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Determination of sex by morphometric study of malleus bone in human cadaver

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ABSTRACT

Background: Identification is the process of determining a person's uniqueness, whether they are alive or dead. Skeletal remains contain an abundance of information which is helpful in determination of identity of an individual. This is an Analytical Cross-Sectional Study carried out on 45 adult male and 45 female cases that came for medico-legal autopsy at Guru Teg Bahadur Hospital, Dilshad Garden, and East Delhi with known sex and of any age from January 2021 to Aug 2022.The three measurements were taken for malleus bone i.e. Total length of malleus bone, the length of manubrium (handle) of malleus bone and Index of malleus bone. The bone was then measured by using digital vernier calipers of least count 0.001mm.
Result: In this study, we found that length of malleus bone was range from 7.15mm to 8.83mm inMales (Mean±SD, 7.97± 0.433) whereas in females it range from 6.67mm to 8.29mm (Mean±SD, 7.73± 0.296).The Maximum length of Handle (5.41mm) of malleus bone was in Males (Mean±SD, 4.79 ± 0.297) whereas in Females the maximum length of handle of malleus bone observed was 5.29mm (Mean±SD, 4.54± 0.282).The Total length of Malleus bone, Handle of malleus and Malleus index were more is Male as compared to Female and which is found to be statistically significant (p=0.003), (p=0.001) and (p=0.019) respectively.
Conclusion: There is a clear-cut demarcation between the values of male and female bone and considered fairly good criteria in sex determination. The sexual dimorphism is most marked in the Total length of Malleus bone, Handle of malleus and Malleus index of Malleus bone, and there is a significant difference was observed.

1. Introduction

On 18th May 2022, Delhi NCR witnessed a heinous crime, a 27 years old female was strangled by her live-in partner, a 28-year-old male over an argument and then he proceeded to dismember her body into 35 pieces and allegedly burn to char her face to hide her identity. A large fridge was used to store her body parts and thereafter he disposed each part separately into the nearby woods over the next 18 days.[1] Identification in such cases is very difficult as most of the long bones, skull and pelvis are destroyed by the perpetrator. In order to identify the victim, the investigator must adopt a different approach.[2]

Absolute (full) identification denotes 100% accuracy in identifying a person, whether they are alive or deceased. For example, dactylography (fingerprinting) anything less than 100% certainty is considered partial (circumstantial, incomplete, probable) identification. For example age, race, stature and sex.[3]

The issue of Sex discrimination is very complicated through physical characteristics where dismembered or parts of the body recovered in cases of extensively harmed body, bodies in an advanced state of putrefaction or mutilated or fragmentary and skeletonized remains.[4] In

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extensively damaged body where soft tissue has been destroyed or mutilated, the sex determination by external examination of the body is not possible leaving the forensic expert to depend upon the bones as they resist putrefaction for relatively long period. Skeletal remains contain abundance of information which is helpful in determination of identity of an individual.[5]

In the absence or destruction of the long bones, pelvis, and skull, forensic experts must rely upon other bones of the skeleton for sex determination. Malleus bone remains protected in the petrous part of the temporal bone. The possibility of finding intact ear ossicles (malleus, incus and stapes bone) in fragmented skeletal remains or severely mutilated or in decapitate crushed head is much higher as compared to other bones. The malleus referred to as a hammer or mallet, is the largest among the ear ossicles.[6]

Every individual has distinctive qualities. In situations involving bomb explosions, fire accidents, terrorist attacks, major natural catastrophes, mutilated victims, decomposing bodies, and skeletal remains, identification becomes a difficult endeavour. Age, sex, and stature can all be used to identify a person. A study conducted by Javia M K et al. (2018).[7] conducted morphometric analysis of various measures of malleus on the basis of sexual dimorphism. The sample consist of 30 malleus retrieved from the male cadavers and 30 malleus retrieved from the female cadavers. Male malleus averages are greater than those of female malleus averages in terms of overall malleus length, manubrium length, and head and neck length, whereas male malleus averages are smaller than those of female malleus.This shows that these measurements were useful for the sexual dimorphism. They measured the total length, length of manubrium, length of head and neck and index of malleus in population of Kachchh, Gujarat, India. Mean of total length of malleus in male was 7.8847 mm with SD 0.4451 and in female it was 7.628 mm with SD 0.4801 mm. Mean of length of manubrium of malleus in male was 4.5943 mm with SD 0.4514 mm and in female it was 4.4787 mm with SD 0.3667 mm. Mean of length of head and neck of malleus in male is 5.0627 mm with SD 0.383 mm and in female it was 4.949 mm with SD 0.2489 mm. Mean of index of malleus in male was 58.2517 with SD 4.3775 and in female it was 58.786 with SD 4.4245.

Singh K et al. (2012).[8] conducted a study based on "Morphometry of Malleus a Possible Tool in Sex Determination". It was conducted on sixty (30 male and 30 female) unidentified 9 cadavers. This study shows potential source of forensic investigation for evaluation of sex in severely mutilated and decomposed bodies during post-mortem examination. Sexual dimorphism in malleus with respect to total length of malleus and length of handle revealed subtle sexual dimorphism. They observed no statistical difference on comparison of morphometric parameters of malleus of right and left side when analysed collectively from both sexes. But found statistical significant difference ($p>0.014$) in the total length of malleus between the male and female on the right side alone and similarly significant difference was observed in the length of handle of malleus between male and female on the right side ($p>0.02$) as well as on the left ($p>0.14$). However other parameters like length of head and neck and weight of malleus were not significantly different in two sexes on right as well as left side.

Therefore, this study was an attempt to identify morphological variations with regard to sex.

2. Materials and Methods

The present study was an Analytical Cross-Sectional Study, done for determination of sex using morphometry of malleus bone in human cadaver. It was carried out in the Department of Forensic Medicine, University College of Medical Sciences & GTB Hospital Delhi. A Sample size of 90 cadavers (45 males and 45 females), subjected to medicolegal autopsy was included in the study.

After dissection of cranial cavity, a brain was removed and strips off the attached dura as per standard autopsy procedure. An area two thirds of way from calvarium to the foramen in middle cranial fossa, just anterior to the arcuate eminence on the ridge of petrous temporal bone and postero-lateral to the foramen spinosum were located (Figure 1). A sharp ended chisel was placed anterior to this ridge and a sharp blow was made with a mallet in anteroposterior direction. A second chisel blow was then made lateral to this about one third of the way from the Dural surface to the middle of the base of skull. A third chisel cut was then made with a chisel turned through 90 degrees between the first two cuts. Tegmen tympani was removed and expose the middle ear.[9] (Figure 2). Then malleus bone was carefully removed using crocodile forceps (Figure 3).

The dimensions of the malleus were measured from referred points (Figure 4). These were measured by the digital vernier calliper with the least count of 0.01 mm. All the measurements were taken thrice, and the mean of all the three was taken to rule out any inadvertent error.

The parameters of the malleus studied (Figure 4).

1. Total length (a-b): Maximal distance between the top of the head and the end of the handle;
2. Length of handle (b-c): Distance from the end of the lateral process to the end of handle;
3. To calculate the Index of malleus

Malleus index (MI) = length of manubrium /total length of Malleus × 100 Cadavers of known sex, of any age were included in the study.

2.1. Exclusion criteria

1. Person suffering from degenerative disease of born or fracture of malleus bone.

Table 1: Proforma for observation of the parameters of malleus bone

S. No	Parameters of malleus bone (Right ear)	Observation 1	Observation 2	Observation 3	Mean
1	Length of manubrium (in mm)				
2	Total length (in mm)				
3	Malleus index				

Table 2: Distribution of sex among the study groups

S. No	Sex	No. Of cases
1.	Males	45
2.	Females	45
	Total	90

Table 3: Maximum length of malleus bone (All measurements in mm)

	Range	Mean	S. D
Males	7.15-8.83	7.97	0.433
Females	6.67-8.29	7.73	0.296

N=90

Table 4: Handle of malleus (All measurements in mm)

	Range	Mean	S. D
Males	4.22-5.41	4.79	0.297
Females	3.36-5.29	4.54	0.282

N=90

Table 5: Malleus index (All measurements in mm)

	Range	Mean	S. D
Males	0.539-0.671	0.6009	0.0329
Females	0.53-0.659	0.5855	0.0281

N=90

Table 6: Comparison of morphometric parameters of male and female N=90

Variable	Male	Mean	SD	Female	Mean	SD	p-value
Total length (mm)	45	7.97	0.43	45	7.73	0.29	0.003
Handle of malleus (mm)	45	4.79	0.29	45	4.54	0.28	<0.001*
Malleus index (mm)	45	0.60	0.03	45	0.58	0.02	0.019

*P-value of less than 0.05 was regarded as statistically significant, Student t-test

2. Trauma to Middle ear.
3. Eroded and broken ossicles.
4. Any cadaver in which sex cannot be determined on examination.
5. Any history of suffering from any systemic disease or drug intake such as Amiodarone, Budesonide etc. which could effect on skeleton development.

2.2. Statistical analysis

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 20. Data was summarized using mean, standard deviation, median, minimum and maximum in quantitative data. Comparisons between quantitative variables were done using the Student t-test. P-values less than 0.05 were considered as statistically significant.

3. Results

The present study was conducted in the department of Forensic Medicine University College of Medical Sciences and Guru Teg Bahadur Hospital, Delhi. The study comprises bones of a total of ninety individuals, who came for medico-legal autopsy at Guru Teg Bahadur Hospital, Dilshad Garden, East Delhi between the period January 2021 to August 2022. Out of ninety subjects, 45 were male and 45 were females. Each case was studied thoroughly, and the observations were recorded according to the proforma (Table 1). All the individuals never had a history of any disease or deformity affecting the bones during their lifetime.

Table 7: Showingthe comparison of findings of various parameters of malleus bone of male andfemale in the present study with the findings of other Indian researchers

No	Researcher	Location	Sex	Side	Total length Mean ± SD	Length of handle Mean ± SD	Malleus index Mean ± SD
1	Present study	Delhi	M	RT	7.97±0.433	4.79±0.297	60.09 ±3.29
			F	RT	7.73±0.296	4.54±0.282	58.0±2.80
2	Harneja NK and Chaturvedi RP (1973)	Rajasthan	-	-	7.14±0.31	4.22±0.35	-
3	Arensburg et al (1981)	Indian	-	-	7.8±0.35	4.4±0.47	56.6
4	Bhatnagar DP et al (2001)	Patiala Punjab	-	-	7.8±0.35	4.65±0.27	-
5	Singh K et al (2012)	Haryana	M	RT	8.078±0.453	4.89±0.384	–
			F	RT	7.817±0.334	4.62±0.48	
6	Nadeem G (2012-13)	Indian	-	-	8±0.046	4.58±0.015	
7	Mogra K et al (2014)	Rajasthan		RT	8.515±0.655	5.10±0.46	60.18±3.55
				LT	8.545±0.505	5.30±0.48	61.84±3.788
8	Vinayachandra PH et al (2014)	South Indian	-	-	8.545±0.50	-	-
9	Rathava J et al (2015)	Gujrat	-	-	7.81±0.32	4.59±0.34	-
10	K Radha (2016)	South India	-	-	7.4	4.2	-
11	Sodhi S (2017)	North Indian			7.83	4.44	56.77
				RT	7.87±0.37	4.47±0.41	56.77
				LT	7.8±0.54	4.42±0.42	56.78
12	Mayankkumar Javia (2017)	Gujrat	M		7.88±0.44	4.59±0.51	58.25±4.377
			F		7.62±0.48	4.47 ±0.36	58.78±4.424
13	David Victor Kumar (2018)	Indian			8.23±0.36	4.17±0.137	-

Table 8: Showing the comparison of findings of various parameters of malleus bone of male and female in the present study with the findings of other researchers outside India.

No	Researcher	Location	Sex	Total length Mean ± SD (mm)	Length of handle Mean ± SD (mm)	Malleus index Mean ± SD (mm)
1	Present study	India	M	7.97±0.433	4.79±0.297	60.09 ±3.29
			F	7.73±0.296	4.54±0.282	58.0±2.80
2	Oschman Z and Meiring JH (1991)	South Africa	-	7.844	4.399	-
3	Unur E et al (2002)	Turkey	-	7.69±0.6	4.7±0.45	60.97±3.77
4	Ramirez LM and Ballesteros LE (2013)	COLUMBIA	-	8.18±0.24	4.91±0.25	-

All the individuals were of known sex and age. The Malleus bone from right side of males and females were taken out by fine dissection. The bones were then properly tagged and buried under the soil for six to eight weeks to create natural climatic conditions. Subsequently , the bones were removed, washed and air dried. The bone was then measured by digital vernier calipers of least count 0.001mm. The three measurements taken for malleus bone using digital vernier calipers-

1. Total length of malleus bone (Figures 5 and 6)
2. The length of manubrium(handle) of malleus bone (Figures 7 and 8)
3. Index of malleus bone

In this study, we found that the total numbers of Male were 45 and the total numbers of Females were 45. The total numbers of cases taken for the studies were 90 (Table 2).

It was observed that Maximum length of malleus bone in Males was 8.83mm and the minimum length was 7.15mm with a mean of 7.97mm and standard deviation of 0.433. In females the maximum length of malleus bone observed was 8.29mm and the minimum length of malleus bone observed

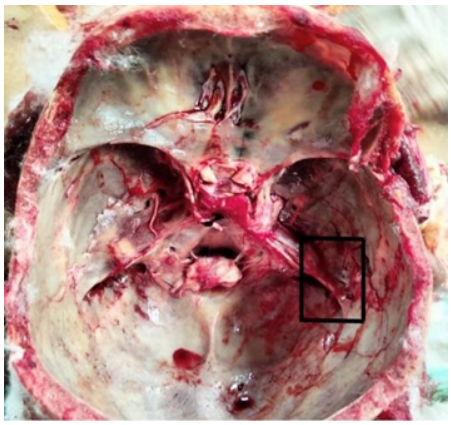

Figure 1: Showing area of exposingmalleus bone through the ridge of petrous temporalbone

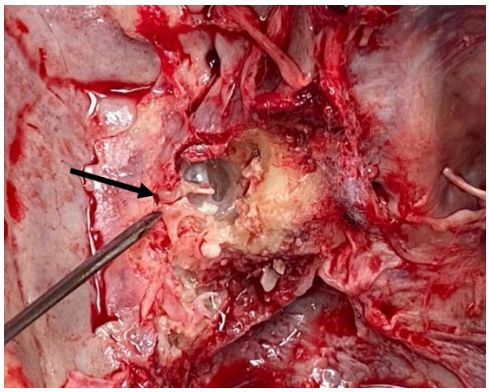

Figure 2: Tegmen tympani is removed and malleus bone is exposed

Figure 3: Malleus bone is carefully removed using crocodile forceps

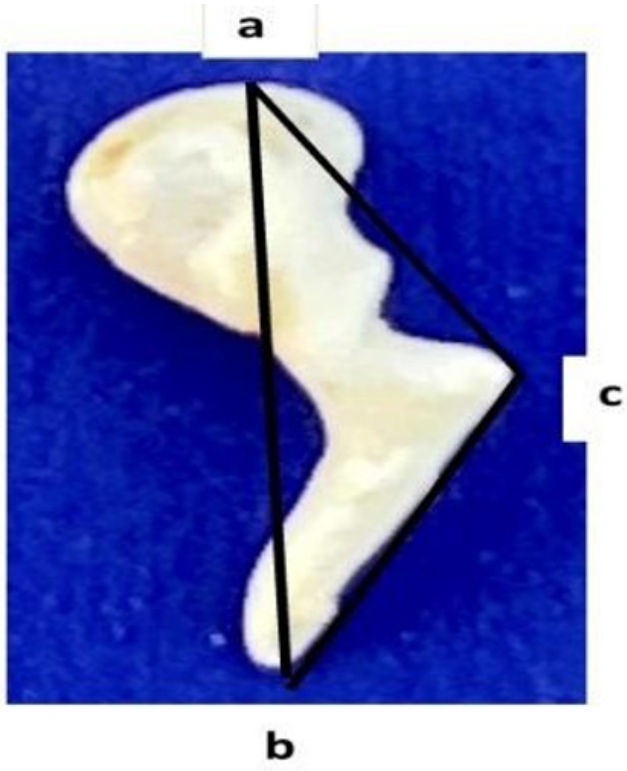

Figure 4: The parameters of the malleusbone

Figure 5: Measuring totall ength of malleusbone by digital vernier calliper

Figure 6: Magnified version of total length of Malleus bone.

Figure 7: Measuring length of manubrium (handle) of Malleusbone by DigitalVernier Calliper.

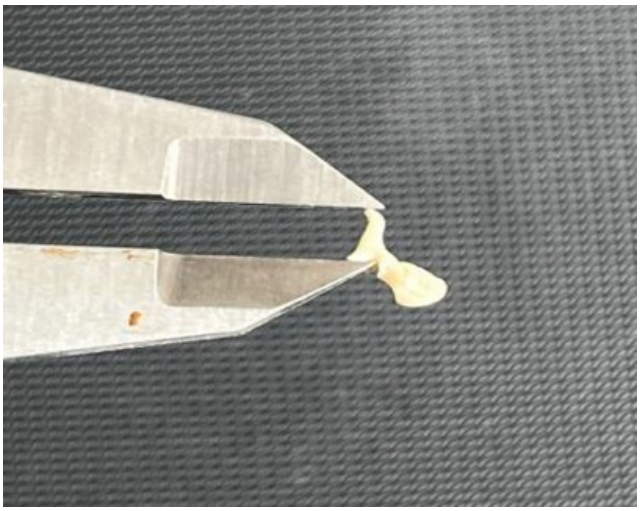

Figure 8: Magnified version of length of manubrium (handle)

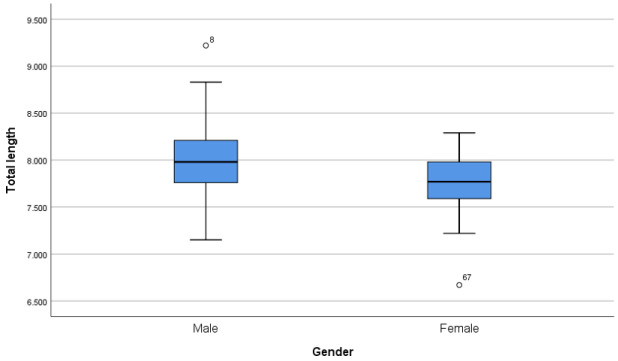

Figure 9: Showing box and whisker plot representing mean, standard deviation, range of length of malleus bone in males and females

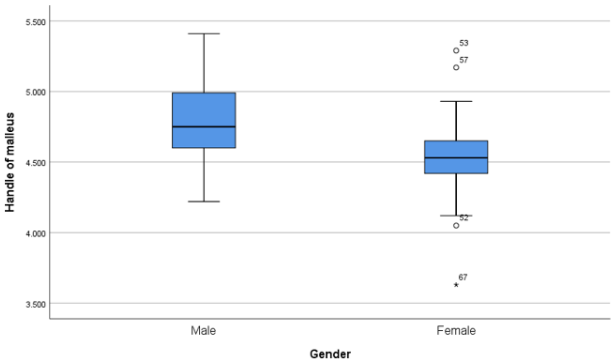

Figure 10: Showing box and whiskerplot representing Mean, standard deviation, range of length of handle of malleusbone in males and females

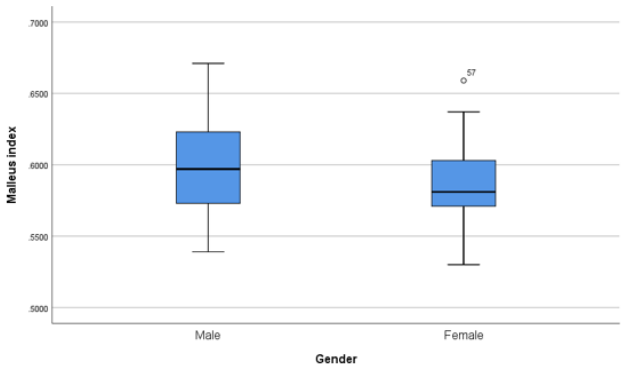

Figure 11: Showing box and whisker plot representing mean, standard deviation, range of malleus Index of malleus bone in males and females

was 6.67mm with a mean of 7.73mm and standard deviation of 0.296 (Table 3 and Figure 9).

Maximum length of Handle of malleus bone in Males was 5.41mm and the minimum length of Handle of malleus in males was 4.22mm with mean of 4.79mm and standard deviation of 0.297. Whereas in Females the maximum length of handle of malleus bone observed was 5.29mm and minimum length of handle of malleus in females observed was 3.36mm with mean 4.54mm and standard deviation of 0.282 (Table 4 and Figure 10).

It was also observed that Maximum Malleus Index in Males was 0.671mm and the minimum malleus index was 0.539 with mean 0.6009 and a standard deviation of 0.0329. whereas in female's maximum malleus index observed was 0.659mm and the minimum malleus observed was 0.53mm with mean 0.5855mm and standard deviation of 0.0281 (Table 5Figure 11). Represents the Comparison of Morphometric Parameters of Male and Female malleus bone. It is observed that Total length of Malleus bone, Handle of malleus and Malleus index were more is a Male as compared to Female and which is found to be statistically significant (p=0.003), (p=0.001) and (p=0.019) respectively. Total length of Malleus bone, Handle of malleus and Malleus index are fairly good criteria to significant test in sexual dimorphism.

4. Discussion

Ossicles are essential for hearing. Interest in morphometric analysis of ear ossicles dates back to the middle of the fifteenth century.[10] The morphometry of ossicles has been studied by various authors more so in males which is comparable to our study findings.

Some authors have studied the morphometry irrespective of sides e.g. Arensburg et al.[10] from Israel took ossicles of either left or right side in an individual and not from both sides. They studied malleus in different races of different era. They reported malleus length 7.7, 8.1, and 7.8 mm and manubrium length of 4.5, 4.6, and 4.4mm in three races. Harneja et al.[11] reported the malleus length of 7.15 mm and manubrium length of 4.22 mm. Bhatnagar et al.[12] reported the malleus length of 7.8mm and manubrium length of 4.65 mm. Rathava J et al.[13] reported the malleus length of 7.81mm and manubrium length of 4.59 mm. Nadeem G et al.[14] reported the malleus length of 8.0 mm and manubrium length of 4.58 mm.

Some authors have studied the morphometry with respect of sides e.g. Mogra K et al.[15] from Rajasthan took out 66 malleus bones from right and left sides, irrespective of sex and found malleus length on right side as 8.51 mm and left side as 8.54 mm while manubrium length 5.10 mm over right side and 5.30 over left side. Sodhi S et al.[16] found malleus length on right side as 7.87 mm and left side as 7.80 mm while manubrium length 4.47 mm over right side and 4.42 mm over left side.

Some authors have studied the morphometry of malleus bone with respect of sides and sex e.g. Singh K et al.[8] reported malleus length 8.0 mm, manubrium length 4.89 mm on right side in males and malleus length 7.8 mm, manubrium length 4.62 mm on right side in females which are comparable with our findings. Ramirez LM and Ballesteros et al.[17] reported malleus length 8.18 mm, manubrium length 4.91 mm in Columbia population. Our findings are comparable to these studies. Vincentiis & Cimino.[18] studied a large series which included infants, juvenile, adult male & females. They reported the length of 9 mm in infants and 9.41 mm in adults with a median of 9.20 mm which is comparable to our findings; however they observed no significant difference with age and sex.

Some authors also calculated malleus index with respect of sides and irrespective of sex eg. Mogra K et al.[15] studied Malleus index as 60.18 over right side and as 61.84 over left side. Sodhi S.[16] studied malleus index as 56.77 over right side and 56.78 over left side which are comparable to our findings. However, we observed that total length of malleus and manubrium length on the right side as significantly sexually dimorphic. It is difficult to understand that total length of malleus is more on right side of males than females.

Further, the bones are slightly bigger as whole on right side in the upper part e.g. humerus as compared to left. We observed that the total length of malleus bone, handle of malleus and malleus index on right side was significantly more in males as compared to females which may be due to the simple fact that all bones are larger in males. However this has not been reported in literature. This could be due to racial difference in various studies as compared to the present. (Table 7)

Oschman Z and Meiring JH.[19] in 1991 measured the total length and length of manubrium of malleus in South African population (n = 122). On comparing with the

present study, the mean of total length of malleus bone was more in males and was less in females whereas the mean of length of manubrium was more in males and was more in females of Indian population compared to South African population. *Unur E* et al.[20] in 2002 measured the total length, length of manubrium, length of head and neck and index of malleus in Turkish population (n= 40). On comparing with the present study, the mean of total length of malleus bone was more in males and females, the mean of length of manubrium was 0.09 mm more in males and was 0.16 mm less in females and mean of index was 0.88 mm less in males and was 2.97 mm less in females of Indian population compared to Turkish population. *Ramirez LM et al.*[17] in 2013 measured the total length and length of manubrium of malleus in Columbian population (n= 23). On comparing with the present study, the mean of total length of malleus bone was 0.21 mm less in males and was 045 mm less in females whereas the mean of length of manubrium was 0.12 mm less in males and was 0.37 mm less in females of Indian population compared to Columbian population. (Table 8).

5. Conclusion

There is a definite sexual dimorphism in the Malleus bone. There is a clear-cut demarcation between the values of male and female bone. The sexual dimorphism is most marked in the Total length of Malleus bone, Handle of malleus and Malleus index of Malleus bone, and there is a significant difference was observed. Hence, it is possible to determine the sex of cadavers using the malleus bone. The sex of the person can be identified with a respectable level of accuracy when more than one parameter is employed. In such cases, the Total length of Malleus bone, Handle of malleus and Malleus index of Malleus bone can be used as one of the parameters for the sexual dimorphism.

6. Abbreviations

TL: Total Length of malleus bone, HM: Handle of malleus bone, MI: Malleus Index of malleus bone, SD: Standard Deviation, RT: Right, LT:Left, M: Male and F:Female.

7. Availability of Data and Material

All raw materialsare available upon reasonable request.

8. Authors' Contributions

A. H.: contributed in the selection of patients, taking samples performance and interpretation of the findings, drafting, final revision and approval of the manuscript. A.K.: contributed in the selection of patients, drafting and final revision of the manuscript. S.K.: final revision and approval of the manuscript.

9. Ethics Approval and Consent to Participate

The study was approved by Taken from Institutional Ethical Committee (GTB Hospital) and was performed in accordance with the ethical standards. Written consents were obtained from relatives of the deceased before starting.

10. Consent for Publication

Not applicable.

11. Source of Funding

None.

12. Conflict of Interest

None.

13. Acknowledgements

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