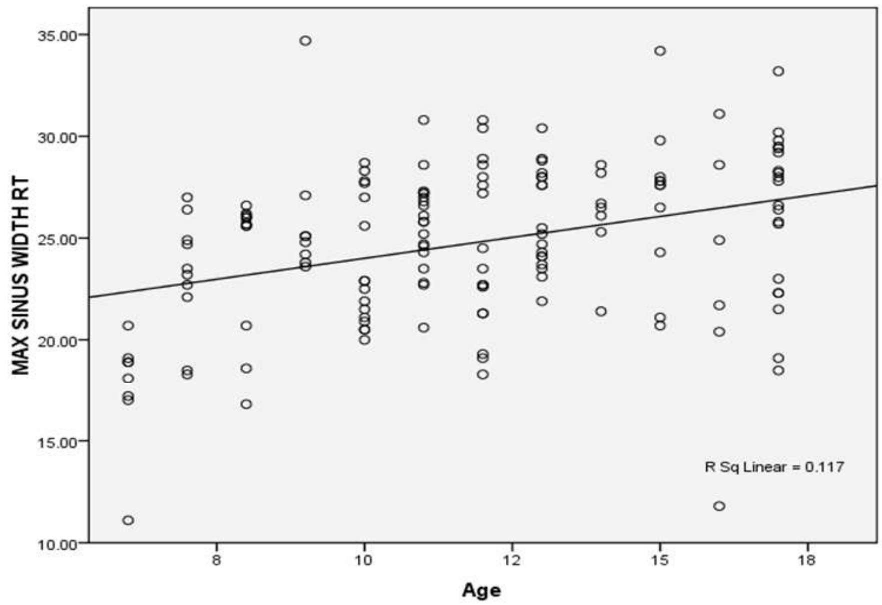
Table 2:

Age Intervals	Frequency	Percent
6 to 8 yr	29	19.2
9 to 11 yr	43	28.5
12 to 14 yr	42	27.8
15 to 17 yr	37	24.5
Total	151	100.0

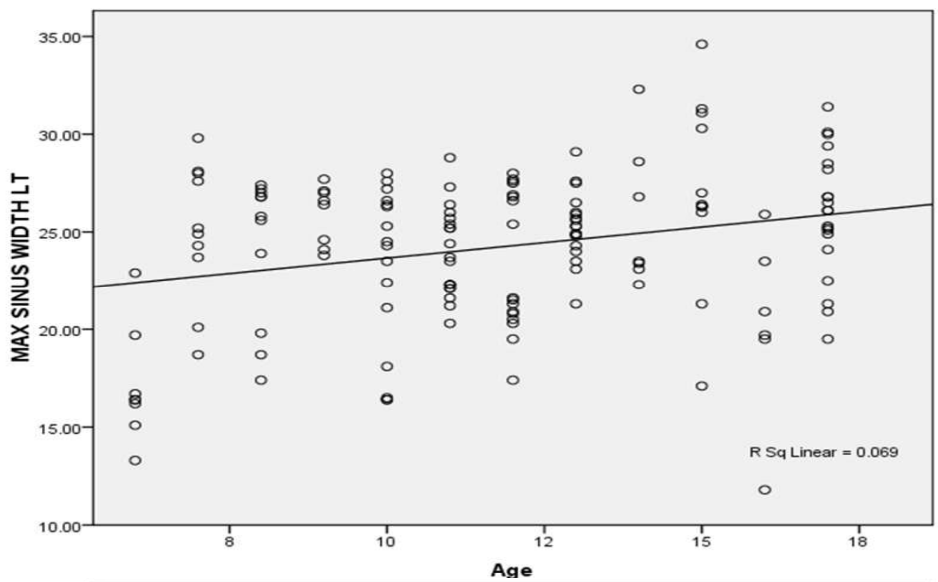
Table 3:

Gender	Frequency	Percent
Male	75	49.7
Female	76	50.3
Total	151	100.0

Graph 1:



Graph 2:



Graph 3:

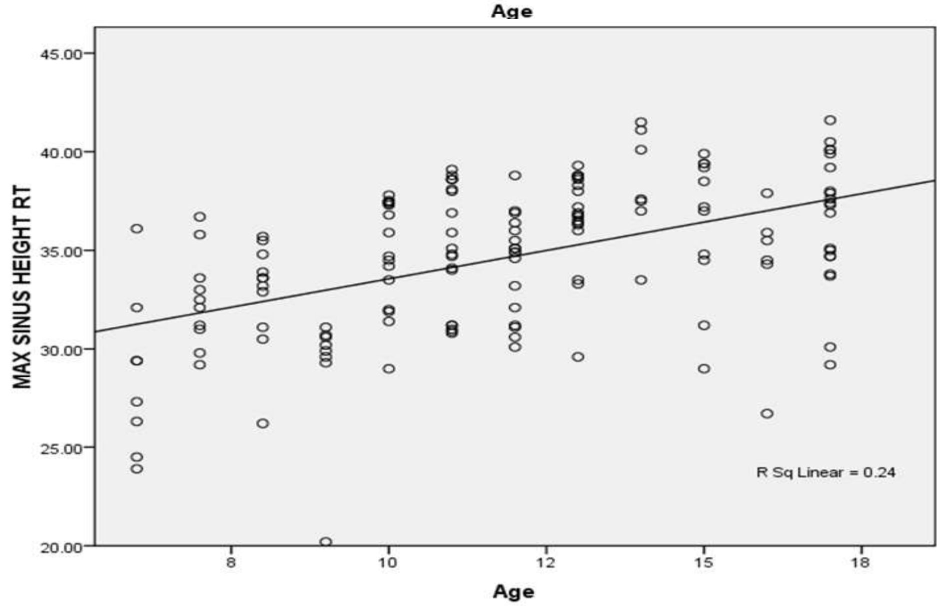


Table 4:

	Gender	N	Mean	Std. Deviation	P value
Max Sinus Width (Right side)	Male	75	25.6187	3.31364	0.007*
	Female	76	23.9013	4.30979	
Max Sinus Width (Left side)	Male	75	24.3480	3.60305	0.743
	Female	76	24.1368	4.26258	
Max Sinus Height (Right side)	Male	75	35.0987	3.82981	0.115
	Female	76	34.1118	3.81016	
Max Sinus Height (Left side)	Male	75	34.6667	3.73592	0.166
	Female	76	33.8355	3.60265	
Intermaxillary Distance	Male	75	31.8520	3.32620	0.819
	Female	76	31.9750	3.26260	
Bizygomatic Width	Male	75	91.4013	4.55437	0.100
	Female	76	90.2000	4.37188	

(Applied unpaired t test for significance. *Significant)

Table 5:

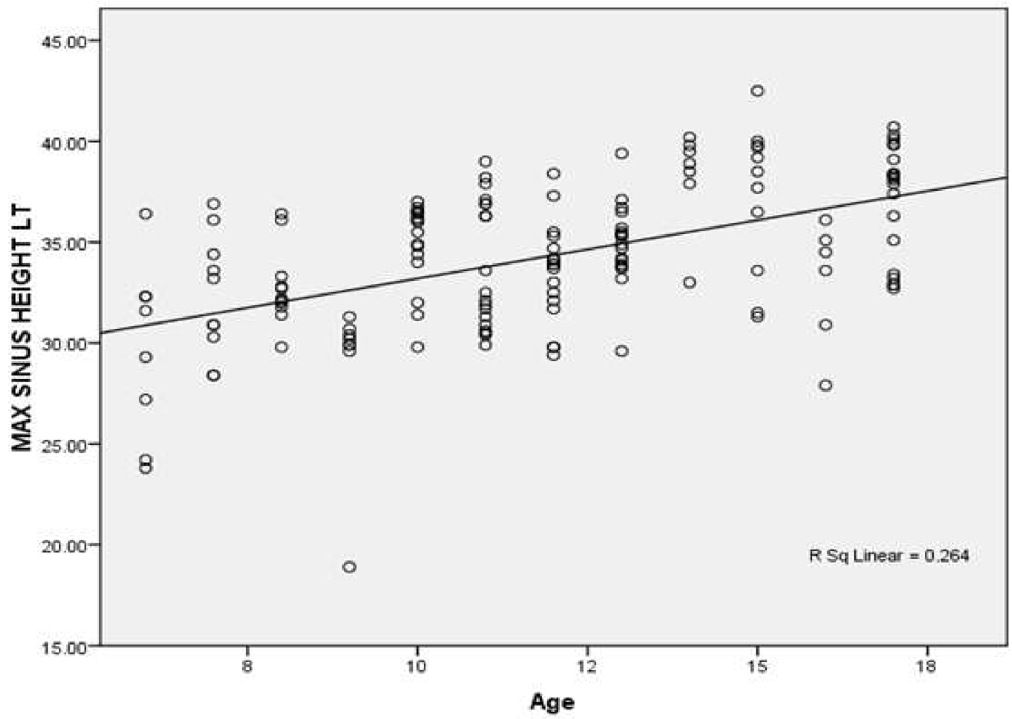
		N	Mean	Std. Deviation	P value
Max Sinus Width (Right side)	6 to 8 yr	29	21.9379	4.09254	
	9 to 11 yr	43	25.0186	3.03741	<0.001*
	12 to 14 yr	42	25.4095	3.22247	
	15 to 17 yr	37	25.9108	4.51595	
	Total	151	24.7543	3.93017	
Max Sinus Width (Left side)	6 to 8 yr	29	22.5345	4.80879	
	9 to 11 yr	43	24.0395	3.15135	
	12 to 14 yr	42	24.6571	3.03413	0.029*
	15 to 17 yr	37	25.3432	4.54793	
	Total	151	24.2417	3.93706	
Max Sinus Height (Right side)	6 to 8 yr	29	31.5483	3.46921	
	9 to 11 yr	43	33.9721	3.85390	
	12 to 14 yr	42	35.9881	2.89467	<0.001*
	15 to 17 yr	37	36.1541	3.53275	
	Total	151	34.6020	3.83923	
Max Sinus Height (Left side)	6 to 8 yr	29	31.7517	3.28640	
	9 to 11 yr	43	33.3279	3.67834	
	12 to 14 yr	42	34.9071	2.77598	<0.001*
	15 to 17 yr	37	36.5270	3.40821	
	Total	151	34.2483	3.68088	
Intermaxillary Distance	6 to 8 yr	29	29.8897	3.47495	
	9 to 11 yr	43	31.2860	2.63444	
	12 to 14 yr	42	31.9619	3.28180	<0.001*
	15 to 17 yr	37	34.1757	2.47929	
	Total	151	31.9139	3.28392	
Bizygomatic Width	6 to 8 yr	29	88.3138	4.56936	
	9 to 11 yr	43	89.1279	3.96481	<0.001*
	12 to 14 yr	42	91.7619	3.85739	
	15 to 17 yr	37	93.5865	3.88152	
	Total	151	90.7967	4.48918	

(Applied One way ANOVA for significance. *Significant)

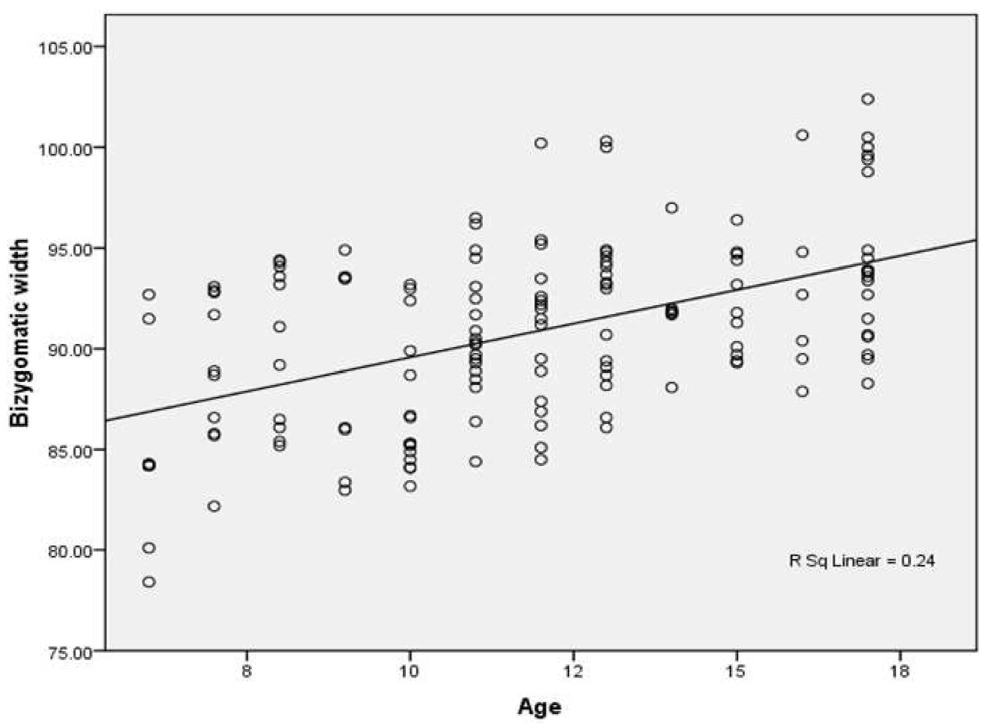
Table 6:

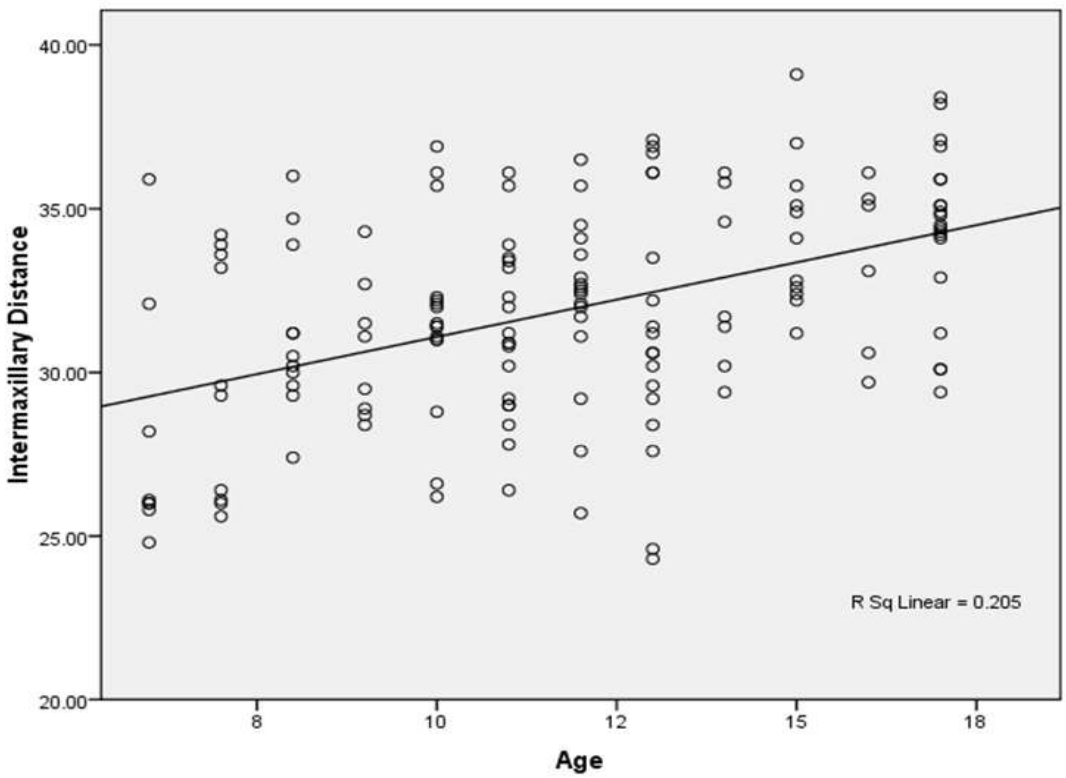
	Pearson correlation coefficients (r)	P value	Mathematical equations derived from linear regression analysis
Max Sinus Width(Right side)	0.342	<0.001	Age =4.763+0.285*(MAX SINUS WIDTH RT) **Graph.1**
Max Sinus Width(Left side)	0.264	<0.001	Age=6.506+0.219*(MAX SINUS WIDTH LT) **Graph.2**
Max Sinus Height(Right side)	0.490	<0.001	Age=(-2.636)+0.418*(MAX SINUS HEIGHT RT) **Graph.3**
Max Sinus Height(Left side)	0.514	<0.001	Age=(-3.837)+0.457*(MAX SINUS HEIGHT LT) **Graph.4**
Intermaxillary Distance	0.453	<0.001	Age=(-2.587)+0.451*(Intermaxillary Distance) **Graph.5**
Bizygomatic Width	0.490	<0.001	Age=(-20.577)+0.357*(Bizygomatic width) **Graph.6**

Graph 4:



Graph 5:





Graph 6:

Maxillary sinus height , Intermaxillary distance and Bizygomatic width.

The Linear regression analysis have been performed to predict the age of the study subject on the basis of various study parameters.The various mathematical equation has been derived for age prediction. However age prediction by maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width was strongly significant i.e on the basis of above parametrs age can be predicted with high accuracy. (Table 6, Graph 1,2,3,4,5,6).

Discussion

In the field of forensic science, sexual dimorphism remains a crucial initial step toward establishment of positive identity of the deceased individual. It has been reported that the accuracy rate of sex determination is 100% from a skeleton, 98% from both the pelvis and the skull, 95% from the pelvis only or the pelvis and the long bones, 90–95% from both the skull and the long bones and 80–90% from the long bones only [22]. Next to the pelvis, the skull is the most easily sexed portion of the skeleton. Though, the determination of sex from the skull is not reliable until after puberty [23], the craniofacial structures have the advantage of being composed largely of hard tissue, which is relatively indestructible [24]. It has been reported in previous studies that the maxillary sinuses are significantly larger in males than in females [22].

Jehan et al [25] stated that the overall average dimensions of each parameter was statistically greater for males compare with females. The mean ± SD of Bizygomatic distance in male was 9.55± 0.41cm and in female was 9.26±0.52cm however the total average (M+F) was 9.41±0.462cm which were significant statistically ($p<0.0001$). Ewunonu EO et al [26] stated that In Igbo people in South East Nigeria, the bizygomatic diameter was 13.73±0.79 cm for male and 13.07±0.77cm for female which was greater than our results probably due to different regions and raceswhereas in our study all the dimensions were statistically greater in male as compare to females. In present study, the mean ± SD of bizygomatic distance in male is 91.40±4.55 mm and in female is 90.20±4.37mm which were significant statistically ($P<0.01$). Chung CS et al [27] studied that bizygomatic diameter appears to behave as a partial dominant trait and the racial mean of bizygomatic diameter or the ratio of this measure to head length were found to have a relationship with the racial incidences of cleft lip with or without cleft palate. According to Latta GH et al [28] in edentulous patients, the bizygomatic width varied widely even when the population was separated into groups by sex and/or race. Black men differed significantly from black women, white women and white men in interalar and bizygomatic width.

Jehan et al [25] suggested that the anteroposterior (AP) diameter (mean± SD) in male was 36.43±4.26mm which were significantly ($p<0.05$) larger than for female which was 34.93±4.14mm. In Baweja et al [29] study the average anteroposterior (AP) diameter for male was 34.1±5.1mm and for female was 33.0± 5.6mm. Studies done by Teke HY et al [22] had an average sinus antero-posterior(AP)diameter 43.14±7.84mm for male, 37.7±5.85mm for female and 40.42±6.84 mm as the total (male+female) average which were larger than our results. The study conducted by Sharma SK et al [30] stated that mean sinus anteroposterior (AP) for male was 34.89±3.26 mm for the right side and 35.03±3.56 mm for the left side and average was 34.96± 3.4 mm which was significantly ($P>.005$) greater than the recorded for the female i.e 33.2± 2.94 mm for right side and 33.59±2.92mm for left side and average was 33.39±2.929mm.

Uthman et al [31] suggested that the mean value for maximum length of maxillary sinus for male group was 39.3±3.8mm for the right side and 39.4±3.7 mm for the left side which was greater than for female group 36.9±3.8 mm for right side and 37±4 mm for left side and with statistically significant difference ($P>.005$).

Whereas in our study it is found that for males,theantero-posterior(AP)diameter of right maxillary sinus is 35.09±3.82 mmand for left maxillary sinus , the antero-posterior (AP) diameter is 34.66±3.73 mm.For females, the antero-posterior(AP)diameter of right maxillary sinus is 34.11±3.81 mmand for left maxillary sinus, the antero-posterior(AP) diameter is 33.83±3.60which is statistically non-significant ($P>.005$). Jehan et al [25] also stated that the sinus width in male (mean± SD) was 24.04±4.71mm while in female, it was 23.9±4.38mm which were not statistically significant ($P>.05$). Baweja et al [29] stated that for male,the sinus width (mean± SD) was 21.8 ± 3.4 mm and for female it was 21.6 ± 3.7mm, total (male+female) average width was 21.7±3.5mm. Teke HY et al [22] suggested that the average sinus width was 27.04±5.49mm for male, 24.36±3.795mm for female and 25.7±4.64mm as the total (male+female) average. In context of maxillary sinus width,the findings in our study population does not corresponds to findings of Jehan et al [25], Baweja et al [29], Teke HY et al [22]. This difference was probably due to combination of many factors but mainly due to different ethnic and racial groups with different body stature, skeletal size, height and physique of an individual, environmental conditions and pneumatization [32] process of sinus in different age and sex groups.

Sharma SK et al [30] stated that mean sinus width for male was 24.33±4.26 mm and 24.93±4.84 mm for the right side and left side respectively which was not significantly($P>.005$) and greater than female with 23.39±3.8 mm for right side and 23.88±3.89 mm for left side.whereas in our study, sinus width for male for right side is 25.61±3.31 and for left side,it is 24.34±3.60 and for female the sinus widh is 23.90±4.30 and 24.13±4.26 for right and left side of maxillary sinus respectively. it is found that it is statistically non significant($p>.05$).However Chaurasia et al [33] concluded that thatonly Bizygomatic distance was significantly ($p=0.01$) different between male and female. All other parameters were statistically non significant ($P>.005$).

Conclusion

As maxillary sinus width (right & left), maxillary sinus height (right & left), intermaxillary distance and bizygomatic width was strongly significant(P value $<.05$). It was concluded that in paediatric population, all the maxillary parameters can be used as strong dimorphic tool for sex determination by cone beam computed tomography.

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