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Sexual dimorphism of human crania – An osteometric analysis

Anadi Gupta[1], Tanuj Kanchan[2*], Raghvendra Singh Shekhawat[3], Kewal Krishan[4]

[1]Former Intern, Kasturba Medical College, Mangalore, Manipal University, India
[2]Associate Professor, Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, Jodhpur
[3]Senior Resident, Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, Jodhpur
[4]Associate Professor, Department of Anthropology, Panjab University, Sector-14, Chandigarh, India

* Corresponding author: Dr. Tanuj Kanchan, MD, Associate Professor, Department of Forensic Medicine, All India Institute of Medical Sciences, Jodhpur, India · tanujkanchan@yahoo.co.in

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ABSTRACT

Estimation of sex from skeletal remains is a challenging task for the forensic experts. The aim of the present research was to study the sex differences in human crania based on osteometric analysis. The study was conducted on a total of 118 human crania. It was observed that the Maximum Cranial Length, Inter Orbital Breadth, Biorbital Breadth, Maxillo Alveolar Breadth, Maxillo Alveolar Length, Bizygomatic Breadth and NasionProsthion Length are the parameters which are statistically significant and better determinants of sex than the other parameters taken into consideration. Maximum Cranial Breadth and Orbital Height are observed to be poor determinants of sex.

Keywords: Forensic Anthropology, Skeletal Remains, Cranium, Sexing, Identification

Introduction

Amongst the most challenging and cumbersome tasks a forensic anthropologist encounter, the one of determination of sex of skeletal remains has a pivotal merit. Such situations may arise in a multitude of medico-legal circumstances like mass disasters, archeological excavations, criminal cases and investigations relating to human right infringements. Determination of sexual dimorphism remains an essential task in the forensic case work, as this information can reduce

search out population by nearly half(1, 2).Sexing of the remains is highly reliable if complete skeleton is available for examination. Many times however, a part of the skeleton or an individual bone is brought for examination. Hence, there arises a need to study the various skeletal elements individually for studying sexually dimorphic characteristics. It has been documented in various studies that sexing based on cranial analysis has an accuracy rate of 85-95%(3). The bony characteristics which are used to determine sexing of skeletal remains gets influenced by varying phases, duration and patterns of adolescent growth. It has been documented that males have a longer and more intense adolescent growth spurt than females(4).

Thetwoapproaches to sex determination are based on the visual assessment of the shape or relative portions of sexually dimorphic features and the metric approach(5-7). The metric approach is more objective and less dependent on observer experience. Moreover, its replicability in forensic investigations is high. The present research is conducted to study the sexual dimorphism of human crania of Indian origin based on craniometric analysis.

Material and Methods

This osteometric study wasconductedon the dry skulls at Kasturba Medical College, Mangalore, Manipal University, India. An approval was obtained from the Institutional Ethics Committee prior to conducting the study. All the intact crania showing distinct sexually dimorphic traits on visual examination were included in the study.Thecraniawith ambiguous sexually dimorphictraitson visual examination / damaged / deformed were excluded from the study. A total of 118 crania that met the criteria were included in this study that included 68 males and 50 females.

A total of 10 measurements were taken into consideration. Standard landmarks and instruments wereusedin obtaining the various measurementson the crania accurately. The measurements were taken using standard anthropometric instruments; sliding callipers and verniercallipers.Thelandmarksincluded in the study were; Dacryon, Ectoconchion, Eurion, Nasion, Prosthion, Zygion, Glabella, Opisthocranion, Alveolon, Basion, Ectomolare, Opisthion. The measurements included in the study are shown in **Figure 1** and described as:

Maximum Cranial Length(MCL): distance between opisthocranion and glabella

Maximum Cranial Breadth(MCB): distance between both the eurions

Inter Orbital Breadth(IOB): distance between both the dacryons

BiorbitalBreadth(BOB): maximum distance between outer and lateral margins of orbital rims

Orbital Breadth(OB): distance between lateral and medial border of the orbit

Orbital Height (OH): distance between the superior and inferior border of the orbit

NasionProsthionLength(NPL): distance between nasion and prosthion

BizygomaticBreadth(BZB): distance between two zygions

Maxillo Alveolar Breadth(MAB): distance between two ectomolares

Maxillo Alveolar Length(MAL): distance between alveolon and prosthion

The data wasanalysed using SPSS version 16.0 software.Student's t- test was employed to study the sex differences in cranial measurements. p-value< 0.01 was considered as significant. Index of sexual dimorphism for each parameter was obtained by the formula;

$$Index\ of\ sexual\ dimorphism = \frac{Male\ mean\ value\ x\ 100}{Female\ mean\ value}$$

The deviation from 100 indicates at the level of sex differences in the study sample.

Results

In the present investigation, the maximum cranial length was found to be significantly larger in males ($p< 0.001$). Maximum cranial breadth was found to be larger in males too; the male- female differences however, were not significant.Inter Orbital Breadth was found to be significantly larger in females ($p< 0.001$),biorbital Breadth on the other hand was significantly larger in males ($p< 0.001$). Orbital breadth ($p=0.042$) and orbital height ($p=0.684$) did not show any significant male-female differences.Maxillo Alveolar Breadth and Maxillo Alveolar Length were larger in males than in females and showed statistically significant sex-differences($p<0.001$).Craniometric dimensions such as Bizygomatic Breadth and NasionProsthion Length in this study have been found to be higher in males and also are significantly sexually dimorphic ($p<0.001$). The statistical observations of the present study are depicted in **Table 1.**

On analysis of the Indices of sexual dimorphism, it is observed that Maximum Cranial Breadth and Orbital Height are poor determinants of sex. NasionProsthion Length showed the maximum degree of sexual dimorphism followed by Biorbital Breadth, InterorbitalBreadth and MaxilloAlveolarLength. Bizygomatic Breadth, Maxillo Alveolar Breadth, Maximum Cranial Length, Orbital Breadth. The degree of sexual dimorphism for the different measurements is shown in **Figure 2.**

Discussion

The scientific technique of estimating sex of an individual from human remains is always a problem for the fraternity of Forensic anthropologists and medicolegal experts(8). The existence of sexual dimorphism in human skeletons and its growing importance has been deeply acknowledged and vastly studied upon. In earlier times, distinguishing male and female human remains was based on morphological characteristics such as a distinct Fronto-Nasal Angulation in male skulls and the characteristic wide and shallow Greater Sciatic Notch in a female pelvis. Various parts of a skeleton such as tibia, pelvis, femur, humerus, radius, mandible, and cranium were used in estimation of sex. A conscientious examination of the cranial remains by the forensic osteologist or anthropologist can give important clues for identification(9).

The skull in human remains has been the mainstay of many studies conducted on identification of human remains. In the historical study conducted on 70 skeletal remains it was proposed that sex determination can be done with a reasonable accuracy. The level of reliability was reported to be 100% when the whole skeleton was present, 92% using the skull alone and 98% when combining the pelvis and skull(10). Skull is composed of hard tissue and remains well preserved in circumstances when the other parts of the skeleton either missing or is in a damaged state(11). Numerous morphological and metric traits of different parts of skull have been documented and studied upon in an effort to quicken the process of sex determination and nevertheless to increase the reliability of the same e.g. cranium(9, 12-17), mandible(18-23), glabella(24) mastoid process(25-28),occipital bone(29-32). Currently with the development of CT and other medical imaging techniques, a 3D reconstruction of the skull can be created which is a much more reliable technique to differentiate sex because of the ability to assess various craniofacial parameters(33).

Metric studies generally provides the advantage of being a more objective way of attaining data as compared to the subjective assessment of morphological traits. With the use of osteometric techniques, determination of sex from skulls is dependent on statistical analysis. Among the prominent published reports on sexing the crania, the study by Giles and Eliot conducted on 408 black and white crania observed that cranial height, bizygomatic diameter and mastoid length had a statistically significant correlation with anthropological sexual attributes of the crania, classification accuracy being 85.5%(34). A similar study by Hanihara on Japanese skulls reported that a classification accuracy was 89.7%(35). The study conducted by Işcan and his coworkers on 84 Japanese skeletons of known age and sex observed the statistical accuracy of various cranial dimensions and found that mastoid length promises an prediction accuracy of 84% for determination of sex of the human remains (36). Later, Işcan and Steyn worked on 91 South African White crania of known age and sex, taking 12 standard cranial measurements and proposed that the prediction accuracy from 80% (bizygomatic breadth alone) to 86% (cranium) (12). In a craniometric study of Thai skulls based on 3D CT, parameters such as foramen magnum length and breadth, bi-orbital breadth, maxillary breadth and various other craniofacial parameters have been showed to have relatively high statistical significance as compared to the other 24 parameters taken into consideration(33).

The growth of facial bones is not a uniform process of surface accretion but is dependent on the concert between many components(37). Kemkes and Gobel proved the fact that diversity in size and shape of facial skeleton is due ontogenic, environmental, epigenetic influences and masticatory function(27). Sexual dimorphism in facial size is the most significant at around 14 years of age and progresses with onset of puberty. Males have a longer and more intense growth spurt than females. A female face shows decline in growth rate at 13 years of age and finally halts at around 15 years of age while in males, facial development is a lifelong process with onset at puberty and reaching into early adulthood(4, 38, 39).A cross sectional study conducted on African-American populations of age ranging from 9 months to adulthood, revealed that sexual dimorphism in facial shape is present at all stages of growth and that the final shape is achieved by the extension of male size and shape vector(39).

In the present study conducted on 118 human dry crania, Maximum Cranial Length and Bizygomatic Breadth exhibited high degree of significance in sexing, which is in agreement with the findings of studies done by Franklin et al(13),Rooppakhunet al.(33), Saini et al.(37), Kranioti et al(9) and Zavando et al(40).Contrary to the observations of studies conducted on the modern Cretan population(9) and Northern Indian population(37),where Inter Orbital Breadth was not found to be statistically significant parameter in sexing,our study observed it to be a significant determinant of sex.BiorbitalBreadth as derived from studies done by Saini et al.(37), Kranioti et al(9) is significant and the same result was obtained in our study.Maxillo Alveolar Breadth andMaxillo Alveolar Length proved to be sexually dimorphic in our study and also in another study(33).NasionProsthion Length, had a very high index of sexual dimorphism indicating that it is a very good determinant of sex which is in agreement with a study conducted by Zavando et al(40).In our study Orbital height did not show significance in determining sex unlike in other studies(33, 37).

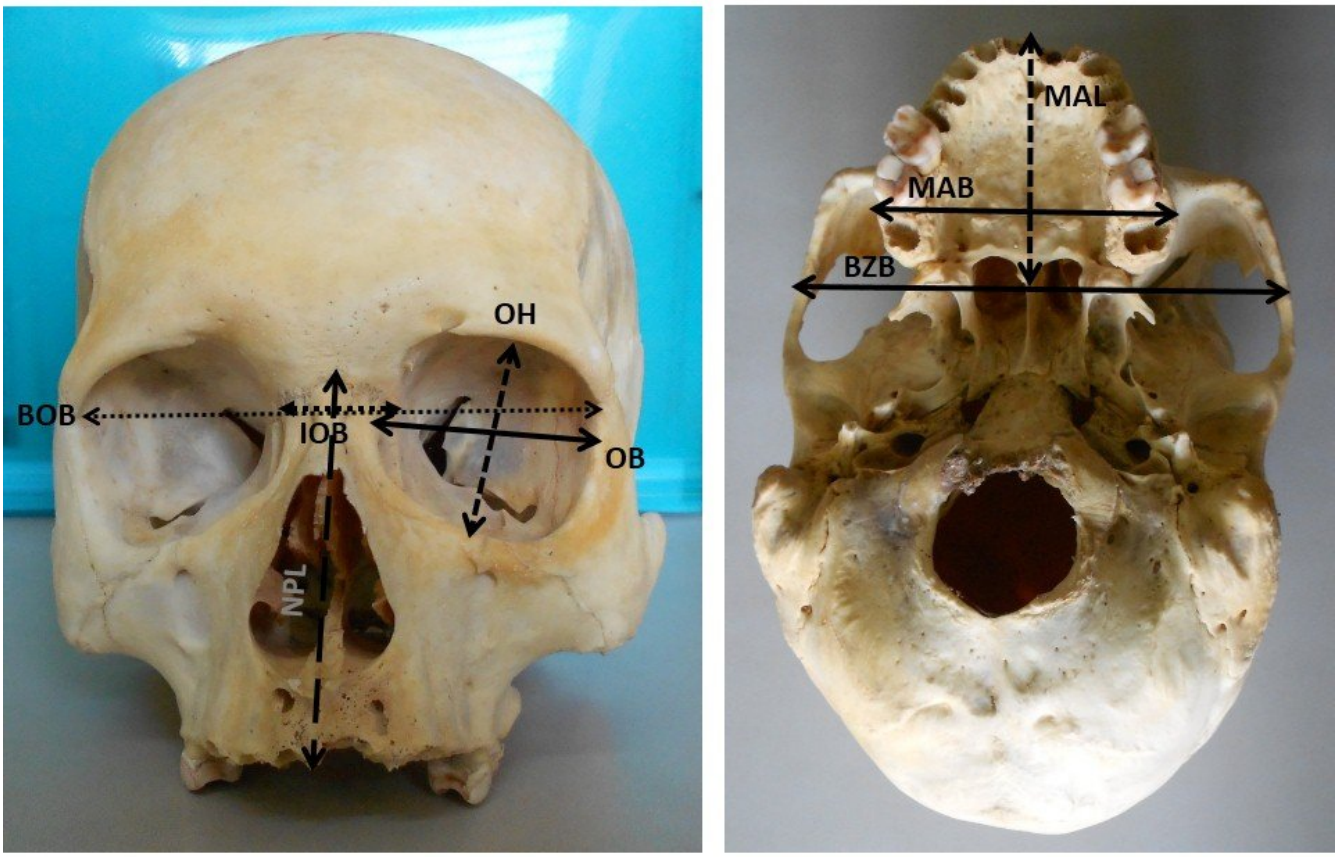
It is recommended that more population based studies are undertaken to validate the findings of craniometric analysis done by different authors. Future studies on a larger sample are proposed on craniawith confirmed sex for more reliable results.

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Table 1: Descriptive statistics for various cranial parameters

Variable	Male			Female			t-value	p-value
	Mean	S.D	Range	Mean	S.D	Range		
Maximum Cranial Length	13.6	0.6	12.5-15.0	12.8	0.7	12-14	7.173	0.000
Maximum Cranial Breadth	10.5	0.7	9.5-12.0	10.3	0.3	10-11	1.280	0.203
Inter Orbital Breadth	2.2	0.2	1.8-2.6	2.4	0.3	2.0-2.8	-5.285	0.000
Biorbital Breadth	10.0	0.6	8.7-10.5	9.1	0.5	8.5-10.1	8.036	0.000
Orbital Breadth	4.0	0.2	3.6-4.5	3.9	0.3	3.3-4.4	2.057	0.042
Orbital Height	3.3	0.3	2.9-3.9	3.3	0.3	2.9-3.8	-0.409	0.684
NasionProsthion Length	4.9	0.4	4.0-6.2	4.3	0.6	3.3-6.2	5.168	0.000
Bizygomatic Breadth	10.2	0.5	9-11	9.5	0.5	9.0-10.0	8.318	0.000
Maxillo Alveolar Breadth	6.3	0.3	5.7-6.6	5.9	0.5	5.3-6.7	5.863	0.000
Maxillo Alveolar Length	5.4	0.4	4.4-5.8	5.0	0.3	4.6-5.3	5.964	0.000



BOB= Biorbital breadth, IOB= Inter orbital breadth, OH= Orbital height, OB= Orbital breadth, NPL= Nasion Prosthion Length, MAL= Maxillo-alveolar length, MAB= Maxillo-alveolar breadth, BZB= Bi-zygomatic breadth

Figure 1: Measurements on the human cranium included in the present study

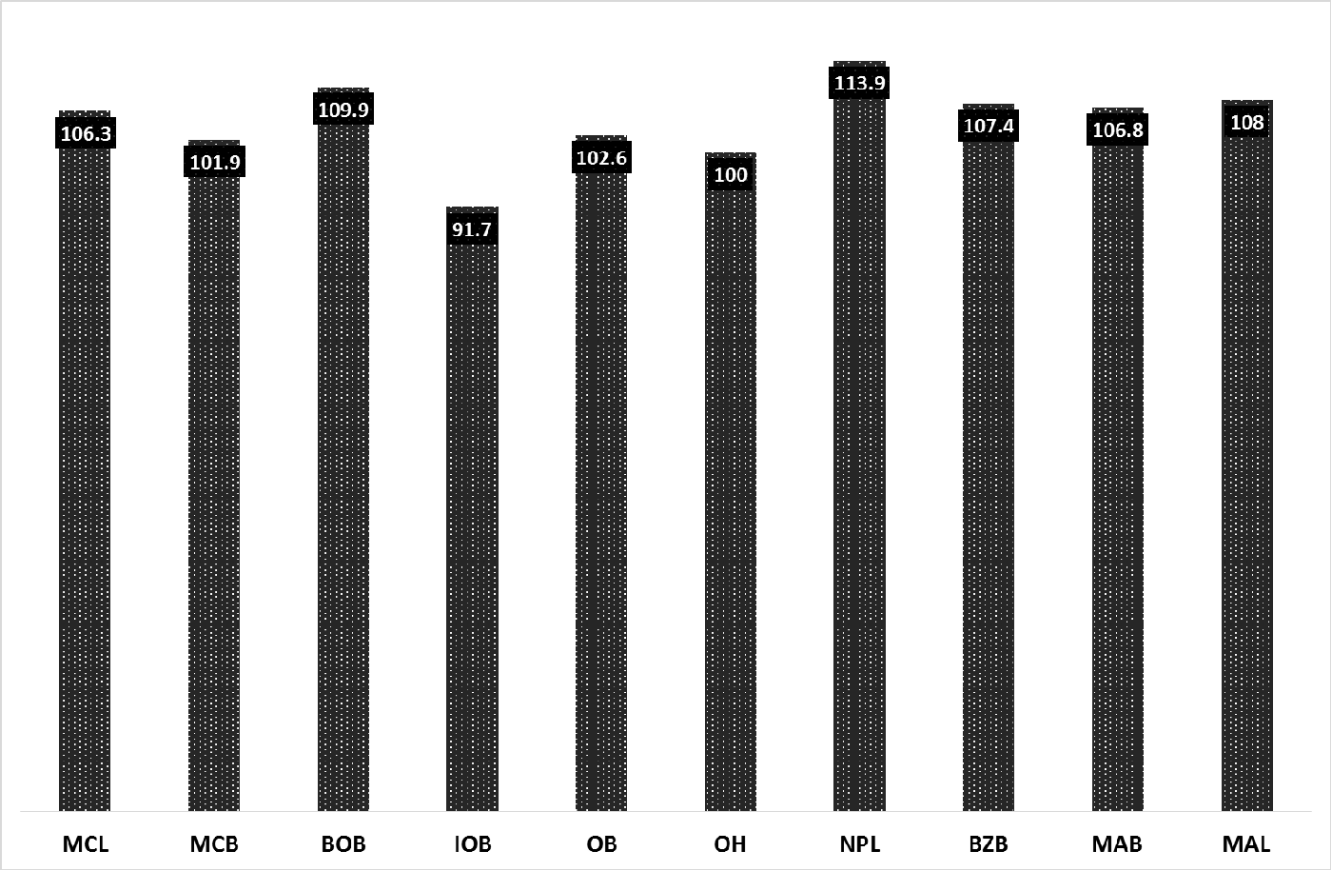


Figure 2: Index of sexual dimorphism for the different measurements

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