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Bizygomatic distance as a predictor of age and sex determination: a morphometric analysis using cone beam computed tomography

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SUMMARY

Despite advancements in diagnostic technologies, one of the most challenging tasks in forensic medicine is the identification of skeletal and decomposing body parts of the deceased. Estimating gender and age is also a significant issue in the identification of unknown skulls. The aim of the present study was to estimate the sexual dimorphism and variations occurring with ageing in bizygomatic distance. This was a prospective observational study performed on 180 subjects, comprising 90 males and 90 females. Linear measurements of bizygomatic distance were evaluated using cone-beam computed tomography. The study showed that there was significant difference in bizygomatic distance among different age groups and gender, with males depicting comparatively higher values than females. The results obtained were statistically significant. It was concluded that the linear measurements of bizygomatic distance on CBCT images can be used in forensic anthropology as an aid for the determination of age and sex.

Key words: Forensic science – Cone beam computed tomography – Forensic anthropology – Sex determination – Zygomatic arch

INTRODUCTION

Forensic odontology has been used to identify victims of major catastrophes (aviation, earthquakes, and tsunamis), in criminal investigations, ethnic studies, and in identifying the decomposed and disfigured bodies of drowned people, fire victims, and car accident victims. Rugoscopy, cheiloscopy, bite marks, teeth prints, radiography, photographic analysis, and molecular approaches are some of the techniques used in forensic odontology (Kavitha et al., 2009). Despite advancements in diagnostic technologies, one of the most challenging tasks in forensic medicine is the identification of skeletal and decomposing body parts of the deceased (Jehan et al., 2014). When the remains are decomposed or burnt, the DNA is destroyed; when there are no previous dental records, forensic anthropology becomes the

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preferred technique to aid in person identification (Nunes Rocha et al., 2021). Estimating gender and age is also a significant issue in the identification of unknown skulls (Jehan et al., 2014).

Unknown deceased bodies are difficult to identify, and it has serious legal and social consequences. Comparison of X-ray images of the deceased with those of missing individuals is a means of appropriate identification, especially after significant post-mortem alterations (Jehan et al., 2014; Riepert et al., 2001). However, if significant post-mortem alterations have occurred, routine forensic procedures for person identification may be futile (Teke et al., 2007).

Various parameters, including the circumference of the head, the length of the supraorbital margin, the mastoid process and the mandibular ramus, the height of the mandibular symphysis, the shape and length of the palate, the circumference of the occipital condyle, the size of the teeth, the foramen magnum, the maxillary, sphenoid, and frontal sinuses, the bizygomatic distance, and the sella turcica, have lately been used to identify age and gender in unidentified human remains (Teke et al., 2007; Uthman et al., 2012).

Because of bone fragmentation, identification can be particularly difficult in mass disasters like explosions, warfare, accidents, etc. The skull, pelvis, and femur are the most effective for determining age and sex. Radiography can help by providing precise measurements to which equations can be applied for age estimation as well as sex determination (Uthman et al., 2012). Since most of the bones that are used conventionally for sex determination are typically fractured or partial when recovered, it has become important to employ denser bones that are more frequently retrieved intact (Jehan et al., 2014; Mathew et al., 2020). Although the skull and other bones may be extensively disfigured in victims, the zygomatic bones and maxillary sinus have been reported to be intact (Jehan et al., 2014; Paknahad et al., 2017; Sujatha et al., 2017; Aishwarya et al., 2021).

Teeth and facial bones are resilient in the human body and may resist decomposition or destructional pressures even when subjected to high forces and/or temperature fluctuations (Kumar et al., 2015). Radiographs are a useful tool in forensic sciences, as they can record particular anatomical features. Radiographic identification has been used for a long time, and the process is efficient and relatively simple. Records can be obtained from both live and deceased people, and it is less expensive than DNA technology (Kumar et al., 2015). In forensic anthropology, several radiographic techniques, such as measurements on dry skulls, conventional radiography, computed tomography (CT), and cone-beam computed tomography (CBCT), have been used to assess various parameters for determining an individual's sex and age (Paknahad et al., 2017; Abu El Dahab et al., 2018). CBCT is a new way to look at craniofacial structures with great dimensional accuracy (Paknahad et al., 2017; Abu El Dahab et al., 2018). CBCT has been also used in a number of investigations, including 3D reconstruction, bitemark analysis, age estimation, person identification and anthropological assessment, with promising results (Tambawala et al., 2016). In much of the literature on maxillary sinus dimensions and bizygomatic distance, it has been proved that these can be used in age estimation and sex determination. These structures are well appreciated in CBCT images (Aishwarya et al., 2021).

The purpose of this study is to evaluate the reliability of bizygomatic distance as a predictor for age and sex determination of an individual using CBCT imaging.

MATERIALS AND METHODS

This is a prospective observational study performed on 180 subjects, comprising 90 males and 90 females. The study samples were selected by a simple purposive sampling method. The population origin of the sample is homogeneous. Ethical clearance of the study has been obtained from the Institutional Ethical Committee. The study subjects were then divided into 3 groups based on chronological age, and each group was comprised of 30 males and 30 females.

Group I: 20-40 years (30 males and 30 females).

Group II: 41-50 years (30 males and 30 females).

Group III: 51-60 years (30 males and 30 females).

Eligibility criteria

Inclusion criteria

- Subjects willing to be part of the study signed an informed consent form.
- Subjects without malocclusion and without a previous history of orthodontic treatment.
- Radiographs are devoid of any developmental anomalies or pathologies, including fractures.
- Radiographs that are free of any artefacts.

Exclusion criteria

- Subjects with missing or partially erupted maxillary teeth other than the third.
- Ideal CBCT images with poor diagnostic quality and images that do not clearly show the maxilla, including the zygomatic arch.
- Radiographs with any maxillofacial pathologies or trauma.

A clinical examination was carried out after obtaining written informed consent from the subjects eligible for the study. Clinical findings were recorded in an individual proforma specially designed for the study. Individuals satisfying the eligibility criteria were subjected to CBCT examinations at fixed operating parameters based on the build of the subject by adopting the requisite radiation protection measures. Linear measurements of bizygomatic distance were performed on axial sections using Planmeca Romexis 5.3 (3D Software).

Each of these measurements was repeated twice by the same observer at an interval of 15 days. An average of these measurements was taken into consideration to avoid intra-examiner variations.

Bizygomatic distance

Bizygomatic width is measured as the maximum distance between the most prominent points on the right and left zygomatic arches on an axial section (Fig. 1, an axial section showing maximum bizygomatic distance).

Statistical analysis

The collected data was tabulated and statistically analysed, and a comparison was made between different age and sex groups. The mean value, SD, p value, and t value were calculated separately. The collected data was then subjected to descriptive statistics, one-way ANOVA, and independent

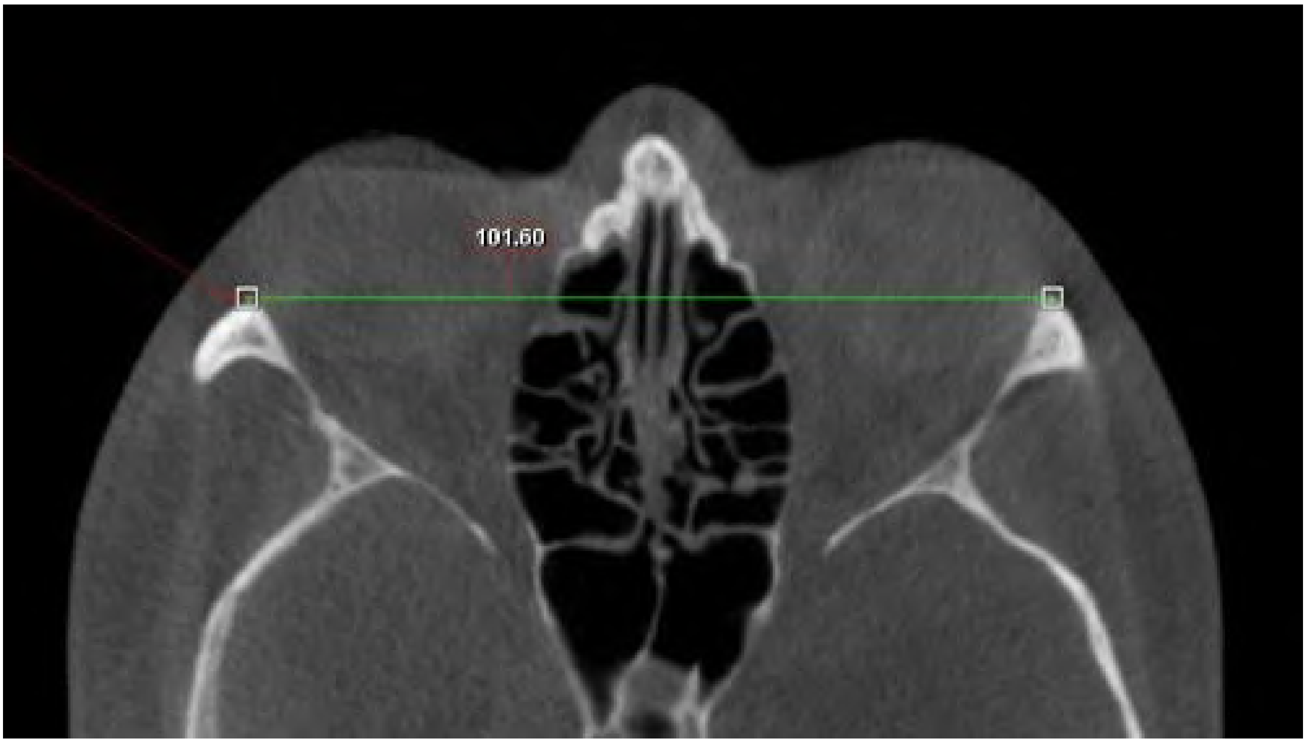

Fig. 1.- An axial session showing maximum bizygomatic distance.

sample tests. p value of less than or equal to 0.05 was considered to be statistically significant. The statistical analysis was performed using SPSS software version 22.0.

RESULTS

The study population consisted of 180 patients, of which 90 (50%) were males and 90 (50%) were females. The mean value of bizygomatic distance in Group I, Group II and Group III were calculated separately and subjected to statistical analysis.

Age

The mean values of the bizygomatic distance among Group I, Group II, and Group III were 94.9530, 94.6140, and 92.2085, respectively (Table 1 indicates comparison of mean bizygomatic distance between different age groups). The highest mean value of bizygomatic distance was observed in Group I. The data collected when subjected to one-way ANOVA to evaluate co-relation between age group and study parameter (bizygomatic distance) were statistically significant with a p value of 0.008 (Table 2 indicates correlation of bizygomatic distance with age groups). There was a significant difference in bizygomatic distance among the age groups.

Sex

The mean value of the bizygomatic distance was calculated for males (n = 90) and females (n = 90). The mean value among males was 97.0693 and among females was 90.7810, with a standard deviation of 4.75505 for males and 3.75127 for females (Table 3 indicates comparison of mean of bizygomatic distance between males and females). The correlation between the bizygomatic distance and sex of the study population was calculated using an independent sample t-test. A significant difference was noted in the bizygomatic distance between males and females, with males depicting comparatively higher values than females. The results obtained were statistically significant, with p = 0.00 and t = 9.850 (Table 4 shows the correlation of bizygomatic distance with sex).

Regression ANOVA

Independent variable: Age

The results when subjected to regression ANOVA (Table 5 – depicting regression ANOVA) with age as the independent variable, revealed an F value of 3.256 with a p value of 0.073. Regression ANOVA showed no significant difference between age and bizygomatic distance.

DISCUSSION

Forensic science has made a lot of progress in a short period of time. Identity is described in the realm of forensic science as the identification of a person's individuality, whether living or dead (Rao, 2010). Age, sex, ethnicity, and physical characteristics such as weight, height, complexion, cornea, hair colour, and facial contour can be all used to identify a person. Bizygomatic distance shows a wide range of variability in each

Table 1. Comparison of mean bizygomatic distance between different age groups (descriptive statistics).

Age groups	N	Mean	SD	Std Error
Group I 20-40	60	94.9530	5.31207	.68579
Group II 41-50	60	94.6140	4.81731	.62191
Group III 51-60	60	92.2085	5.43289	.70138

N= number of subjects, SD= Standard deviation

Table 2. Correlation of bizygomatic distance with age groups (One way ANOVA).

	Sum of Squares	df	Mean Square	F value	P value
Between Groups	268.673	2	134.336	4.979	.008

df= degrees of freedom

Table 3. Comparison of mean of bizygomatic distance between males and females (descriptive statistics).

Parameter	Sex	N	Mean	SD	Standard Error
Bizygomatic distance	M	90	97.0693	4.75505	.50123
	F	90	90.7810	3.75127	.39542

N= number of subjects, SD= Standard deviation

Table 4. Correlation of bizygomatic distance with sex (independent sample test).

Parameter	t	df	Sig. (2-tailed)	Mean Difference
Bizygomatic distance	9.850	178	.000	6.28833

t= t value, df= degrees of freedom, Sig= significance probability

Table 5. Regression ANOVA.

	Sum of Squares	df	Mean Square	F value	Sig.
Regression	90.605	1	90.605	3.256	.073
Residual	4953.577	178	27.829		
Total	5044.182	179			

The independent variable is Age. df= degrees of freedom, Sig= significance probability

individual according to different age groups and sex (Aishwarya et al., 2021). According to a few studies, the accuracy rate of estimating age from a skeleton is 92% since it can anatomically tolerate major traumas (Aishwarya et al., 2021).

The current study was designed to investigate the reliability of the bizygomatic distance as a method for age estimation and sex determination by utilizing Cone-Beam Computed Tomographic (CBCT) images of 180 subjects comprising of 90 males and 90 females.

Riepert et al. (2001), in their study on the identification of unknown dead bodies by x-ray image comparison of the skull using the x-ray simulation programme FoXSIS, aimed at enhancing the objectivity of X-ray image comparison for identifying unidentified deceased people. The results of the study concluded that the skull breadth, biorbital breadth, and bizygomatic breadth were the most consistent parameters throughout different positions (Kavitha et al., 2009).

In a study by Jehan et al. (2014) on sexual dimorphism of the bizygomatic distance and maxillary sinus using CT scan, to the aim was find out whether the bizygomatic distance, the AP diameter and breadth of the maxillary sinus, and the intermaxillary distance could be used to determine gender using a CT scan. A statistically significant difference was observed in the bizygomatic distance between males and females. In the current study, CBCT was used to measure the bizygomatic distance, and the results obtained were consistent with this study and were statistically significant with a p value of 0.00.

Abu El Dahab and colleagues (2018), in their study to investigate the possibilities of sex identification using radiographic maxillary sinus measurements in an Egyptian population sample, found that all measurements of males showed higher mean values than females. In their study, the mean value of bizygomatic distance among males was 93.5, and among females it was 88.7, which has proved statistical significance. These results were consistent with the results obtained in our study, wherein the mean value among males was 97.06, and among females was 90.78. The results showed a statistically significant difference between males and females.

Mathew et al. (2020), in their study on 3D evaluation of the maxillary sinus in gender determination, a cone beam computed tomography study found that the overall values of maxillary sinus dimensions measured, including bizygomatic distance, were significantly greater in males when compared to females with $p < 0.05$ (Mathew et al.,2020). The results obtained in the present study also showed similar results, with higher values of bizygomatic distance in males than in females.

A study on morphometric evaluation of bizygomatic distance and maxillary sinus width as a dimorphic tool using CBCT by Chaurasia et al. (2016), conducted in 202 study subjects, revealed a statistically significant difference in bizygomatic distance between males and females, but no statistical difference was observed among different age groups. These results were in accordance with our present study, where a significant difference was noted in the bizygomatic distance between males and females, with males depicting comparatively higher values than females. There was a significant difference in bizygomatic distance among the different age groups.

In a study by Meral et al. (2021) on estimation of sex from computed tomography images of skull measurements in an adult Turkish population, they evaluated the skull measurements of 300 males and 300 females. Maximum cranial length, maximum cranial breadth, bimastoid diameter, bizygomatic diameter, and bigonial breadth were measured by computed tomography. They found a significant difference between males and females with an accuracy of 88%. Results of the present study were in accordance with this previous study with a significant difference in bizygomatic distance between males and females.

González-Colmenares et al. (2019), in their study on sex estimation from skull base radiographs in a contemporary Colombian population, measured five parameters, including maximum cranial base length, foramen magnum length and breadth, maximum cranial breadth, and bizygomatic breadth. Sexual dimorphism was observed in all the variables statistically, whereas in the present study only bizygomatic distance was considered, which showed sexual dimorphism.

In our previous study on bizygomatic distance and maxillary sinus dimensions as predictors for age estimation using CBCT, the results showed a difference in mean values among different age groups, although it was statistically non-significant (Aishwarya et al., 2021). But the results of the present study showed a significant difference in bizygomatic distance among the age groups, and the results were statistically significant with a p value of 0.008.

CONCLUSION

The current study sought to determine whether bizygomatic distance could be used as a good predictor of age and gender. The results obtained in the present study revealed that bizygomatic distance shows anatomical variations between different ages groups and sex groups. Males revealed statistically significant higher values than females. The bizygomatic distance also showed significant difference among different age groups. Therefore, it can be concluded that the linear measurements of bizygomatic distance on CBCT images can be used in forensic anthropology as an aid for age estimation and sex determination. Interpopulation differences do not allow establishing a range of standardized measurements.

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