*Original Article*

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# Bizygomatic Distance and Maxillary Sinus Dimensions as Predictors for Age Estimation: A Morphometric Analysis using Cone Beam Computed Tomography

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**Abstract**

***Aims:*** Aim of the study was to estimate, compare and differentiate the anatomical variations according to ageing in the bizygomatic distance and dimensions of maxillary sinuses on Cone Beam Computed Tomography (CBCT) images and to assess their authenticity in age estimation that might be used as an evidence in forensics.

***Settings and Design:*** CBCT images of bilateral maxillary sinus were obtained from 30 subjects, categorized into 3 groups of age ranging between 20-40, 41-50, 51-60 years.

***Methods and Material:*** Measurements such as bizygomatic distance and maxillary sinus dimensions namely length, height, width, area, perimeter and volume were evaluated.

***Statistical Analysis Used:*** The data was subjected to descriptive statistical analysis followed by Chi-square test, One way ANOVA, regression ANOVA, Pearson's correlation and Post-Hoc test.

***Results:*** The study showed a difference among mean values of different age groups but was statistically non significant. As age increased the left width, mean width of right and left maxillary sinus, left area, left perimeter, left volume and right and left mean volume of maxillary sinus decreased linearly and significantly with significant P values. The regression ANOVA revealed that volume is the true predictor of age of the subjects.

***Conclusion:*** Age estimation with few linear measurements of maxillary sinus dimensions was possible among the study population. It was found that as the age increased few of the maxillary sinus dimensions decreased. Hence this study positively recommends the use of maxillary sinus dimensions for the purpose of age estimation in the field of forensics.

**Keywords:** Age estimation; Bizygomatic distance; Cone Beam Computed Tomography; Maxillary sinus.

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## Introduction

Forensic anthropology is the application of the medical science in criminal law.[1] No two radiographs are alike,[2] paranasal sinuses show minute changes among the age groups radiographically. It is proved in few studies that when the different bones are severely mutilated among fatalities the maxillary sinus and zygomatic bone will remain intact.[3,4]

Cone Beam Computed Tomography (CBCT), is used as standard imaging modality for the visualization of structures in multiple planes with thin sections.[5] This study was undertaken to establish if any anatomical variation exists in the bizygomatic distance and maxillary sinus dimensions according to ageing.[6]

## Materials and Method

A prospective observational study performed on 30 apparently healthy subjects of age ranging between 20 - 60 years selected by the simple purposive sampling method and for those subjects who were advised CBCT imaging as a protocol for assessment of any maxillofacial conditions without evidence of any developmental defects or trauma to head and neck region with no evidence of midfacial fracture. The study samples were categorized into 3 different age groups. Group 1: 20-40 years. Group 2: 41-50 years. Group 3: 51-60 years.

## Eligibility Criteria

### *Inclusion criteria*

- Subjects without malocclusion and without previous history of orthodontic treatment.
- Radiographs free from the developmental anomalies, pathology and malunion of fractures affecting the bones of the maxillofacial region.
- Radiographs free from any artefacts.

### *Exclusion criteria*

- Subjects without full complement of completely erupted maxillary teeth with or without the third molars.
- Ideal CBCT images with poor diagnostic quality, and images not clearly showing the maxillae including maxillary sinuses and the zygomatic arch.

## Method

The clinical examination was carried out after procurement of the written informed consent from the selected subjects and the clinical findings were recorded in individual proforma specially designed for the study. Individuals satisfying the eligibility criteria were then subjected to CBCT examination at fixed operating parameters according to their built.

The requisite radiation protection measures were followed during the examination. Linear measurement of bizygomatic distance and measurements on axial and coronal sections for both right and left maxillary sinuses were performed using Planmeca Romexis 5.3 (3D Software). (Fig. 1) (Fig. 2) (Fig. 3) (Fig. 4)

The same observer repeated each of these measurements twice at an interval of 15 days each and the average was taken into consideration in order to overcome the intra examiner variability. Other parameters like area, perimeter and volume were calculated by using the following formula.

Area = Length x Width ($cm^2$)

Perimeter = 2 x Length + 2 x Width (cm)

Volume = Length x Width x Height x ½ ($cm^3$)

### *1. Bizygomatic Distance*

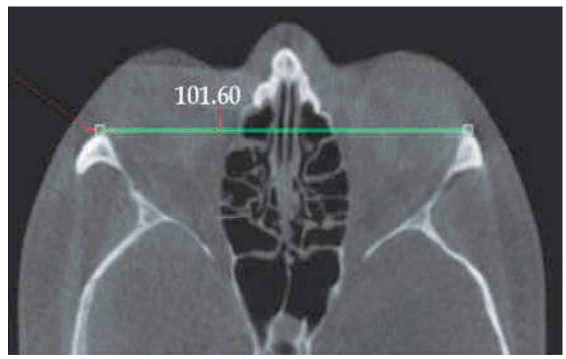



**Fig. 1:** Bizygomatic distance.

The bizygomatic width: Maximum distance between the most prominent points on both right side and left side zygomatic arches on axial images.

### *2. Maxillary sinus dimesnsions*

*(a) Length of the maxillary sinus*

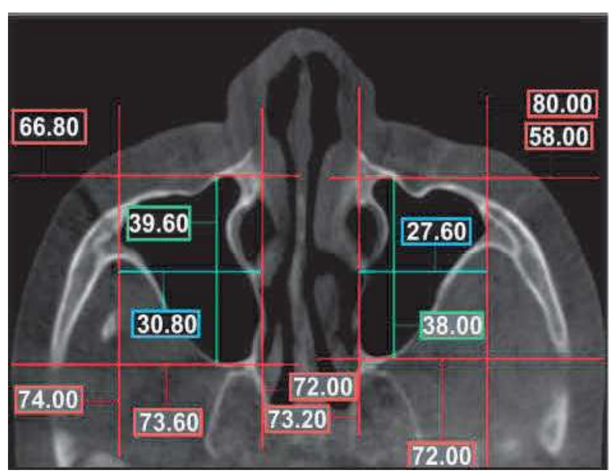



**Fig. 2:** Length of the maxillary sinus.

The length of the maxillary sinus: Longest anteroposterior distance from the point most anteriorly to the point most posteriorly on axial sections.

***(b) Height of the maxillary sinus***

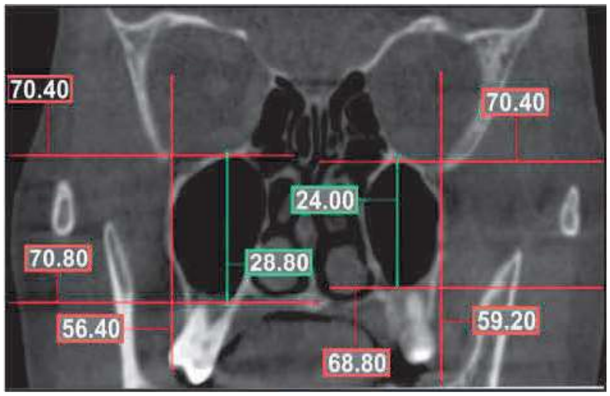



**Fig. 3:** Height of the maxillary sinus.

The height of the maxillary sinus: Longest distance from the point most inferiorly on the sinus floor to the point most superiorly on the sinus roof in the coronal sections.

***(c) Width of the maxillary sinus***

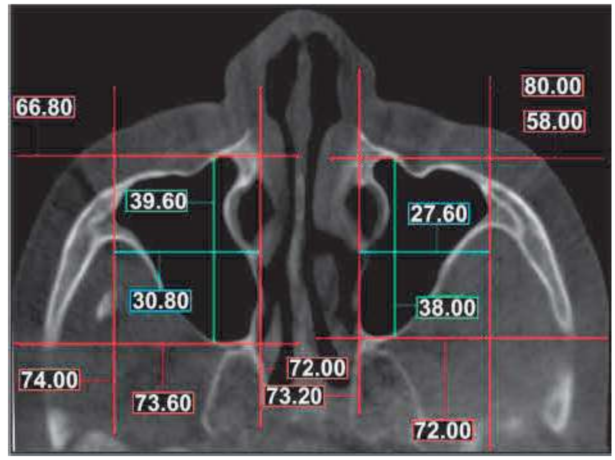



**Fig. 4:** Width of the maxillary sinus.

The width of the maxillary sinus: Longest distance perpendicularly from the medial wall of the

**Table 1:** Comparison of Age with bizygomatic distance and various parameters of right and left maxillary sinus.

| Age | 20-40 Years | | | 41-50 Years | | | 51-60 Years | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | n | Mean | Std deviation | n | Mean | Std deviation | n | Mean | Std deviation | F | P |
| Bizygomatic distance | 10 | 94.9530 | 5.55256 | 10 | 94.6140 | 5.03540 | 10 | 92.1100 | 5.77827 | 0.808 | 0.456 |
| MS right length | 10 | 40.0600 | 4.10317 | 10 | 38.8820 | 3.57990 | 10 | 37.3600 | 3.07072 | 1.407 | 0.262 |
| MS left length | 10 | 40.0400 | 3.82483 | 10 | 38.6840 | 3.97182 | 10 | 36.9010 | 4.11261 | 1.571 | 0.226 |
| Mean of right & left length | 10 | 40.0500 | 3.88652 | 10 | 38.8610 | 3.55795 | 10 | 37.1300 | 3.42346 | 1.638 | 0.213 |
| MS right height | 10 | 36.4400 | 6.09393 | 10 | 34.6410 | 5.15764 | 10 | 31.5400 | 4.03986 | 2.302 | 0.119 |
| MS left height | 10 | 37.3600 | 6.40888 | 10 | 35.0420 | 6.51138 | 10 | 31.0600 | 5.52171 | 2.673 | 0.087 |
| Mean of right & left height | 10 | 36.9000 | 6.20054 | 10 | 34.8400 | 5.65591 | 10 | 31.3000 | 4.56095 | 2.638 | 0.090 |
| MS right width | 10 | 30.6000 | 3.79122 | 10 | 30.9250 | 3.84380 | 10 | 26.9620 | 4.79530 | 2.785 | 0.079 |
| MS left width | 10 | 31.5400 | 2.12927 | 10 | 30.0000 | 4.85890 | 10 | 26.9000 | 5.07127 | 3.111 | 0.061 |
| Mean of right & left width | 10 | 31.0700 | 2.66835 | 10 | 30.4620 | 4.16805 | 10 | 26.9310 | 4.85742 | 3.116 | 0.061 |
| MS right area | 10 | 1235.4200 | 254.54554 | 10 | 1212.4400 | 250.09712 | 10 | 1036.7340 | 274.76075 | 1.747 | 0.193 |
| MS left area | 10 | 1267.1400 | 187.88496 | 10 | 1147.8100 | 328.30694 | 10 | 1008.5160 | 288.42007 | 2.221 | 0.128 |
| Mean of right & left area | 10 | 1251.1400 | 210.00121 | 10 | 1179.7650 | 286.33432 | 10 | 1022.4890 | 277.99042 | 2.019 | 0.152 |
| MS right perimeter | 10 | 142.9200 | 15.11561 | 10 | 139.6140 | 14.17903 | 10 | 128.6040 | 15.16828 | 2.555 | 0.096 |
| MS left perimeter | 10 | 143.1600 | 10.80979 | 10 | 137.2880 | 16.77773 | 10 | 127.4400 | 17.94926 | 2.627 | 0.091 |
| Mean of right & left perimeter | 10 | 143.0000 | 12.18159 | 10 | 153.9640 | 56.73754 | 10 | 128.0000 | 16.11652 | 1.405 | 0.263 |
| MS right volume | 10 | 23806.4000 | 9035.15989 | 10 | 21453.2000 | 6914.38147 | 10 | 16452.4000 | 5635.92089 | 2.625 | 0.091 |
| MS left volume | 10 | 24531.5000 | 7948.44279 | 10 | 21212.1000 | 8763.71119 | 10 | 16202.0000 | 6895.74774 | 2.813 | 0.078 |
| Mean of right & left volume | 10 | 24168.8000 | 8264.98390 | 10 | 21332.4000 | 7718.24145 | 10 | 14275.2000 | 7050.09746 | 4.385 | 0.022 |

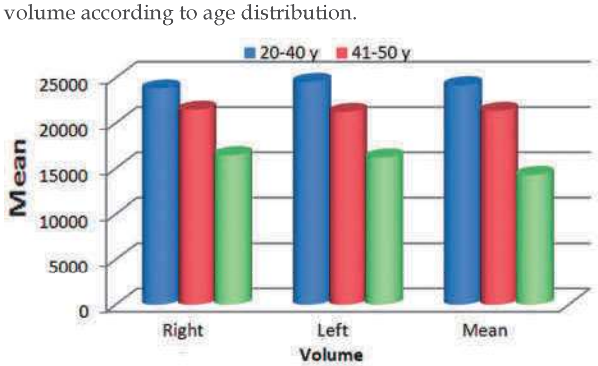
maxillary sinus to the outermost point on the lateral wall of the lateral process on axial sections. The obtained data were tabulated and then subjected to statistical analysis, comparision was made between both the right and the left maxillary sinuses of the same individual and between the age groups respectively using SPSS software version 22.0. The data obtained was then subjected to descriptive statistical analysis followed by Chi-square test, One-way ANOVA, Pearson's correlation and Post-Hoc test to arrive at the results.

### Results

Of the 30 subjects, 15 (50%) were males and 15 (50%) were females. Each age group comprised of 05 (25%) males and 05 (25%) females with a mean age of 43.1333 for males and 41.8667 for females. The mean value of bizygomatic distance among group 1 (20-40 years) was 94.9530, group 2 (41-50 years) was 94.6140 and group 3 (51-60 years) was 92.1100. There were differences in the mean values between the groups but were statistically non-significant with P>0.05. The comparison was made within groups and between groups with ANOVA test for right and left maxillary sinus length, height, width, area, perimeter and volume along with their means.

Even though the differences were noted in the mean squares, it was statistically nonsignificant with P>0.05. Whereas, the mean volume of both right and left side sinus showed significant difference and was proven statistically significant with P<0.05, with means of 24168.8000cm3 in 20 to 40 years, 21332.4000 cm3 in 41 to 50 years and 14275.2000 cm3 in 51 to 60 years. Hence it was proved that as the age increases the volume of the sinus decreases. (Table 1)

**Graph 1:** Graph depicting mean values of maxillary sinus volume according to age distribution.

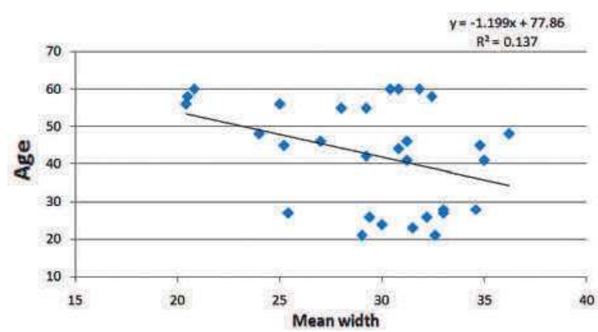



On application of Pearson's correlation, as the age increased the left width, left area, left perimeter, left volume and mean width and volume of right and left maxillary sinus decreased linearly and significantly with significant P<0.05. (Table 2)

**Table 2:** Pearson's correlation test for comparison between age and various parameters.

| Variable 1 | Variable 2 | Pearson Correlation | N | Sig. (2-tailed) |
|---|---|---|---|---|
| Age | Bizygomatic distance | -0.145 | 28 | 0.445 |
| Age | Right width | -0.286 | 28 | 0.126 |
| Age | Left width | -0.422 | 28 | 0.020 |
| Age | Mean width | -0.371 | 28 | 0.044 |
| Age | Right length | -0.277 | 28 | 0.138 |
| Age | Left length | -0.282 | 28 | 0.131 |
| Age | Mean length | -0.289 | 28 | 0.121 |
| Age | Right height | -0.325 | 28 | 0.080 |
| Age | Left height | -0.346 | 28 | 0.061 |
| Age | Mean height | -0.344 | 28 | 0.063 |
| Age | Right area | -0.262 | 28 | 0.163 |
| Age | Left area | -0.365 | 28 | 0.048 |
| Age | Mean area | -0.323 | 28 | 0.082 |
| Age | Right perimeter | -0.342 | 28 | 0.064 |
| Age | Left perimeter | -0.377 | 28 | 0.040 |
| Age | Mean perimeter | -0.180 | 28 | 0.342 |
| Age | Right volume | -0.336 | 28 | 0.069 |
| Age | Left volume | -0.371 | 28 | 0.043 |
| Age | Mean volume | -0.439 | 28 | 0.015 |

**Graph 2:** Graph depicting Pearson's correlation between maxillary sinus mean width and age.




**Graph 3:** Graph depicting Pearson's correlation between maxillary sinus mean volume and age.

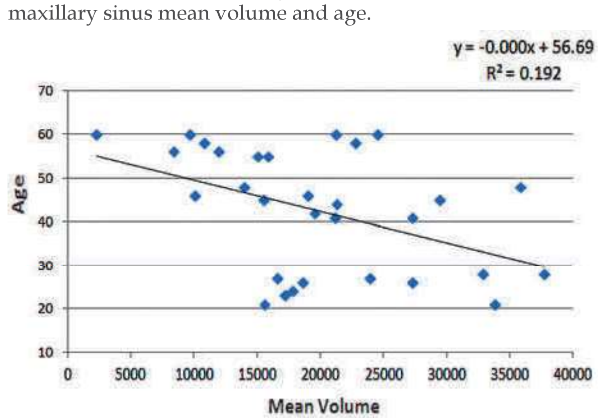


**Table 3:** Regression ANOVA.

***Model Summary***

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .439a | .192 | .164 | 12.68510 |

a. Predictors: (Constant), Mean volume.

ANOVA

| Model | Sum of Squares | DF | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 1073.973 | 1 | 1073.973 | 6.674 | .015b |
| Residual | 4505.527 | 28 | 160.912 | – | – |
| Total | 5579.500 | 29 | – | – | – |

a. Dependent Variable: Age

b. Predictors: (Constant), Mean volume

**Coefficients**

| Model | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (Constant) | 56.691 | 5.961 | – | 9.510 | .000 |
| Mean volume | -.001 | .000 | -.439 | -2.583 | .015 |

a. Dependent Variable: Age

16.4% of the right and left mean volume predicted the age of the selected sample out of 6 variables entered into the equation. Remaining variables like width, length, height, area and perimeter did not predict the age of the sample selected. The regression ANOVA revealed F value 6.674 with P value of 0.015 confirming that volume is the true predictor of age of the subjects with the beta value of -0.439 with the significance level of 0.015.

## Discussion

In the field of forensic anthropology, the age estimation by morphological valuation is been considered to be the oldest procedures.[7] Identification of the human skeleton remains is one of the important challenging steps in forensics. Bizygomatic distance and maxillary sinus dimensions show high variability in its linear measurements in each individual according to sex and different age groups. In the present scenario, judicial demand for age estimation is being increased as there is increase in the criminal cases. Age estimation is considered to be one of the definitive procedures after the sex determination in the field of forensics as the estimation of age forms a major inchoative step in the identification of deceased person that helps in narrowing down the prediction of an unidentified cadaver in the direction of a precise possibility. In the field of forensics, the common procedures in post-mortem for identification include general external examination with complementary biological methods and radiographic methods.[8] Individual identity is based on their age, sex, ethnicity, and appearance that includes height, weight, hair colour, skin colour, cornea, facial profile etc.[9]

According to few literature reviews, it is stated that the accuracy rate of age estimation from the skeleton is 92%8,7 as it can anatomically withstand heavy injuries. Almost all craniofacial structures are being comparatively non-breakable as they are composed of hard tissues, because of which the possibility of getting intact maxillary sinus and zygomatic complex without deformity is very high. Henceforth the present study was outlined based on the above background in order to determine the reliability of the bizygomatic distance and dimensions of maxillary sinus as a tool for age estimation by using CBCT images of 30 subjects of age ranging between 20-60 years categorized into 3 different age groups.

Another study was conducted on 60 patients reporting to the Department of Radiology, Mamata General Hospital, Khammam. MRI of the brain and paranasal sinuses were obtained. Later the dimensions of maxillary sinus were measured by using Siemens software followed by statistical analysis. The estimation of age by utilizing the volume of maxillary sinus demonstrated no significant difference statistically from the actual age of the study subjects. The authors concluded that the dimensions and volume of the maxillary sinuses was found to be larger in males when compared to females, upon which they tend to be lesser with the increase in age.[10]

In a study which was carried out in Alexandria University with 82 CBCT scans of Egyptian patients aged between 20-65 years, designed to measure the height, width and length of maxillary sinus bilaterally on both the axial and coronal sections using On-Demand®software. No statistically significant differences were established in maxillary sinus measurements between different age groups. They concluded that the linear measurements of the maxillary sinus on the images of CBCT cannot be utilized for age estimation.[11]

In contradictory to this study our study showed positive results in regard to age estimation. There was a positive association noted between the age of the individual and few parameters of maxillary sinuses. As the age increased the left width, left area, left perimeter, left volume and mean width and volume of right and left maxillary sinus decreased linearly and significantly with significant P values < 0.05. Hence, the differences in few of the study results obtained for age estimation with bizygomatic distance and dimensions of the maxillary sinus may be ascribed to the combination of numerous features like sample size, the difference in ethnic groups and racial groups, size of skeletal components, variations in stature of body, their physique and height, environmental and genetic factors, anatomical differences of the sinus and zygomatic complex, variations in the osteoclastic and osteoblastic activity and the pneumatization process of the sinus.[3,6]

In the current study, we primarily aimed at whether bizygomatic distance and maxillary sinus dimensions are good predictors for age estimation. Further studies can be undertaken with larger sample size for its accuracy rate. Research works in the field of forensics is being carried out since many years on both the living population and non-living things for various investigative purposes. Radiographic images are considered to be the best vital tool for age estimation in the field of forensic sciences. Out of many, the measurements of the bizygomatic distance and the maxillary sinus are of at most important as these can be considered as stable indicators even when the skull is severely destructed. The results obtained in the present study revealed that the Bizygomatic distance cannot be used as a tool for age estimation, but maxillary sinus dimensions show anatomic variations between different age groups of which few parameters were statistically significant. Therefore, it is concluded that the linear measurements on CBCT images with significant differences among different age groups can be used in forensic anthropology as a valuable tool for the estimation of age. Hence these measurements are supported for providing evidence in the field of forensics, to enhance the accuracy of estimation made by other means particularly when other skeletal structures are unobtainable. As this study was a time-bounded study only the best possible sample size was taken into consideration. Further studies with larger sample size have to be considered to authenticate the present findings.

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