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Original Article

Anatomy Section

Sexual Dimorphism in Adult Human Mandibles: a Southern Indian Study

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ABSTRACT

Introduction: The mandible is a Latin word which means lower jaw. the word mandible is derived from "Mandere" which means to chew. The mandible is the largest, strongest and lower jaw bone in the face. It has lower teeth, gives attachment to the muscles of mastication. Mandible is the best choice to determine the sex, since it resists environmental and post mortem changes.

Aim: This study aimed to determine the important morphological and morphometric parameters in order to determine the sex of unknown Mandibles belonging to the South Indian Population.

Materials and Methods: Bones are very important tools for identification of deceased and sex determination; the pelvis and skull are the most reliable sources, in their absence the mandible becomes an important source. The mandible is the largest, strongest and hardest facial bone thus, can provide information about sexual dimorphism. A random collection of 120 adult, dry, undamaged Human Mandibles belonging to South Indian population were subjected to Morphological and Metrical parameters.

Results: Around 5 morphological and 7 morphometric indicators were observed, measured and evaluated. Statistical analysis was done using student t-test, chi-square test and p-value. The mean values were higher among males as compared to females. The parameters showing extremely significant values in our study were Chin, Bigonial Diameter, and Divergence of Gonial Angle indicating that these can be of paramount importance in identifying the sex of unknown mandibles.

Conclusion: Mandible can be considered as an important tool in the determination of sex with high accuracy and these morphological and morphometric indicators help us to determine the sex of adult human mandibles.

Keywords: Mandibles, Sex determination, Sexual dimorphism

INTRODUCTION

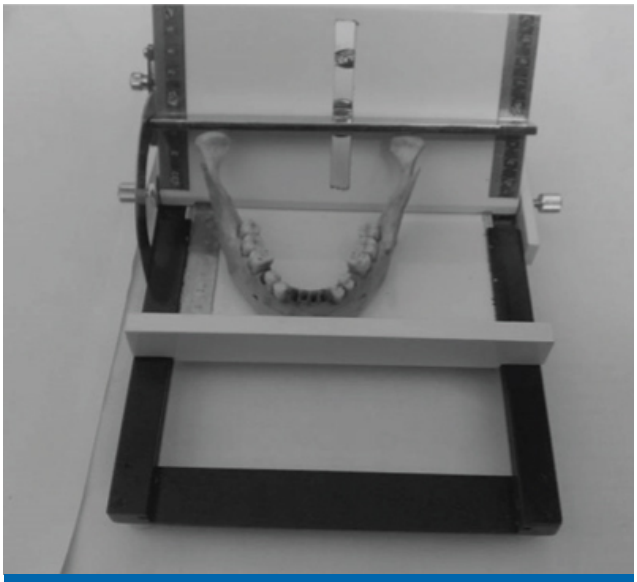
The mandible is the largest, strongest and lower jaw bone in the face. It has lower teeth, gives attachment to the muscles of mastication. It has a curved body anteriorly with two rami attached to it posteriorly. The body of the mandible supports the mandibular teeth within the alveolar process. The rami bears the coronoid and condylar process. Each condylar process articulates with adjacent temporal bone of the skull to form the Temporo- mandibular joint. Identification of human skeletal remains is a critical problem and is very important in medico – legal and anthropological work. Mandible next to pelvis in human remains will help us in identification of age, sex and race. Morphometric study of the mandible and its correlation with sex performs valuable role in the anthropological diagnosis [1]. Mandible represents a reliable skeletal resistance to environmental factors, being usually well- preserved even in archaeological context [2]. Mandible is very durable part of skull bone due to the dense layer of compact bone which can be observed in it and because of this it tends to maintain its shape and contour well for a year's duration when compare to any other bones. The shape and size of mandible reflects the dimorphism characteristics. Female bones are generally smaller and less robust than male bones. The shape of the mandible can vary according to the different lifestyles and chewing habits [3]. Sex determination of a cadaver is usually done by checking the dental records during accidents and war, but when records are not available, then the sex determination is done by using mandibles [4]. Of all the skeletal bones, the mandible alone has escaped being indexed even though it is one of the hardest bones and the one most likely to survive decomposition for the longest period of time [5]. Sex determination by morphological factors is sometimes a deciding factor like a mandible with pointed chin is indicative of female and square shape is of males. The mandibles are larger in size with large dentition among males.

Methods based on morphology and morphometry are accurate and can be used in sex determination of skull bones [6]. A large number of reference literatures are devoted to mandible anatomy, sexual polymorphism, race and age transformations, most of the parameters in Indian mandibles differ markedly from other ethnic groups. Such a racial variation is expected to exist because of genetic makeup and social habits of different races. Numerous studies have clearly demonstrated that skeletal characteristics vary by population specific standards for sex determination [7]. The present study was conducted with an aim to get some information about mandibular geometry in South Indian population and to derive discriminant factors to determine the sex of mandible and important morphometric parameters. This study will be helpful not only for Anatomists but also for Anthropologists, Dental surgeons and Forensic Scientists.

MATERIALS AND METHODS

This cross sectional study was conducted on 120 adult, dry, human mandibles of unknown sex, belonging to South Indian population, collected between July 2016-July 2017, from the Department of Anatomy and Forensic Medicine of various Medical Colleges in South India. Ethical Clearance was taken from the Institutional Ethical Committee before the study.

The different parameters were taken using the following instruments: Mandibulometer [Table/Fig-1], Vernier calipers, measuring scale, and protractor.

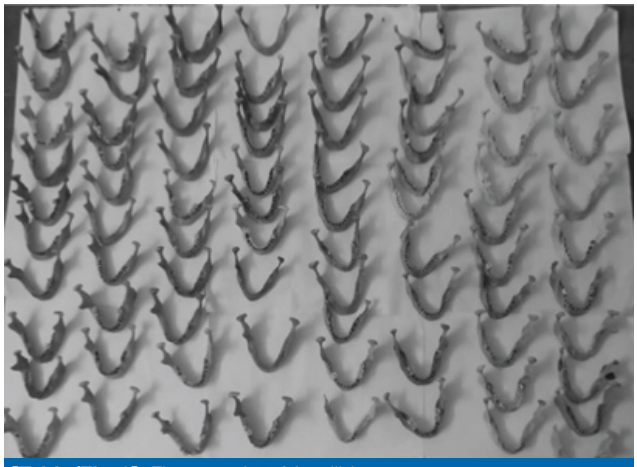


[Table/Fig-1]: Mandibulometer used for taking morphometric measurements.

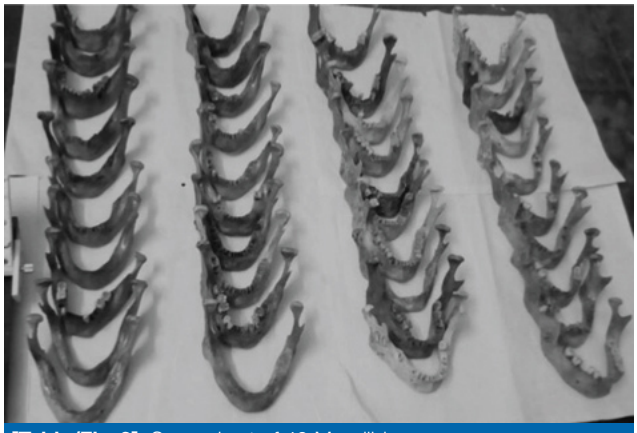
The Inclusion criteria for selecting the mandibles: Presence of bilateral molar teeth; prominent alveolar sockets; intact condylar or coronoid processes and well developed adult mandibles.

The Exclusion criteria: Any pathosis of mandible; fractures or deformed mandible; broken condylar or coronoid processes; broken mandibular angles and damaged, mutilated or deformed mandibles were excluded from the study.

Morphological indicators observed were: Shape and Weight of the mandible; muscular markings; divergence of Gonial Angle; shape of the chin; and rough or smooth surface of the mandible [Table/Fig-2,3]



[Table/Fig-2]: First set of 80 Mandibles.



[Table/Fig-3]: Second set of 40 Mandibles.

Morphometric measurements:

Bigonial diameter (BGD): Distance between the right and left gonion. Instrument used was Mandibulometer.

Bicondylar Distance (BCD): Distance between the right and left condyles. Instrument used was Vernier calipers.

Gonial angle: Angle formed by the inferior border of the corpus and the posterior border of the ramus. Instrument used was Mandibulometer.

Ramus length (RL): Direct distance from the highest point on the mandibular condyle to gonion. Instrument used was Vernier caliper.

Ramus breadth (RB): The smallest breadth of the mandibular ramus measured perpendicularly to the height of ramus. Instrument used was Vernier caliper.

Body length (BL): Distance between the alveolar margins to the lower margin of the mandible in the level of mental foramen perpendicular to the base. Instrument used was Vernier caliper.

Body Breadth (BB): Distance between the two anterior margins of the right and left rami. Instrument used was measuring tape.

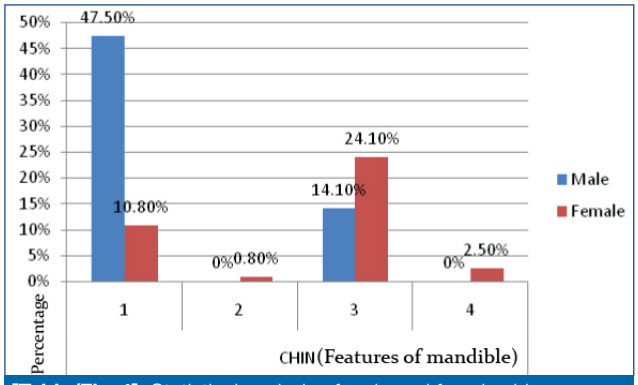
STATISTICAL ANALYSIS:

Statistical analysis was done using SPSS 22.0 software.

RESULTS

Morphological Results:

1. Chin: In males, square shaped chin of mandible is 47.5%, round shaped chin of mandible is 0%, point shaped chin of mandible is 14.1% and round pointed shape of mandible is 0%. In females, square shaped chin of mandible is 10.8%, round shaped chin of mandible is 0.8%, point shaped chin of mandible is 24.1% and round pointed shape of mandible is 2.5%. The p-value is less than 0.001, statistically significant [Table/Fig-4,5].



[Table/Fig-4]: Statistical analysis of male and female chin.
1:square; 2:round; 3:pointed; 4:oval chin shapes

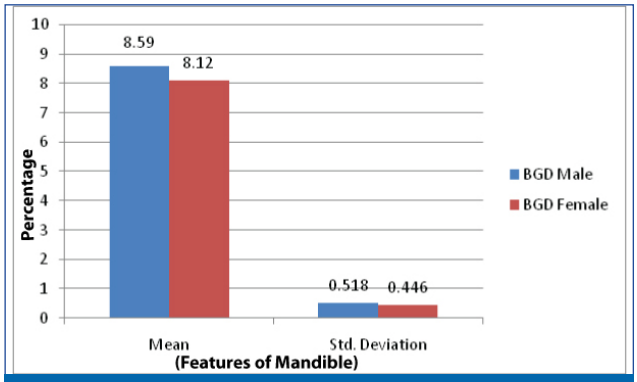
Shape of the chin	Male	Female	Chi-Square Value	p-value
Square	57 (47.5%)	13 (10.8%)	29.636	0.001
Round	0 (0%)	1 (0.8%)		
Pointed	17 (14.1%)	29 (24.1%)		
Oval	0 (0%)	(2.5%)		

[Table/Fig-5]: Statistical analysis of the chin of male and female mandibles.

2. Muscular Markings: In males, prominent muscular markings of mandible are 13.6%, less prominent muscular marking of mandible are 12.5%, no muscular markings of mandible are 17.5%. In females, prominent muscular markings of mandible are 13.3%, less prominent muscular marking of mandible are 11.6%, no muscular markings of mandible are 13.3%.

3. Rough/Smooth Surface: In males, rough surface of mandible is 29.1%, no so rough surface of mandible is 4.1% and smooth surface of mandible is 28.3%. In females, rough surface of mandible is 13.3%, no so rough surface of mandible is 2.5% and smooth surface of mandible is 23.3%.

4. Divergence of Gonial Angle: In males, everted angle of mandible is 60.8%, inverted angle of mandible is 0.8% and straight angle of mandible is 0%. In females, everted angle of mandible is 0%, inverted angle of mandible is 40% and straight angle of mandible is 5%. The p-value is less than 0.001, statistically significant [Table/Fig-6,7]



[Table/Fig-6]: Statistical analysis of male and female Bigonial diameter.
1:square; 2:round; 3:pointed; 4:oval chin shapes

S.No	Male	Female	Chi-Square Value	p-value
Everted	73 (60.8%)	0 (0%)	141.347	0.001
Inverted	1 (0.8%)	40 (33.3%)		
Straight	0 (0%)	6 (5%)		

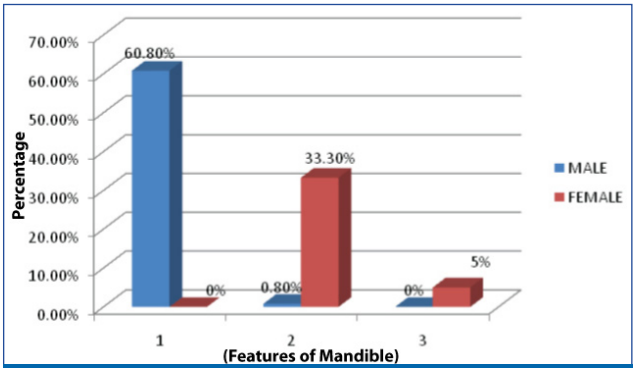
[Table/Fig-7]: Statistical analysis of divergence of gonial angle of male and female mandibles.

5. Shape and Weight of the Mandible: In males, the big and heavy sized mandibles are 30%, big and light sized mandibles are 9.1%, small and heavy sized mandibles are 3.33%, small and light sized mandibles are 12.5%, big and medium sized mandibles are 2.5%, medium and medium sized mandibles are 0.83%, medium and light sized mandibles are 0.83%, medium and heavy sized mandibles are 0.83%, light and medium sized mandibles are 1.6 %. In females, the big and heavy sized mandibles are 10.8%, big and light sized mandibles are 5%, small and heavy sized mandibles are 4.1%, small and light sized mandibles are 12.5%, big and medium sized mandibles are 0.83%, medium and medium sized mandibles are 0%, medium and light sized mandibles are 0.83%, medium and heavy sized mandibles are 2.5%, light and medium sized mandibles are 1.6 %.

Morphometric Results:

1. Bicondylar Diameter: Mean for the Bicondylar diameter of the male mandible's is 7.87 with standard deviation 0.592. Mean for the Bicondylar diameter of the female mandible's is 7.75 with standard deviation 0.502. The Mean difference between the male and female Bicondylar Diameter is 0.125.

2. Bigonial Diameter: Mean for the bigonial diameter of the male mandible's is 8.59 with standard deviation 0.518. Mean for the bigonial diameter of the female mandible's is 8.12 with standard deviation 0.446. The mean difference between the male and female bigonial diameter is 0.477. The gender difference between male and female with respect to the bigonial diameter is significant (p=0.001) [Table/Fig-8,9].



[Table/Fig-8]: Statistical analysis of male and female divergence of gonial angle.
1:Everted; 2:Inverted; 3:straight divergence of gonial angle

Sex	Mean	Mean Difference	t-value	p–value
Male (61.6%)	8.59±0.518	0.477	5.159	0.001
Female (38.3%)	8.12±0.446			

[Table/Fig-9]: Statistical analysis of bigonial diameter in male and female mandibles (Cms).

3. Gonial Angle: Mean for the gonial angle of the male mandible's is 13.87 with standard deviation 4.293. Mean for the gonial angle of the female mandible's is 13.88 with standard deviation 4.839. The mean difference between the male and female gonial angle is -0.010.

4. Mandibular Body Length: The Body Length of the male mandible's mean is 6.55 with standard deviation 0.572. The Body Length of the female mandible's mean is 6.51 with standard deviation 0.507. The mean difference between the male and female body length is 0.041.

5. Mandibular Body Breadth: The Body Breadth of the male mandible's mean is 2.53 with standard deviation 0.570. The Body Breadth of the female mandible's mean is 2.48 with standard deviation 0.045. The Mean difference between the male and female body Breadth is 0.484.

6. Mandibular Ramus Length: The ramus length of the male mandible's mean is 5.15 with standard deviation 0.655. The ramus length of the female mandible's mean is 4.92 with standard deviation 0.647. The mean difference between the male and female ramus length is 0.226.

7. Mandibular Ramus Breadth: The Ramus Breadth of the male mandible's mean is 2.93 with standard deviation 0.305. The Ramus Breadth of the female mandible's mean is 2.93 with standard deviation 0.327. The Mean difference between the male and female Ramus Breadth is 0.003.

DISCUSSION

There are many quantitative studies describing the morphometry of mandibles among different population, but the literature regarding the Indian mandibles are very low. This study is an effort to know more about the morphometry of mandibles among the South Indian population with a large sample size and its usefulness in determining the sex. This study will not only emphasize the inter-population variation but will also provide knowledge regarding the various parameters of the mandibles.

Chin: Naira FD and Nilton A found that the square shape of the chin in black male individuals is (p = 0.001) which is significant and among white individuals is (p=0.005),this morphological index was significant among black males(82.7%) compared to the white males (61.9%) [1]. Tejavathi N et al., found that male mandibles showed rocker-shaped predominantly (58.9%), whereas about 41.1% of female mandibles exhibited a straight inferior border of the mandible. The shape of the chin in most of the males was bilobate (45.5%), square (43.6%), and pointed (10.9%), whereas female mandible had either square (8.6%) or bilobated (20.0%) and pointed chin (71.4%). Shapes of coronoid process observed were hook in 27.8%, rounded (31.1%), and triangular (41.1%) with $p < 0.05$ which indicated statistical significance [3]. In the pesent study, In males, square shaped chin of mandible is 47.5%, round shaped chin of mandible is 0%, point shaped chin of mandible is 14.1% and round pointed shape of mandible is 0%. In females, square shaped chin of mandible is 10.8%, round shaped chin of mandible is 0.8%, point shaped chin of mandible is 24.1% and round pointed shape of mandible is 2.5% .The p-value is 0.000 which is statistically significant.

Muscular Markings: Aparajitha S and Anjali J, found the muscle markings were more prominent in 81% males while they were less prominent in 89.6% females. On analysis with chi square test of independence p for all the three parameters it was found to be <0.001 which is highly significant [8]. In the present study in males, prominent muscular markings of mandible are 13.6%, less prominent muscular marking of mandible is 12.5%, no muscular markings of mandible is 17.5%. In females, prominent muscular markings of mandible are 13.3%, less prominent muscular marking of mandible

is 11.6%, no muscular markings of mandible is 13.3%. The p-value is 0.184 is statistically insignificant.

Surface: This parameter was not found in the previous literature. In the present study, in males, rough surface of mandible is 29.1%, no so rough surface of mandible is 4.1% and smooth surface of mandible is 28.3%. In females, rough surface of mandible is 13.3%, no so rough surface of mandible is 2.5% and smooth surface of mandible is 23.3%.

Divergence Of Gonial Angle: Naira FD and Nilton A found that the divergence of the Gonial angle showed a statistically significant difference among the black males and females (p=0.01). Among white males it was everted in shape more frequently than the females, and the females presented the inverted shape. The accuracy in determining sex using this morphological indicator was 93.1% in black males, 95.2% in white males, 34.3% in black females and 26.6% in white females [1]. Muller EK (1998) used a single morphological character and found that the gonial flaring provided a more accurate sex indicator (76%) than either chin shape or ramus flexure [9].

In the present study, in males, everted angle of mandible is 60.8%, inverted angle of mandible is 0.8% and straight angle of mandible is 0%. In females, everted angle of mandible is 0%, inverted angle of mandible is 40% and straight angle of mandible is 5%. The p-value is 0.001 is statistically significant.

Shape and Weight: Wood BS (1976) studied the mandibular dimensions for sexual dimorphism in the primate skeleton, and concluded that sexual dimorphism in shape was predominantly the result of allometric relationships (i.e. differential size) [10].

In the present study, in males, the big and heavy sized mandibles showed a greater percentage (30%) compared to the females (10.8%) and small and light sized mandibles showed the same percentage (12.5%) in both males and females.

Bicondylar Diameter: Deepak NK et al., found that, the bicondylar breadth of all the mandibles under investigation measured in males is having mean=11.2693 cm, standard deviation 0.6468 and standard error of mean=0.0924 while in females mean is 10.75 cm, standard deviation is 0.6617 and standard error of mean is 0.1559 [11].

Anupama D et al., found mean value of the bicondylar breadth of mandible was found to be 112.72 mm in males and 107.48 mm in females. Standard deviation for bicondylar breadth in male was 5.57 and in female were 7.68 [12].

Rahul S et al., found the bicondylar breadth was 10.17 ± 0.58 cm in females and 11.22 ± 0.68 cm in males. Student t- test was done for the two sets of mean values. P value was <0.0001 and indicated that the results were statistically extremely significant [13].

In the present study, mean value of bicondylar diameter in male mandible's was 7.87 with standard deviation 0.592 and in female mandible's was 7.75 with standard deviation 0.502. The mean difference between the male and female bicondylar diameter was 0.125.

Bigonial diameter: Deepak NK et al., found the Bigonial diameter of mandible among males was having mean 9.5632 cm, standard deviation 0.6146 and standard error of mean is 0.0878 while in females the mean was 8.9833 cm, standard deviation 0.7679 and standard error of mean 0.1810 [11]. Anupama D et al., found mean value of the bigonial breadth of mandible was found to be 95.70 mm in males and 88.75 mm in females. The standard deviation for bigonial breadth in male was 5.19 and in female 6.78. The values in the female mandible were lesser as compared to that obtained in males [12]. Rahul S et al., found the bigonial breadth was 8.43±0.47 cm in females and 9.62cm±0.72 cm in males. Student t test was done for the two sets of Mean values. The p-value was <0.0001 and indicated that the results were statistically extremely significant [13].

In the present study, the bigonial diameter of the male mandible's mean is 8.59 with standard deviation 0.518. the bigonial diameter of the female mandible's mean is 8.12 with standard deviation 0.446. The mean difference between the male and female bigonial diameter is 0.477. The gender difference between male and female with respect to the bigonial diameter is extremely significant (p=0.001). Flossie J et al., studied 207 south Indian mandibles, they measured nine mandibular parameters like length of base, height of ramus, mandibular angle, bicondylar width, bigonial breadth, symphysial height, depth of right and left coronoid notch. They derived a discriminant function using four parameters, the bigonial breadth, mandibular height, length of base and depth of the right coronoid notch. On applying the discriminant function analysis to their sample, 96 of the 122 subjectively-sexed-male mandibles fell in the male category (78.7%) while 71 of the 85 subjectively-sexed-female fell in the female category (83.5%) [14].

Gonial Angle: Anupama D et al., found the mean value of gonial angle was found to be 126.6° in male and 135.72° in females. The standard deviation in male was 6° and female was 8°. The values of female mandibles were higher than that of males [12]. Study conducted by Vinay G et al., found that mandibular angle of male mandible varies from 111°-136° with an average of 121°±6° and that of female mandible varies from 97°-137° with an average of 122°±7° [4].

In the present study, the gonial angle of the male mandible's mean is 130.87° with standard deviation 4.293°. The gonial angle of the female mandible's mean is 130.88° with standard deviation 4.839°. The mean difference between the male and female gonial angle is -0.010°.

Body Length: Deepak NK et al., found the mean of height of mandibular body in males is 2.3959 cm, standard deviation 0.4092 and standard error of mean is 0.0584 while in females mean is 2.2833 cm, standard deviation 0.3091 and standard error of mean is 0.0728.The p-value is 0.235 which is not significant [11]. In the present study, the body length of the male mandible's mean is 6.55 with standard deviation 0.572. The body length of the female mandible's mean is 6.51 with standard deviation 0.507. The mean difference between the male and female body length is 0.041.the gender difference between male and female with respect to the body length is insignificant (p=0.691).

Body Breadth: Deepak NK et al., found the body breath of mandible in males having mean 1.1183 cm, standard deviation 0.1495, standard error of mean 0.0213 whereas, in females the mean was 1.0222 cm, standard deviation 0.1895, standard error of mean 0.0446 and p-value was 0.064 [11]. In the present study, the Body Length of the male mandible's mean is 6.55 with standard deviation 0.572. The body length of the female mandible's mean is 6.51 with standard deviation 0.507. The mean difference between the male and female body length is 0.041. The gender difference between male and female with respect to the body length is insignificant (p=0.691).

Ramus Length: Deepak NK et al., found the maximum ramus height of mandible in males is having mean 6.0061 cm, standard deviation 0.5249 and standard error of mean is 0.0749 while in females mean is 5.0888 cm, standard deviation is 0.3878 and standard error of mean 0.0914 [11]. Anupama D et al., found mean height value of ramus to be 67.98 in males and 55.10 in females. The standard deviation for the height of ramus in male was 4.40 and in female was 5.33 [12]. De Villiers H (1968) measured white South African mandibles and confirmed the early findings of Morant, Martin and Hrdlicka. It was found that the ramus had higher sexual dimorphism than the measurements of body height and breadth, and differences between the sexes were more marked in the ramus than in the body [15]. In the present study, the ramus length of the male mandible mean was 5.15 with standard deviation 0.655. The ramus length of the female mandible mean was 4.92 with standard deviation 0.647. The Mean difference between the male and female ramus length was 0.226. More CB et al., observed that the dimensions of mandibular ramus measured by digital orthopantomogram had the mean values which were higher in males compared to the females [16]. A cross sectional study conducted using 100 panoramic radiographs was done and the gonial flexure was found to be more obtuse in females compared to males and the ramus was more wider in males than females [17].

Ramus Breadth: Deepak NK et al., found that the minimum ramus breadth of mandible in males was having mean 3.1346 cm, standard deviation 0.3243, and standard error of mean 0.0463 with values of female mandible having mean 2.9 cm, standard deviation 0.23, standard error of mean 0.0542.The p-value was 0.006, which was insignificant [11]. In the present study, the ramus breadth of the male mandible mean was 2.93 with standard deviation 0.305. The ramus breadth of the female mandible mean was 2.93 with standard deviation 0.327. The Mean difference between the male and female ramus breadth was 0.003.

Kartheeki B et al., conducted a cross-sectional study using 500 digital orthomographs among south Indian population and observed that the ramus breadth showed higher mean values among males compared to the female [18].

Forensic odontology plays a major role in identification of fragmented jaw bones in mass disasters, as intact skulls are not available for analysis [19]. Kanchankumar PW et al., found that a single parameter like Bigonial breadth in central Indian population can determine the sex, the bigonial breadth was significant among males in 70.7% cases and in females 69.5% cases [20]. Puja H et al., noticed that 87.5% of their radiographic studies revealed statistically significant results that the adult mandible could be used to identify both sex and population affinity compared to other standard analytical techniques [21].

LIMITATIONS

The limitation of this study was the inability to assess the gender in cases of edentulous mandibles and larger sample size could not be attained.

CONCLUSION

The present study proves that the adult mandibles exhibit sexual dimorphism and can be used to identify the genders and population affinity with increased sensitivity and specificity. The mean values in males were higher than the females. The parameters showing significant values were chin, bigonial diameter, and divergence of gonial angle indicating that these can be of paramount importance in identifying the gender. It also establishes the morphological and morphometric criteria and recognizes a significant sexual dimorphism in the mandible. Among the demarcating values and limiting values found out in this study can help set up baseline parameters for sex determination in the South Indian population.

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