

Morphometric evaluation of Bizygomatic distance and maxillary sinus width as dimorphic tool- A CBCT study

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Abstract

Objectives: The objective of this study is to determine the age prediction on the basis of Bizygomatic 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 202 study subjects which was carried out in Department of oral medicine and radiology using Care stream 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: There was no significant ($p > 0.05$) difference in the study parameters among the age groups. It was found that only Bizygomatic distance was significantly ($p = 0.01$) different between male and female all other parameters were statistically non significant ($P > 0.05$).

Conclusion: It was concluded that bizygomatic distance is a 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 personal 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 the processes of comparative dental identification, post mortem profiling 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, 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.⁽⁴⁾ 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 important problem 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, e.g. 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 disfigured in victims who are incinerated and therefore, the maxillary sinuses can be used for identification.⁽⁹⁾ 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, maxillofacial surgery may benefit from this information.⁽¹³⁾

A primary component of any skeletal analysis is determination of age and sex. Identification of the individual from skeletal remnants and decomposing parts of human is one of the most difficult 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 identification 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 identification. Next to the pelvis, the skull is the most easily sexed portion of 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 field of identification. Visual inspection, anatomic measurement and precise measurement of bone dimensions often exceed radiologic contribution, particularly where identification 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 identification 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.

Materials and Methods

This is prospective study of 202 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 159 male and 43 females. The CBCT scans of patients who came for other reasons 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. Ethical clearance is obtained from Institutional ethical committee. 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 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. **(Fig. 1)**



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

- The Intermaxillary distance was also measured on axial reconstructed image by measuring the maximum distance between medial walls of right & left maxillary air sinuses(Fig. 2).

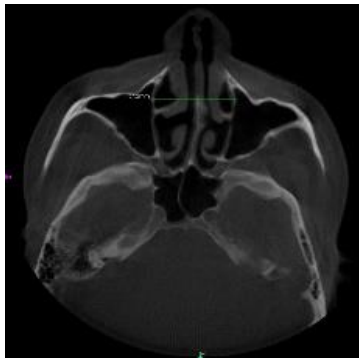


Fig. 2: CBCT (Axial sections) showing Intermaxillary distance

- 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(Fig. 3).



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

- 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 (Fig. 4).



Fig. 4: CBCT (Axial sections) showing right and left maxillary sinus width

Statistical analysis: The statistical analysis was performed using SPSS software version 16. One way ANOVA is used to study the comparison of the parameters and age groups. The unpaired t-test is used to evaluate co-relation between study parameters and sex. The linear regression analysis is performed to derive mathematical equations which are used for age prediction depending on specific parameters.

Results

The study population consists of 202 patients. The demographics of study population includes 78.7% male population however female population consists of 21.3% of study population. Most of study subjects belongs to age group 20-30 years (Table 1). The ANOVA test is used to evaluate co-relation between age group and various study parameters. It was found that There was no significant ($p > 0.05$) difference in the study parameters among the age groups (Table 2). The co-relation between study parameters and sex of study population is calculated by using Unpaired t-test. It was found that only Bizygomatic distance was significantly ($p = 0.01$) different between male and female, all other parameters were statistically non-significant ($P > .005$) (Table 3).

Table 1: Showing age and sex distribution of study subjects

Age in years	Sex					
	Male		Female		Total	
	No.	%	No.	%	No.	%
<20	11	68.8	5	31.2	16	7.9
20-30	62	77.5	18	22.5	80	39.6
31-40	60	90.9	6	9.1	66	32.7
>40	26	65.0	14	35.0	40	19.8
Total	159	78.7	43	21.3	202	100.0

Table 2: Showing correlation of study parameters with age

Study parameters	Age in years				p-value ¹
	<20	20-30	31-40	>40	
Bizygomatic distance	94.99±3.27	96.27±3.29	96.25±4.06	96.91±5.10	0.44
Intermaxillary distance	34.36±2.81	36.49±3.25	35.54±3.30	36.65±3.01	0.06
AP diameter right	37.07±3.20	36.90±3.23	37.68±4.20	36.71±3.30	0.48
AP diameter left	37.28±3.77	36.99±3.35	37.71±4.23	36.56±2.90	0.41
Maxillary sinus width right	26.76±5.59	25.25±4.45	26.67±5.44	26.01±5.09	0.34
Maxillary sinus width left	26.12±6.26	24.54±4.46	26.24±5.18	25.39±5.34	0.21

¹ANOVA test**Table 3: Showing correlation of study parameters with sex**

Study parameters	Sex		p-value ¹
	Male	Female	
Bizygomatic distance	96.66±4.14	94.97±2.87	0.01*
Intermaxillary distance	36.05±3.29	36.02±3.08	0.95
AP diameter right	37.29±3.65	36.55±3.28	0.23
AP diameter left	37.22±3.74	36.94±3.13	0.65
Maxillary sinus width right	26.27±5.01	24.91±4.93	0.11
Maxillary sinus width left	25.65±5.11	24.42±4.74	0.15

¹Unpaired t- test, *Significant

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. It was found that age prediction with only bizygomatic width is statistically non significant. However age prediction by Intermaxillary distance, Antero-posterior diameter right, Antero-posterior diameter left, Maxillary sinus width right and Maxillary sinus width left significantly predicted age.(Table 4)

Table 4: Showing the mathematical equations derived by linear regression analysis for age prediction from study parameters

Study parameters	Regression equation	p-value
Bizygomatic distance	Age=7.88+0.25 X Bizygomatic distance	0.65
Intermaxillary distance	Age=20.23+0.34 X Intermaxillary distance	0.01*
AP diameter right	Age=37.07-0.11 X AP diameter right	0.0001*
AP diameter left	Age=40.65-0.21 X AP diameter left	0.0001*
Maxillary sinus width right	Age=32.43+0.01 X Maxillary sinus width right	0.0001*
Maxillary sinus width left	Age=31.19+0.05 X Maxillary sinus width left	0.0001*

The mathematical equations for prediction of age of an individual by radiographic parameters are as follows:

- Intermaxillary distance Age=20.23+0.34 X Intermaxillary distance
- Antero-Posterior diameter right Age=37.07-0.11 X AP diameter right
- Antero-Posterior diameter left Age=40.65-0.21 X AP diameter left
- Maxillary sinus width right Age=32.43+0.01 X Maxillary sinus width right
- Maxillary sinus width left Age=31.19+0.05 X Maxillary sinus width left
- Bizygomatic distance Age=7.88+0.25 X Bizygomatic distance

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 & in female was 9.26±0.52cm & 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 & 13.07±0.77cm for female, which was very greater than our results probably due to different region & race whereas in our study also all the dimensions was statistically greater in

males as compare to females. The mean \pm SD of Bizygomatic distance in male in our study is 96.66 ± 4.14 mm and in female is 94.97 ± 2.87 mm which were significant statistically (0.01^*). Chung CS et al⁽²⁷⁾ studied that bizygomatic diameter appears to behave as a partial dominant trait & 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 study,⁽²⁸⁾ in edentulous patients, the widths 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 widths.

Jehan et al⁽²⁵⁾ suggested that The AP diameter (mean \pm SD) in male was 36.43 ± 4.26 mm which were significantly ($p < 0.05$) larger than for female which was 34.93 ± 4.14 mm. In Baweja et al⁽²⁹⁾ study the average AP diameter for male was 34.1 ± 5.1 mm & for female was 33.0 ± 5.6 mm. Studies done by Teke HY et al⁽²²⁾ had an average sinus AP diameter 43.14 ± 7.84 mm for male, 37.7 ± 5.85 mm for female and 40.42 ± 6.84 mm as the total M+F average which were larger than our results. study conducted by Sharma SK et al⁽³⁰⁾ stated that mean sinus 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 ± 2.92 mm for left side and avg was 33.39 ± 2.929 mm.

Uthman et al⁽³¹⁾ suggested that the mean value for maximum length of maxillary sinus for male group was 39.3 ± 3.8 mm for the right side and 39.4 ± 3.7 mm for the left side which was greater than that recorded 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, the AP diameter of right maxillary sinus is 37.29 ± 3.65 and for left maxillary sinus, the AP diameter is 37.22 ± 3.74 . For females the AP diameter of right maxillary sinus is 36.55 ± 3.28 and for left maxillary sinus, the AP diameter is 36.94 ± 3.13 which is statistically non-significant ($P > .005$).

Jehan et al⁽²⁵⁾ also stated that the sinus Width in Male (mean \pm SD) was 24.04 ± 4.71 mm & for Female 23.9 ± 4.38 mm which were not significant statistically.

Baweja et al⁽²⁹⁾ stated that for male was 21.8 ± 3.4 mm & for female was 21.6 ± 3.7 mm, Total (M+F) average width was 21.7 ± 3.5 mm.

Teke HY et al.⁽²²⁾ suggested that the average sinus width was 27.04 ± 5.49 mm for male, 24.36 ± 3.795 mm for female & 25.7 ± 4.64 mm as the total M+F average which were differ than our results. This difference was probably due to combination of many factors but mainly due to different ethnic & racial groups with different body stature, skeletal size, height & physique

of an individual; environmental conditions & pneumatization⁽³²⁾ process of sinus in different age & 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 ($P > .005$) greater than that of female with 23.39 ± 3.8 mm for rt side and 23.88 ± 3.89 mm for left side. Whereas in our study, sinus width for male for right side is 26.27 ± 5.01 and for left side, it is 25.65 ± 5.11 and for female it is 24.91 ± 4.93 and 24.42 ± 4.74 for right and left side of maxillary sinus width and it is found that it is statistically non-significant.

Conclusion

Bizygomatic distance is a strong dimorphic tool for sex determination by cone beam computed tomography.

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