Indian Internet Journal of Forensic Medicine & Toxicology
ISSN 0973-1970, Vol.6, No.2 (2008) *Original Article*

Determination of sex by measurement of area of mastoid triangle in human skull

Singh RP[1], Verma SK[2], Tyagi AK[2], [1]Junior Demonstrator, [2]Professor Dept. of Forensic Medicine and Toxicology, University College of Medical Sciences, Dilshad garden, Delhi-110 095

Abstract

Identification is one of the parameter that is unique to an individual and is required frequently in medico-legal scenario. Since bones resist putrefaction for considerable long time therefore they provide abundance of information for the purpose of identification of an individual. Skull is one such bone which provides one of the best parameters to ascertain sex with reasonable accuracy. A prospective randomized study has been conducted in the Department Of Forensic Medicine, University College of Medical Sciences & Guru Teg Bahadur Hospital, Delhi. In this study area of mastoid triangle is correlated with the sex of the individual in 200 cases (100 male and 100 female). The dead bodies of age group between 18 years to 60 years were selected for the study.

The following three osteometric measurements were taken: a. Mastoidale to asterion (M-A); b. Mastoidale to porion (M-P);and c. Porion to asterion (P-A)

Area of mastoid triangle was calculated by using the formula:

$$A = \frac{\sqrt{(a+b+c)(a+b-c)(b+c-a)(c+a-b)}}{4}.$$

The results were compared between age groups and in total sample population using discriminant function analysis. The minimum value for area of mastoid triangle in males was 305.9 sqmm in age group 25-31 yrs and that for females was 245.6 in age group e” 53 yrs. The maximum value for mastoid triangle area in males was 845.0sqmm in age group 46-52 yrs while that for female was 677.1sqmm in age group d” 24 yrs. The mean value of area of mastoid triangle in total age groups, in males was 478.0sqmm and was 412.03sqmm in females. There is a statistically significant difference in the mean of area of mastoid triangle in males and females ($p < 0.01$).

By using discriminant function analysis, discriminating score was reached for total population, by using the formula:

DS=area of mastoid triangle x 0.000175 – 0.203

For correspondence
Dr. S.K. Verma
Professor, Dept. of Forensic Medicine
UCMS & GTBH, Dilshad Garden, Delhi-110 095

Introduction

Historically, human identification is one of the most challenging task that forensic experts often encounter. Identification of a person or a dead body means the determination of the individuality or recognition of that person or dead body[1]. Identification is necessary in civil cases like marriage, inheritance, passport, insurance claims, disputed sex, missing persons, interchange of new born babies in the hospital and impersonation etc, and in criminal cases like persons accused of assault, rape, murder etc[2]. In dead it is important not only as a part of physical and forensic anthropology but also for humanitarian reasons for the purpose of performing last rites of the dead by their relatives. According to Iscan (1981), the reconstruction of an antemortem biological biography, including attempted reconstruction of a victim's way of life up to the time of death is also a part of the assessment[3].

The most frequently used and simplest method of identification in dead bodies is recognition by relatives and friends. But, sometimes, it is very difficult when even near relatives are unable to identify the dead body owing to severe burns, high decomposition, profound mutilation and predator activities, thereby causing major changes in facial and other identifiable features. The process of identification may be complete or partial. When we absolutely fix the individuality of a person, it is called complete identification. But sometimes only some facts (egg. race, age, sex, stature) about the identity are ascertained while others remain unknown, this is called partial identification[4].

The determination of the sex of the skeleton represents an important part of identification process. The studies for sex determination are based on dimorphism between the two genders that is present in majority of human bones. Existing methods of studying bones utilize two main approaches: 1) By description of the morphology of the bones in question; and 2) By the values obtained by the measurements of these bones i.e. morphometry. The studies, which use the description of the morphology of the bones, as a method to determine the sex of the skeleton are less accurate as compared to the morphometric studies since they are not objective in nature. Depending upon their experience in anthropology, different persons can arrive at different conclusions on the same set of bones. So the personal bias, which is inherent in descriptive studies, is not present in morphometry[5].

Various studies have been conducted on long bones for identification purpose by researchers that includes Dwight (1904-05)[6], Pearson (1917-19)[7], Iordanidis (1961)[8], El-Nazzar (1978)[9], Krogman (1986)[10] and many others. In India, pioneers in this field are, Siddiqui and Shah (1944)[11], Jit and Singh (1956)[12], Kotle and Bansal (1974)[13], Patil KR and Modi RN(2005)[14] and few others.

The results are very encouraging especially when the whole skeleton is available. 100% accuracy can be achieved in such cases as Krogman (1986)[10] puts. However problems do arise when either incomplete skeleton or fragmentary remains of skeleton are brought for examination.

In the study by Keen (1950) three cranial features, external auditory meatus, supraorbital ridges and muscle markings on the occipital bone and four measurements, maximum cranial length, facial breadth, depth of infratemporal fossa and length of mastoid process, were studied and an accuracy of 85 % was achieved[15].

Giles and Elliot (1963) studied a number of variables i.e. maximum cranial length, maximum cranial breadth, basion-bregma height, basion-nasion height, facial breadth, basion-prosthion, upper face height, external maxillary length and mastoid length and found the accuracy of sex determination varying between 83% - 85%[16].

In another study, Teixeira (1982) explored the possibility of determining sex by measuring the size of Foramen Magnum. He measured the surface area of the opening of the foramen magnum in 40 adult Brazilian skull and found that in the males the surface area of the foramen magnum is 963 sq mm or larger and in females the surface area is 805 sq mm or less[17].

Steyn and Iscan (1998) used 12 standard cranial and 5 mandibular measurements and these were subjected to Statistical Product and Service Solution (SPSS) discriminant function analysis. They found Bizygomatic breadth as the most dimorphic dimension and in the mandible Bigonial breadth was the most dimorphic one. Average accuracy ranged from 80% to 86%[18].

Paiva and Segre (2003) used the area of the mastoid triangle as a variable for determination of sex. They measured the area of the triangle formed by three points (porion, asterion and mastoidale). For the population studied, values of the total area that were greater than or equal to 1447.40 sq mm belonged to male crania (95% C.I.). Values that were less than or equal to 1260.36 sq. mm belonged to female crania (95% C.I.)[5].

The present study was conducted to correlate area of mastoid triangle with sex of the individual in the Department of Forensic medicine, University College of Medical Sciences & Guru Teg Bahadur Hospital, Shahdara, Delhi.

Materials and method

Design and setting of study

A prospective randomized study has been conducted in the Department Of Forensic Medicine, University College of Medical Sciences & Guru Teg Bahadur Hospital, Delhi. The study was done on the dead bodies coming for medicolegal autopsies in the mortuary of Guru Teg Bahadur Hospital. A total of two hundred dead bodies were studied, consisting of hundred males and another hundred females.

Criteria of inclusion

The dead bodies of age group between 18 years to 60 years, including 18 yr and 60 yr, were selected for the study.

Criteria of exclusion

The dead bodies below the age of 18 years and above the age of 60 yrs were excluded from the study.

Dead bodies having skull fractures and other obvious skull bone pathology were not included in the study.

Method

The bodies were identified by inquest papers submitted by the investigating officer of the case and by the relatives of the deceased.

Inquiries regarding the age, place of birth, residential address and religion were made to the relatives and confirmed from inquest papers.
The height and weight were measured and noted down.
The scalp was cut by giving incision in coronal plane starting from tip of mastoid process of one side, going over the vault, to tip of mastoid process of opposite side.
Then scalp was reflected up to the root of nose interiorly and below opisthocranion posteriorly.
The soft tissue over all the regions surrounding the craniometric points was removed by blunt dissection up to the outer table.
Three craniometric points were identified on each skull:

Porion (most lateral point on the roof of the external auditory meatus).
Asterion (point where sutures between occipital, temporal and parietal bones meet).
Mastoidale (lowest point on the mastoid process when skull is in Frankfurt horizontal plane).

The three arms of the mastoid triangle were measured by the distances between three points which are:1) Porion; 2) Asterion; and 3) Mastoidale.

Area of mastoid triangle was calculated by using the Hero’s Formula.
All the measurements were taken with the spreading calipers and ruler.
The area of mastoid triangle was correlated with the sex of the deceased.
The discriminant function analysis was used for statistical analysis.

Materials

The autopsy table, Weighing machine, Measuring tape, Autopsy instruments- scalpel, surgical blade, forceps, electric saw, spreading calipers, Computer software for data analysis.

Results

Osteometric measurements of skull

Mastoidale – Asterion distance (M–A)- The length varied from 3.5 – 5.5 cm (mean = 4.52) and 0.43 s.d. in males and 3.2 – 5.4 cm (mean = 4.11) and 0.33 s.d. in females.

Mastoidale – Porion distance (M–P)- The length varied from 1.8 – 3.4 cm (mean = 2.31) and 0.52 s.d. in males and 1.7 – 3.2 cm (mean = 2.17) and 0.39 s.d. in females.
Porion – Asterion distance (P–A)- The length varied from 3.4 – 5.6 cm (mean = 4.19) and 0.38 s.d. in males and 3.4 – 5.2 cm (mean = 3.90) and 0.36 s.d. in females.
Table 1 shows the distribution of sex in different age groups. The maximum number of cases were in the age group £24 years (N=76) out of which 27 were males and 49 were females and the least number of cases were in age group ^{3}53 years, (N=12) out of which 4 were males and 8 were females.

Area of mastoid triangle

Distribution of area of mastoid triangle of both sexes in age groups <24 years

The minimum value of area of mastoid triangle in the age group <24 years in males was 359.5 and the maximum was 769.2, mean being 468.326 with standard deviation 97.9449. In females, the

Table 1: Distribution of sex in age groups

Age group	**Male (n1)**	**Female (n2)**	**Total (N)**
<=24	27	49	76
25-31	24	23	47
32-38	18	10	28
39-45	15	5	20
46-52	12	5	17
>=53	4	8	12
Total	100	100	200

minimum value was 321.0 and the maximum was 677.1, mean being 415.074 with standard deviation 69.1415. There was overlapping between the values of male and female, however, the percentage accuracy was 66.2% (Table 2).

Distribution of area of mastoid triangle of both sexes in age groups 25-31 years

The minimum value of area of mastoid triangle in the age group 25-31 years in males was 305.9 and the maximum was 742.7, mean being 466.303 with standard deviation 98.5627. In females, the minimum value was 265.3 and the maximum was 639.2, mean being 444.128 with standard deviation 94.8295. There was overlapping between the values of male and female, however, the percentage accuracy was 55.3% (Table 3).

Distribution of area of mastoid triangle of both sexes in age groups 32-38 years

The minimum value of area of mastoid triangle in the age group 32-38 years in males was 341.3 and the maximum was 693.9, mean being 510.208 with standard deviation 108.3283. In females, the minimum value was 354.4 and the maximum was 533.4, mean being 412.598 with standard deviation 56.5603. There was overlapping between the values of male and female, however, the percentage accuracy was 66.7% (Table 4).

Distribution of area of mastoid triangle of both sexes in age groups 39-45 years

The minimum value of area of mastoid triangle in the age group 39-45 years in males was 341.3 and the maximum was 733.9, mean being 456.240 with standard deviation 107.1068. In females, the minimum value was 313.9 and the maximum was 384.9, mean being 355.440 with standard deviation 26.0977. There was overlapping between the values of male and female, however, the percentage accuracy was 75% (Table 5).

Table 2: Distribution of area of mastoid triangle of both sexes in age groups <24 years

	Sex	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
<=24	**Male(n=27)**	359.5	769.2	468.326	97.9449
	Female(n=49)	321.0	677.1	415.074	69.1415

Table 3: Distribution of area of mastoid triangle of both sexes in age groups 25-31 years

	Sex	Minimum	Maximum	Mean	Std. Deviation
25-31	**Male (n=24)**	305.9	742.7	466.303	98.5627
	Female(n=23)	265.3	639.2	444.128	94.8295

Table 4: Distribution of area of mastoid triangle of both sexes in age groups 32-38 years

	Sex	Minimum	Maximum	Mean	Std. Deviation
32-38	**Male(n=18)**	341.3	693.9	510.208	108.3283
	Female(n=10)	354.4	533.4	412.598	56.5603

Table 5: Distribution of area of mastoid triangle of both sexes in age groups 39-45 years

	Sex	Minimum	Maximum	Mean	Std. Deviation
39-45	**Male(n=15)**	341.3	733.9	456.240	107.1068
	Female(n=05)	313.9	384.9	355.440	26.0977

Distribution of area of mastoid triangle of both sexes in age groups 46-52 years

The minimum value of area of mastoid triangle in the age group 46-52 years in males was 359.2 and the maximum was 845.0, mean being 520.007 with standard deviation 152.4426. In females, the minimum value was 341.5 and the maximum was 486.5, mean being 382.712 with standard deviation 60.7950. There was overlapping between the values of male and female, however, the percentage accuracy was 64.7% (Table 6).

Distribution of area of mastoid triangle of both sexes in age groups ^{3}53 years

The minimum value of area of mastoid triangle in the age group ^{3}53 years in males was 377.8 and the maximum was 466.7, mean being 424.320 with standard deviation 45.9587. In females, the minimum value was 245.6 and the maximum was 478.1, mean being 354.084 with standard deviation 73.1800. There was overlapping between the values of male and female, however, the percentage accuracy was 75.0% (Table 7).

Distribution of area of mastoid triangle of both sexes in total cases

The minimum value of area of mastoid triangle (all cases) in males was 305.9 and the maximum was 845.0, mean being 478.008 with standard deviation 108.2090. In females, the minimum value was 245.6 and the maximum was 677.1, mean being 412.030 with standard deviation 76.7007. There was overlapping between the values of male and female, however, the percentage accuracy was 61% (Table 8).

Table 6: Distribution of area of mastoid triangle of both sexes in age groups 46-52 years

	Sex	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
46-52	**Male(n=12)**	359.2	845.0	520.007	152.4426
	Female(n=05)	341.5	486.5	382.712	60.7950

Table 7: Distribution of area of mastoid triangle of both sexes in age groups ^{3}53 years

	Sex	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
>=53	**Male (n=04)**	377.8	466.7	424.320	45.9587
	Female(n=08)	245.6	478.1	354.084	73.1800

Table 8: Distribution of area of mastoid triangle of both sexes in total cases

	Sex	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Total	**Male (n=100)**	305.9	845.0	478.008	108.2090
	Female(n=100)	245.6	677.1	412.030	76.7007

Table 9: Percentage accuracy of area of mastoid triangle for sex determination

Age groups	**% correct classification**	**Discriminating score**	Classification **criteria**
< = 24	66.2	Area*0.000175 – 0.228	DS>0 = MALEDS<0 = FEMALE
25-31	55.3	Area*0.010 – 4.707	DS>0 = MALEDS<0 = FEMALE
32-38	66.7	Area*0.011 – 5.229	DS>0 = FEMALEDS<0 = MALE
39-45	75	Area*0.010 – 4.525	DS>0 = FEMALEDS<0 = MALE
46-52	64.7	Area*0.007 – 3.572	DS>0 = MALEDS<0 = FEMALE
< = 53	75	Area*0.015 – 5.702	DS>0 = FEMALEDS<0 = MALE
All age groups	61	Area*0.000175 – 0.203	DS>0 = MALEDS<0 = FEMALE

Percentage accuracy of area of mastoid triangle for sex determination

Table 9 shows percentage accuracy of area of mastoid triangle for sex determination.

In the age <24 years the percentage correct classification was 66.2%.

In the age 25-31 years the percentage correct classification was 55.3%.

In the age 32-38 years the percentage correct classification was 66.7%.

In the age 39-45 years the percentage correct classification was 75%.

In the age 46-52 years the percentage correct classification was 64.7%

In the age >53 years the percentage correct classification was 75%.

In all cases the percentage correct classification was 61%.

The maximum % accuracy was present in age group 39-45 yrs and >=53 yrs and minimum was in age group 25-31 yrs.

Discussion

Keen (1950) used both craniometry and morphological traits to determine the sex. He used four measurements (max cranial length, facial breadth, depth of infratemporal fossa, length of mastoid process) and three morphological features (supraorbital ridges, external auditory meatus and muscle markings on the occipital bone) and achieved an accuracy of 85%[15].

Giles & Elliots (1963) studied 408 known sex Americans white and Negro crania taking nine different measurements. These measurements were used in 21 combinations to form discriminant function for sex determination. The sex of a skull can be found out by having similar measurements and multiplying them by proper coefficient and resultant score compared with male female dividing points based on sex material. These workers found accuracy of 82-89% by this method[16].

Teixeira (1981) studied the surface area of the opening of the foramen magnum in 40 adults (20 males and 20 females) Brazilian skulls. He measured the length and breadth of the foramen magnum and took the average of the two as an approximate diameter of the circle. He concluded that if the surface area of the foramen magnum is 963sq.mm or larger, it is a male and if the area is 805sq.mm or less it is female[17].

Krogman and Iscan (1986) stated that determination of sex, age, and race in a collection of 750 skeletons was possible, with levels of reliability of 100% when all the skeleton was present, with 95% reliability when using the pelvis alone, 92% using the skull alone, and 98% using the pelvis and the skull. He summarized the methods of sex determination using different craniometric points on skull[10].

Funayama M, Aoki Y, Kudo T, Sagisaka K. (1986) studied the human skulls with the aid of a personal computer to establish sex differences in quantitative anatomical terms. On the roentgen cephalograms from 50 adult males and 50 adult females, the lateral profile was transcribed onto an acetate sheet, on which the contour from the nasal apex to the forehead was digitized on a tablet digitizer into a series of dots, which were input into the computer system. After this chain of dots was simulated by a spline function, the places most typically reflecting sex difference were determined in the profile based on the radius of curvature computed at each dot. The eminence of glabella and the nasal root, shown to be the places of skull apparently most characteristic of sex, were approximated to circular arcs with the least squares method, the radii of which were expected to serve for sexing. In both places, Student’s t-test revealed a significant difference between the male and female groups (p less than 0.01). It was thus demonstrated that in male the eminence of glabella and the nasal concavity develop much more markedly than in female, presenting as a clear skeletal difference between both sexes [19].

Holland TD (1986) observed that the cranial base can be used to determine the sex of fragmentary or deformed skulls. In this study he used nine measurements taken from 100 crania in the Terry Collection. The sample was divided equally by race and sex. Six regression models were formulated that predicted correctly the sex of the sample with 71-90% accuracy. In a separate test, a control sample of 20 skulls, also drawn from the Terry Collection but not involved with formulating the regression equations, was correctly classified with 70-85% accuracy [20].

Johnson, O'Higgins, Moore & McAndrew (1989) in their study on human skulls, representing each of the modern racial groups of man (Caucasoid, Negroid, Mongoloid, Australoid) used a total of twenty five craniometric points on the entire skull and a series of linear and angular measurements were taken between them. They suggested that the best discriminators for sex are not necessarily the best for sex, and the skulls of unknown provenance are best tested first for race and then for sex, using different variables for each purpose[21].

Inoue M, Inoue T, Fushimi Y, Okada K. (1992) quantified the morphological features of cranial specimens with a personal computer that automatically measured distance and gradient for 39 craniometric points in the lateral contour line of the skull, which were digitized by a tablet digitizer connected to the computer. Specimens used for discriminant analysis were 50 male and 50 female adult Japanese skulls. The lateral contour showed sex differences in the nasal bone, supraorbital ridge, forehead and vertex. The nasal bone and supraorbital ridge were more developed in male contour line, and the forehead was more rounded in female contour line. But compared with the supraorbital ridge and forehead, the vertex had a wide variety of contour lines in both sexes. The vertex seemed to be less reliable as the indicator of sex. The sex differences were better reflected by gradient than distance. From variables of the gradient and distance showing significant sex differences, the discriminant function was derived and tested in 21 other specimens (13 male and 8 female skulls). The mean ratio of correct sexing of the human skull by the discriminant function was 86% [22].

Hsiao, Chang & Liu (1996) attempted to develop a new method to determine sex from the skull with lateral radiographic cephalometry and discriminant function analysis. The superciliary ridges, frontal sinuses, external occipital protuberance, and mastoid processes were adopted as objects of lateral radiographic cephalometric measurements. With discriminant functions created from 18 established cephalometric variables, a total of 100 cases were classified into two sexual groups with 100% accuracy in a random sample of Taiwanese adults. Therefore, a much greater reliability of sex determination can be obtained from skulls according to this newly developed technique[23].

Steyn and Iscan (1998) established the population specific standards for sex determination using skull for south African whites population. They subjected the various measurements to SPSS discriminant function analysis and found that bizygomatic breadth was the most dimorphic dimension. Average accuracy ranged from 80% (bizygomatic breadth alone) to 86% (cranium)[18].

Konigsberg LW, Hens SM. (1998) suggested a method for sexing, using a multivariate cumulative probit model and examined both single indicator and multivariate indicator models on a sample of 138 crania from a Late Mississippian site in middle Tennessee. The crania were scored for five common sex indicators: superciliary arch form, chin form, size of mastoid process, shape of the supraorbital margin, and nuchal cresting. The logistic regression correctly classified 66/74 males and 46/64 females, with an overall correct classification of 81%. The cumulative probit model classified 64/74 males correctly and 51/64 females correctly for an overall correct classification rate of 83%. Finally, they applied parameters estimated from the logit and probit models to find posterior probabilities of sex assignment for 296 additional crania for which pubic indicators were absent or ambiguous[24].

Gunay & Altinkok (2000) attempted to determine whether the area of the foramen magnum was a useful criterion for the sex determination in fragmented skulls. In a total of 219 skeletons (170 males and 39 females) the longest and the shortest diameter of the foramen magnum was measured; the area within was determined using the mean of the diameters as the radius for calculation. The mean of foramen magnum area was significantly different (909.91 +/- 126.02 mm2 in males, 819.01 +/- 117.24 mm2 in females' homogeneous variance, Student's t-test: 4.11 P< 0.001). However, the correlation coefficient between the areas of foramen magnum and sex was 0.27. The results confirmed that the mean foramen magnum area in females is lower than in males. However, the area of foramen magnum is not a very useful indicator for sex identification and can be used only under some circumstances as a supportive finding[25].

Schiwy-Bochat KH (2001) studied the supranasal region for sexing skulls. A total of 80 human skulls of known sex (40 females, 40 males) were collected from autopsy material used in anatomy teaching classes and from forensic cases. The mean age of the female sample was 70.98 years (minimum 38, maximum 93) and that of the male sample was 74.10 years (minimum 57, maximum 99). To quantify the roughness of the supranasal region the calculation of the box-counting dimension was used. The results were normally distributed in both, the male and female group. The male dimension values were well grouped (maximum 1.51111, minimum 0.98765, mean 1.26159, S.D. 0.12268, 95% CI 1.22236-1.26604) whereas the female showed a wide range (maximum 1.46744, minimum 0.44755, mean 1.15052, S.D. 0.21388, 95% CI 1.08212-1.21892), widely overlapping the male range. Statistical analysis showed that there was a less than 1% probability that the female box-counting dimension was lower than the male by chance (P-value 0.00593). For this results the admission of the trait 'quality of the supranasal region' into a catalogue of features regarding morphognostic sex determination following the scheme: hyperfemininity: very smooth and regular—femininity: more smooth and regular—indifferent—masculinity: more rough and irregular—hypermasculinity: very rough and irregular, seems to be justified [26].

Lynnerup N (2001) measured the cranial thickness in 64 individuals (43 males, 21 females). The thickness was measured by taking a biopsy with a trephine at four specific locations on the skull. Complete medical records and pathologic autopsy results were available. While none of the individuals had suffered from diseases affecting bone or bone metabolism as such, a large sub group consisted of individuals with a history of, and autopsy finds consistent with, chronic substance and alcohol abuse. There was no statistically significant difference in cranial thickness measures between this group and the rest of the material. Subsequent analyses failed to reveal any correlations between the cranial thickness and sex and age and height and weight of the individual. It was in accordance with earlier studies, which likewise show no correlation, or only very faint trends, between cranial thickness and these parameters. This study, thus, adds to other studies showing that cranial thickness cannot be used in aging or sexing human remains. Likewise, in a forensic pathological setting, cranial thickness cannot be inferred from the individual stature and build, which may be an issue in cases of interpersonal violence with cranial trauma [27].

Hanihara T, Ishida H (2001) investigated five discrete hypostotic cranial traits i.e. tympanic dehiscence, ovale-spinosum confluence, metopism, transverse zygomatic suture vestige and biasterionic suture in 81 human population samples. Except for ovale-spinosum confluence, marked asymmetric occurrences of the bilateral traits were not detected in the majority of the samples. Significant intertrait association was observed mainly between the biasterionic suture and other sutural variations including accessory ossicles. The traits showing relatively consistent sex differences across diverse populations were tympanic dehiscence, which is predominant in females, and biasterionic suture in males. On a world scale, the 5 hypostotic cranial traits showed distinctive patterns of geographical variation. Different clinal variations within and between macrogeographical areas such as western and eastern parts of the Old World were found for the frequencies of the traits. The Ainu may be the most distinct outlier in the eastern Asian region on the basis of the incidence of the traits, especially the transverse zygomatic suture vestige. The interregional variation without reasonable adaptive value and nonadaptive shift of the possible outliers presented in this study suggest that the genetic background for the occurrence of these traits cannot be excluded completely[28].

Gulekon & Turget (2003) determined the usefulness of the external occipital protuberance (EOP) in the determination of sex, especially in lateral cranium radiographs. The types and configurations of the EOP were investigated on normal lateral cranium radiographs of 1000 subjects (500 males and 500 females) and 694 dry-skull remains (371 males and 323 females) from a 16th Century Anatolian population for the purpose of sex determination. In the radiographic examination, the incidence of less prominent (Type 1) EOP was found to be 85.4% in females whereas 17.8% in males. The spine type (Type 3) EOP was found to be 63.4% in males and to be 4.2% in females. On the other hand, studies of dry-skull remains revealed the incidence of Type 1 EOP to be 67.5% in females and Type 3 EOP to be 55.2% in males. The crest type (Type 2) EOP is approximately equal in both sexes and is found to be less valuable for sex determination in both groups[29].

Paiva and Segre (2003) evaluated the significance for sex determination, of the measurement of the area formed by the xerographic projection of 3 craniometric points related to the mastoid process: the porion, asterion, and mastoidale points. Sixty skulls, 30 male and 30 female, were analyzed. A xerographic copy of each side of the skull was obtained. On each xerographic copy, the craniometric points were marked to demarcate a triangle. The area (mm) of the demarcated triangle for each side of the skull (right (D) and left (E) sides) was determined, and the total value of these measures (T) was calculated. Concerning the right area of the male and female skulls, 60% of the values overlapped; for the left area, 51.67% overlapped, and for the total area, 36.67% overlapped. The analysis of the differences between the sexes in the areas studied was significant for the 3 areas. Regarding the total area, which is the preferred measurement because of the asymmetry between the sides of the skull, the value of the mean was 1505.32 mm for male skulls, which was greater than the maximum value obtained in the female skulls. The value of the mean for female skulls was 1221.24 mm, less than the minimum value obtained for the male skulls. This study demonstrated a significant result in the 3 studied areas, (D), (E), and (T). The total area values show less overlapping of values between the sexes, and therefore can be used for sexing human skulls. For the population studied, values of the total area that were greater than or equal to 1447.40 mm belonged to male crania (95% confidence). Values for this area that were less than or equal to 1260.36 mm belonged to female crania (95% confidence)[5].

Noren A, Lynnerup N, Czarnetzki A, Graw M. (2005) reported on the results of applying the so-called lateral angle method for sex determination on skeletal remains. The lateral angle denotes the angle of the internal auditory canal in relation to the medial surface of the petrous part of the temporal bone. The method involves making a small cast of the proximal part of the internal acoustic canal and determining the angle at which the canal opens up to the surface of the petrous bone. The method was tested using a forensic sample of 113 petrous bones with known sex. Intra- and interobserver testing was also performed. It was found that there is a statistically significant difference in angle size between males and females (mean angle size of males, 39.3 degrees; mean angle size of females, 48.2 degrees; $P < 0.001$). There was no bilateral difference in angle size. In blind trials, 83.2% of petrous bones were assigned to the correct sex. They also tested the lateral angle method against an archaeological skeletal sample. True sex was not known for this sample; instead, sexing had been carried out by assessment of pelvic and cranial morphology in independent trials. They found a higher concordance between the lateral angle and "pelvic" sex than for lateral angle and "cranial" sex. It was also noted that subadult sexing may also be possible with this method[30].

Uysal, Gokharman, Kacar, Tuncbilek & Kosa (2005) investigated the value and accuracy of the measurements of the foramen magnum (FM) by using three-dimensional computed tomography (3DCT). Cases were randomly selected among 100 patients (48 males, 52 females) who had temporal CT in the Radiology Department. Seven measurements of the foramen magnum on 3D images, modified from the nine lines previously defined by Giles and Elliot were made. Using Fisher's linear discriminant functions test, the length and width of right condyle and width of FM diameters were found to be statistically different in each sex ($p < 0.001$) with 81% accuracy so that CT/3DCT can be reliably used in further investigations to provide basis for anthropometric and forensic issues[31].

Graw, Wah & Ahlbrecht (2005) opined that due to its extreme mechanical strength, the pars petrosa ossis temporalis is usually preserved in skulls and the sex dimorphisms of this skeletal part are therefore of particular significance. They tried to clarify the controversial question whether the course of the meatus acusticus internus (M.a.i.) beneath the superior surface also reveals sex-specific differences. Using 410 forensically modern petrous portions, the course of the canal was examined and the respective angles determined using a specifically developed casting and cutting technique. The median values certainly revealed sex differences: the lateral angle on the male petrous portions was found to be 10 degrees smaller than that of females; the medial angles on female petrous portions were approximately 5 degrees smaller than those of male skulls. Using discriminant analysis, approximately 66% of the specimens were determined accurately[32].

Duric, Rakocevic and Donic (2005) tested the applicability of morphological methods for sex assessment, based on seven pelvic and nine cranial traits. Sex was correctly estimated by experienced anthropologist in 100% of individuals using all of the 16 pelvic and cranial criteria. Looking at the skull alone, sex was correctly determined in 70.56% cases. It was also suggested that experience is likely to contribute moderately to the accuracy of sex determination[33].

Franklin & Freedman (2005) examined sexual dimorphism and produced a practical discriminant function for determining the sex of indigenous, Bantu-speaking, South African crania. The types of data used were a small number of traditional, or mathematically transformed three-dimensional, linear measurements, comparable to those in use by most physical and forensic anthropologists. The samples examined, separately and pooled, were of the Cape Nguni, Natal Nguni and Sotho subgroups. In addition, three local populations ('tribes'—Zulu, Xhosa and Southern Sotho) within these subgroups were also studied. Univariate male/female ratios indicate significant sexual dimorphism in the pooled South African crania. Canonical variates analysis of the pooled sample showed that facial width was the strongest discriminating morphometric variable; cranial length and basi-bregmatic height were the next most significant features. Eight measurements derived from the three-dimensional data were used to produce a series of discriminant functions for sex determination in the pooled sample, for which an accuracy of 77-80% was attained. Analysis of the calvaria and face, separately, had shown that the sex of damaged material can be diagnosed with a reasonable degree of accuracy (75-76%)[34].

Rogers (2005) examined the accuracy and precision of 17 morphological features of the skull commonly used to determine the sex of unknown skeletal remains. The sample consisted of 46 identified skulls from the 19th century St. Thomas' Anglican Church Cemetery in Belleville, Canada. Nasal aperture, zygomatic extension, malar size/rugosity, and supraorbital ridge proved the most useful; of secondary value were chin form and nuchal crest; mastoid size was of tertiary consideration; nasal size and mandibular symphysis/ramus size rank fourth; forehead shape ranks fifth; and palate size/shape were sixth. Skull size/architecture provided an internal standard to assess the relative sizes of other traits[35].

Weinberg SM, Putz DA, Mooney MP, Siegel MI (2005) scored 13 non-metric craniofacial traits and analyzed them statistically in a sample of 70 black and white perinatal specimens obtained from the Smithsonian's fetal osteology collection. Chi-square analysis revealed significant ($p<0.05$) differences in the distribution of five of the 13 non-metric traits examined. Compared with black perinates, white perinates more frequently possessed a relatively narrow supraoccipital portion of the occipital bone, a prominent anterior nasal spine, "deep" subnasal margins, an elongated vomer, and semi-circular temporal squamae. When these five traits were entered into a stepwise logistic regression, temporal squamous shape, vomer shape and subnasal margin definition were found to be predictive of race (79.1% overall correct classification). An independent sample of 39 black and white perinates was then used to validate the results; overall, 67.5% of the validation sample could be classified correctly[36].

Williams BA and Rogers T (2006) tested the precision and accuracy of 21 morphological characteristics of the skull on a modern sample of 50 adult crania of European White ancestry. The following craniofacial features were identified as high-quality traits, defined by intraobserver error <or=10% and accuracy >or=80%: mastoid size, supraorbital ridge size, general size and architecture, rugosity of the zygomatic extension, size and shape of the nasal aperture, and gonial angle. Ninety-six percent accuracy and 92% precision were achieved using 20 traits in combination. Fisher's exact probability tests revealed no significant differences ($p=0.05$) in the levels of precision or accuracy between age categories. Sex-related bias in accuracy was found for the following cranial features: ramus symphysis ($p=0.009$), zygomatic extension ($p=0.0016$), and occipital markings ($p=0.0013$). These traits demonstrated a greater tendency to be scored male than female [37].

Mastoid triangle is formed by three points present on skull namely: 1.Porion (most lateral point on the roof of the external auditory meatus); 2. Asterion (point where sutures between occipital, temporal and parietal bones meet); and 3. Mastoidale (lowest point on the mastoid process). In the present study, Area of Mastoid triangle of right side was calculated. The minimum value for area of mastoid triangle in males was 305.9 sq mm in age group 25-31 yrs and that for females was 245.6 in age group e" 53 yrs. The maximum value for mastoid triangle area in males was 845.0sqmm in age group 46-52 yrs while that for female was 677.1sqmm in age group d" 24 yrs. The mean value of area of mastoid triangle in total age groups, in males was 478.0sqmm and was 412.03sqmm in females. There is a statistically significant difference in the mean of area of mastoid triangle in males and females ($p < 0.01$).

By using discriminant function analysis, discriminating score was reached for total population, by using the formula:

DS=area of mastoid triangle x 0.000175 – 0.203

When putting the value of area of foramen magnum in above formula, if the score is > 0 then sex is male and if score is < 0 then sex is female. Similar formulae were used in predicting the sex in different age groups. The maximum predictive accuracy of 75% was obtained in the age groupe" 53 and the minimum predictive accuracy of 55.3% was in age group 25-31 yrs.

Paiva and Segre studied the area of mastoid triangle in 30 males and 30 females. They calculated the area of mastoid triangle of both left and right side of skull and then a total area were obtained by adding the two values. However, means of area of triangle of right and left side were 752 .10sqmm and 753.22sqmm for males and 608.70sqmm and 602.54sqmm for females. In our study, area of mastoid triangle was calculated on right side of skull and means were 478.0sqmm for males and 412 .03sqmm for females.

References:

1. Parikh CK. Parikh's Textbook of Medical Jurisprudence and Toxicology. 5th Ed, Bombay, Medicolegal Center; 1990: p 29.
2. Reddy KSN. The Essentials of Forensic Medicine and Toxicology. 17th Ed Hyderabad, K. Suguna devi; 1998: p 45.
3. Iscan MY. Concepts in teaching forensic anthropology. Medical Anthropol Newsletter. 1981; 13(1): 10-12.
4. Buchner A. The identification of human remains. Int Dent J. 1985; 35: 307-11.
5. Paiva LAS and Segre M. Sexing the human skull through the mastoid process. Rev Hosp Clin Sao Paulo 2003; 58(1): 15-20.
6. Dwight T. Size of articular surfaces of long bones for sex. J Anat. 1904-05; (4): 19-32.
7. Pearson K. A study of long bones of the English skeleton. 1.the femur, chapter 1-4 in Draper's co. research mem. U. of London. Biom series X: 1917-1919.
8. Iordanidis P. Determination due sexe par les os de squellette (atlas, axis, clavicle, omoplate, sternum). Annals de Medicine Legale 1961; 41: 280-291.
9. El-Nazzar MY, McWilliams KR. Forensic anthropology. C.C. Thomas, Springfield, Ilinosis; 1978; 75-91.
10. Krogman WM, Iscan MY. The Human Skeleton in Forensic Medicine. 2nd Ed, C.C. Thomas, Springfield, Ilinosis; 1986: 189-200.
11. Siddiqui MAH, Shah MA. Estimation of stature from long bones of Punjabees. Ind J Med Res 1944; 321: 105-108.
12. Jit J, Singh S. Estimation of stature from clavicles. Ind J Med Res 1955; 44:137-155.
13. Kotle M, Bansal P. Determination of regression formulae for reconstruction of stature from the long bones of the upper limb in Maharastrians of Marathwada region. J Anat Soc India 1974; 23: 6-11.
14. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. Forensic Sci International 2005; 147:175-180.
15. Keen JA. Sex difference in skulls. Am J Phys Anthropol 1950; 8: 65-79.
16. Giles E, Elliot O. Sex determination by discriminant function analysis of crania. Am J Phys Anthropol 1963; 21: 53-68.
17. Teixeira WR. Sex identification utilizing the size of foramen magnum. Am J Forensic Med Pathol 1982; 3(3): 203-6.
18. Steyn M, Iscan MY. Sexual dimorphism in the crania and mandibles of South African whites. Forensic Sci International 1998; 98(1-2): 9-16.

19. Funayama M, Aoki Y, Kudo T, Sagisaka K. Sex determination of the human skull based upon line drawing from roentgen cephalograms. Tohoku J Exp Med 1986; 149(4): 407-16.
20. Holland TD. Sex determination of fragmentary crania by analysis of the cranial base. Am J Phys Anthropol 1986; 70(2): 203-8.
21. Johnson DR, O'Higgins P, Moore WJ and McAndrew T. Determination of race and sex of the human skull by discriminant function analysis of linear and angular dimensions. Forensic Sci International 1989; 41(1-2): 41-53.
22. Inoue M, Inoue T, Fushimi Y, Okada K. Sex determination by discriminant function analysis of lateral cranial form. Forensic Sci International 1992; 57(2): 109-17.
23. Hsiao TH, Chang HP, Liu KM. Sex determination by discriminant function analysis of lateral radiographic cephalometry. J Forensic Sci 1996; 41(5): 792-5.
24. Konigsberg LW, Hens SM. Use of ordinal categorical variables in skeletal assessment of sex from the cranium. Am J Phys Anthropol 1998; 107(1): 97-112.
25. Gunay Y, Altinkok M. The value of the size of foramen magnum in sex determination. J Clin Forensic Med 2000; 7(3): 147-9.
26. Schiwy-Bochat KH. The roughness of the supranasal region—a morphological sex trait. Forensic Sci International 2001; 117(1-2): 7-13.
27. Lynnerup N. Cranial thickness in relation to age, sex and general body build in a Danish forensic sample. Forensic Sci Int. 2001; 117(1-2): 45-51.
28. Hanihara T, Ishida H. Frequency variations of discrete cranial traits in major human populations. II. Hypostotic variations. J Anat 2001; 198(Pt 6): 707-25.
29. Gulekon IN, Turgut HB. The external occipital protuberance: can it be used as a criterion in the determination of sex? J Forensic Sci 2003; 48(3): 513-6.
30. Noren A, Lynnerup N, Czarnetzki A, Graw M. Lateral angle: a method for sexing using the petrous bone. Am J Phys Anthropol 2005; 128(2): 318-23.
31. Uysal S, Gokharman D, Kacar M, Tuncbilek I, Kosa U. Estimation of sex by 3D CT measurements of the foramen magnum. J Forensic Sci 2005; 50(6): 1310-4.
32. Graw M, Wahl J, Ahlbrecht M. Course of the meatus acusticus internus as criterion for sex differentiation. Forensic Sci Int 2005; 147(2-3): 113-117.
33. Duric M, Rakocevic Z, Donic D. The reliability of sex determination of skeletons from forensic context in Balkans. Forensic Sci International 2005; 147(2-3): 159-164.
34. Franklin D, Freedman L, Milne N. Sexual dimorphism and discriminant function sexing in indigenous South African crania. Homo 2005; 55(3): 213-28.
35. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci 2005; 50(3): 493-500.
36. Weinberg SM, Putz DA, Mooney MP, Siegel MI. Evaluation of non-metric variation in the crania of black and white perinates. Forensic Sci International 2005; 151(2-3): 177-85.
37. Williams BA, Rogers T. Evaluating the accuracy and precision of cranial morphological traits for sex determination. J Forensic Sci 2006; 51(4): 729-35.