

Original Research

Morphometric Dimensions of Male Auditory Ossicles among Nigerian Population

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ABSTRACT

Introduction

The auditory ossicles transfer sound vibrations in the tympanic membrane from the middle ear to the inner ear. These ossicles are located in the petrous part of the temporal bone and they form a chain across the tympanic cavity from the tympanic membrane to the oval window.

Aim

The present study was aimed at providing the morphometric dimensions of the male auditory ossicles among the Nigerian population.

Materials and Methods

The study was carried out on 94 malleus (R=44, L=50), 70 incus (R=34, L=36), and 27 stapes (R=10, L=17) auditory ossicles collected from 57 unidentified adult male cadavers from the departments of anatomy of various universities in Nigeria. The various parameters were taken with the help of a digital vernier caliper and weighed with Mettler Toledo weighing balance.

Results

This study revealed no statistically significance difference ($p > 0.05$) between morphometric measurements of the bones of the right and left side except in the malleus. The mean weights (mg) of the malleus, incus and stapes were 22.04, 27.02, and 3.34, respectively. The mean lengths (mm) of the malleus and incus were 8.02 and 6.73, respectively and the mean length of footplates in stapes was 1.94 mm. The mean width of the incus was 4.12 mm and the mean width of the footplate in stapes was 2.88 mm.

Conclusion

The three auditory ossicles are morphometrically identical in both ears except the malleus. The precise measurements of the ossicles have been reported in this study among the adult male Nigerian population which would be very helpful in forensic study. Variations were observed in the dimensions of the ossicles when compared with previous studies which may be due to racial or regional factors as the values from published authors are from Asian and Caucasian populations.

Keywords

Morphometric; Malleus; Incus; Stapes; Ossicles; Auditory.

INTRODUCTION

Ear is an organ that exhibits complicated organization in all organisms in terms of its anatomical and functional features.¹ Overall, in addition to receiving sounds and auditory perception, ear plays an important role in body homeostasis.²⁻⁵ The middle ear communicates to the tympanic cavity by the tympanic membrane (*membrana tympanica*) and communicates with the nasopharynx by the auditory tube (*tuba auditiva*).⁶ The connection between the middle ear and the pharynx is closed except for swallowing or yawning. The opening of this connection allows the air pressure between

the external ear and the middle ear to be balanced.⁷ The transmission of sound waves across the tympanic cavity is mediated by three auditory ossicles including malleus, incus and stapes in a latero-medial sequence.^{8,9} Auditory ossicles transfer the sound vibrations in the tympanic membrane from the middle ear to the inner ear.^{10,11} These ossicles are located in the petrous part (*pars petrosa*) of the temporal bone and in the dorsal aspect of the tympanic membrane^{6,12,13} and form a chain across the tympanic cavity from tympanic membrane to fenestra vestibule (oval window).^{14,15} These bones are bound together by articulations and have ligamentous connections with the walls of the middle ear cavity.¹⁶ The aim of

this study was to provide the morphometric dimensions of male auditory ossicles among the Nigerian population.

METHODOLOGY

This study was institutionally based and was carried out on 57 unidentified adult male cadavers from anatomy departments of various universities in Nigeria. Necessary approval for the study was obtained from the ethical committee. The ossicles were procured manually following bilateral dissection of the temporal bone using Cobbler's Cut Method.^{17,18} The heads of the cadavers were first detached from their bodies using a handsaw for easy maneuvering then the calvaria was removed and the brain was taken out to expose the petrous part of the temporal bone. The temporal bone was cleared off from all the soft tissues attached to it including the mastoid processes. Removal of the intact temporal bone from the skull was done by opening the zygomatic-temporal suture firstly by chisel.¹²

The chisel was placed through the parieto-temporal suture and pushed on the lateral side making the temporal bone relieved from the skull, intact with all its parts. The temporal bone was placed in an upright position with the squamous part as its base and the petrous part as apex.¹² The chisel was placed between the squamous part and the petrous part of the bone and hit vertically and gently by a hammer till the time there appears a crack (cobblers cut) in between the two parts of the temporal bone.

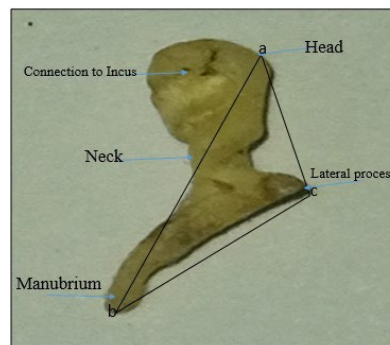
Then with precise and gentle manual force, these two portions were easily separated in two unequal halves of the middle ear; the lateral and medial parts. The lateral part bears the tympanic membrane and two ossicles (malleus and incus) while the medial part with an oblique wall bearing the third middle ear bone (stapes). The ossicles were easily picked up from the exposed parts by fine forceps, the incus bone was taken out first by disarticulation of the incudomalleal joint, followed by the retrieval of the malleus and the removal of stapes with the help of fine forceps. This way, all three ossicles were safely removed. The bones were cleansed (removal of any tissue attachment). They were stored in plastic bags with labels indicating the sides and the name of the ossicular bone. The total number of ossicle bones harvested was 94 malleus (right=44, left=50), 70 incus (right=34, left=36), and 27 stapes (right=10, left=17).

Measurements were taken with the help of a digital Vernier caliper with the least count of 0.01 mm. Each bone was weighed on the Mettler Toledo weighing balance.

Methods of Data Analysis

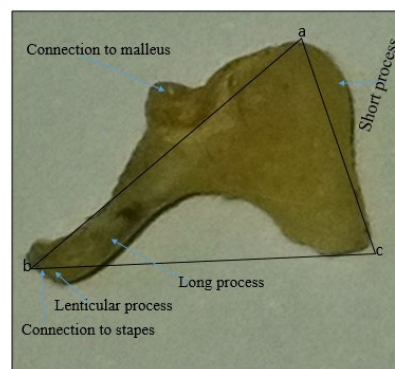
All the statistical calculations were performed using the software statistical package for the social sciences (SPSS) version 20 and Microsoft excel 2019 edition. The measurements were presented in mean±standard deviation (SD). Paired *t*-test was used for side comparison. The confidence interval was set at 95% with a significant difference at $p < 0.05$ (Figures 1, 2 and 3).

Figure 1. Dimensions of the Malleus



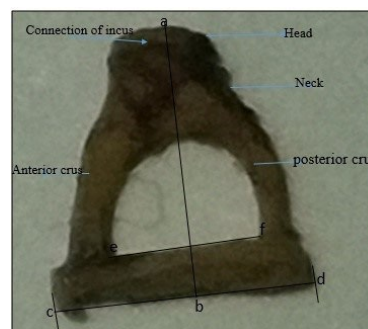
- I. Total length (TL): Maximum distance between the top of the head and the end of the manubrium (mm) (a-b)
- II. Length of manubrium (LM): Distance from the end of the lateral process to the end of manubrium (mm) (c-b)
- III. Length of head and neck (LHN): Maximal distance between the top of the head and the end of the lateral process (mm) (a-c)
- IV. Index (I): Length of manubrium X 100/total length(%)
- V. Weight of malleus (Wt in mg)

Figure 2. Dimensions of the Incus

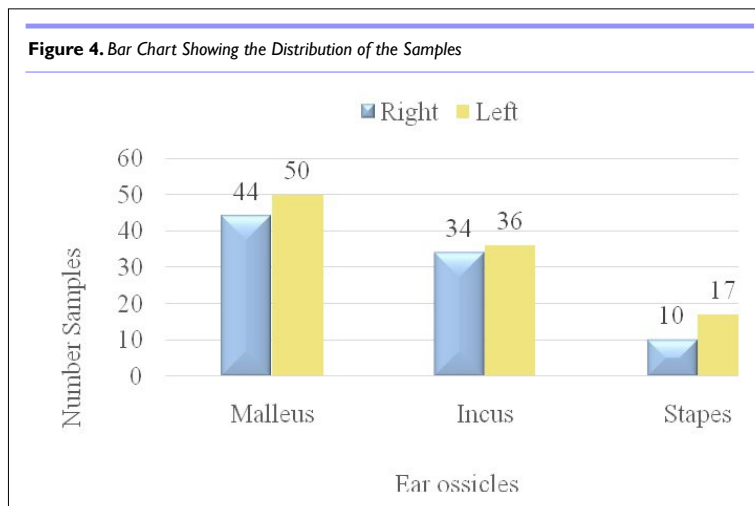


- I. Total length (TL): Maximal distance between the superior edge of the body and the end of the long process (mm) (a-b)
- II. Total width (TW): Maximal distance between the superior edge of the body and the end of the short process (mm) (a-c)
- III. Maximal distance (MD) between the tips of the processes (mm) (b-c)
- IV. Total height (TH): Maximum height of incus (mm)
- V. Index (I): Total width X 100/total length of incus(%)
- VI. Weight of incus (Wt in mg)

Figure 3. Dimensions of Stapes



- I. Total height (TH): maximal distance between the top of the head and the footplate (mm) (a-b)
- II. Length of foot plate (LFP): maximal length of the long axis of foot plate (mm) (c-d)
- III. Width of foot plate (WFP): maximal width of the footplate (mm) (e-f)
- IV. Index (I): Length of footplate X 100/total height of stapes(%)
- V. Weight of stapes (Wt in mg)



RESULTS

The measurements were graphically presented and tabulated as

mean±standard deviation and range (min-max) for the right and left auditory ossicles (Figure 4), (Tables 1, 2 and 3).

Table 1. Descriptive Statistics for Right and Left Malleus

Malleus	Right (N=44)			Left (N=50)		
	Min	Max	Mean±SD	Min	Max	Mean±SD
TL (mm)	7.85	9.17	8.14±0.31	7.39	8.50	7.89±0.17
LM (mm)	4.37	5.20	4.96±0.13	4.54	5.05	4.89±0.10
LHN (mm)	4.85	6.00	5.09±0.28	4.52	5.50	4.89±0.16
Wt (mg)	21.50	22.30	21.68±0.20	22.25	22.43	22.39±0.04
I (%)	52.56	65.00	61.06±2.80	57.37	66.30	62.01±1.42

*Significant at p<0.05, TL=Total length, LM=Length of manubrium, LHN=Length of head and neck, Wt=Weight of Malleus, I=Index, Min=Minimum, Max=Maximum, SD=Standard Deviation, N=Number of Samples

Table 4. Paired t-test Comparing Right and Left Malleus

Comparison	Paired Differences		SEM	Paired t-test		
	MD	SD		df	t value	p value
R-TL vs L-TL	0.25	0.31	0.05	43	5.41	0.00*
R-LM vs L-LM	0.07	0.18	0.03	43	2.61	0.01*
R-LHN vs L-LHN	0.21	0.30	0.05	43	4.53	0.00*
R-Wt vs L-Wt	-0.71	0.22	0.03	43	-21.06	0.00*
R-I vs L-I	-0.85	3.14	0.47	43	-1.80	0.08

*Significant at p<0.05, R=Right, L=Left, TL=Total length, LM=Length of manubrium, LHN=Length of head and neck, Wt=Weight of Malleus, I=Index, MD=Mean Difference, SD=Standard Deviation, SEM=Standard Error of Mean Difference

Table 2. Descriptive Statistics for Right and Left Incus

Malleus	Right (N=34)			Left (N=36)		
	Min	Max	Mean±SD	Min	Max	Mean±SD
TL (mm)	6.32	7.01	6.74±0.17	6.54	7.10	6.72±0.14
TW (mm)	3.58	4.36	4.11±0.20	3.85	4.43	4.17±0.18
MD (mm)	5.57	6.46	6.10±0.21	5.65	6.41	6.04±0.17
TH (mm)	2.05	2.40	2.24±0.11	1.99	2.47	2.25±0.11
Wt (mg)	26.52	27.30	26.98±0.28	26.60	27.43	27.05±0.25
I (%)	51.14	68.35	61.37±4.13	57.68	66.41	62.34±2.74

*Significant at p<0.05, TL=Total length, TW=Total width, MD=Maximal distance, TH=Total height, Wt=Weight of Incus, I=Index, Min=Minimum, Max=Maximum, SD=Standard Deviation, N=Number of Samples

Table 5. Paired t-test Comparing Right and Left Incus

Comparison	Paired Differences		SEM	Paired t-test		
	MD	SD		df	t value	p value
R-TL vs L-TL	0.02	0.25	0.04	33	0.43	0.67
R-TW vs L-TW	-0.04	0.32	0.06	33	-0.77	0.45
R-MD vs L-MD	0.07	0.30	0.05	33	1.29	0.21
R-TH vs L-TH	-0.01	0.14	0.02	33	-0.43	0.67
R-Wt vs L-Wt	-0.07	0.42	0.07	33	-0.95	0.35
R-I vs L-I	-0.80	5.97	1.02	33	-0.78	0.44

*Significant at p<0.05, R=Right, L=Left, TL=Total length, TW=Total width, MD=Maximal distance, TH=Total height, I=Index, Wt=Weight of Incus, MD=Mean Difference, SD=Standard Deviation, SEM=Standard Error of Mean Difference

Table 3. Descriptive Statistics for Right and Left Stapes

Malleus	Right (N=10)			Left (N=17)		
	Min	Max	Mean±SD	Min	Max	Mean±SD
TH (mm)	2.86	3.48	3.25±0.21	2.75	3.46	3.14±0.22
LFP (mm)	1.85	2.01	1.93±0.06	1.75	2.05	1.94±0.09
WFP (mm)	2.52	3.09	2.86±0.20	2.50	3.08	2.89±0.19
Wt (mg)	3.27	3.39	3.34±0.05	3.20	3.39	3.34±0.06
I (%)	54.41	70.28	59.86±4.59	51.47	75.92	62.52±6.85

*Significant at p<0.05, TH=Total height, LFP=Length of foot plate, WFP=Width of foot plate, Wt=Weight of Stapes, I=Index, Min=Minimum, Max=Maximum, SD=Standard Deviation, N=Number of Samples

Table 6. Paired t-test Comparing Right and Left Stapes

Comparison	Paired Differences		SEM	Paired t-test		
	MD	SD		df	t value	p value
R-TH vs L-TH	0.05	0.24	0.08	9	0.70	0.50
R-LFP vs L-LFP	0.02	0.13	0.04	9	0.63	0.54
R-WFP vs L-WFP	-0.02	0.29	0.09	9	-0.17	0.87
R-Wt vs L-Wt	-0.03	0.05	0.02	9	-1.93	0.09
R-I vs L-I	-0.70	7.63	2.41	9	-0.29	0.78

*Significant at p<0.05, R=Right, L=Left, TH=Total height, LFP=Length of foot plate, WFP=Width of foot plate, Wt=Weight of Stapes, I=Index, MD=Mean Difference, SD=Standard Deviation, SEM=Standard Error of Mean Difference

Paired *t*-test was used to compare the right and left dimensions of the malleus, incus, and stapes. Our findings showed that there was a statistically significant difference ($p < 0.05$) observed when all the morphometric data in the malleus were compared in terms of sides except for the Index (Table 4). Tables 5 and 6 showed that there was no statistically significant difference ($p > 0.05$) observed when all the morphometric dimensions of incus and stapes were compared in terms of sides.

DISCUSSION

Over the passage of time, very few studies are reported regarding the precise measurements of these miniature bones. The various parameters of the three bones have been compared with those prescribed by other authors over the period of the past 50-years as reported from different regions of the world. The ear ossicles were

first described in the 16th century. Hast et al³⁸ stated that Vesalius described incus and malleus in 1543 in his monumental work “*De Humani Corporis Fabrica*” whereas Ingrassia et al³⁹ were the first to describe stapes in 1546. Though these bones attain full adult size during fetal life but continue to undergo changes throughout life, so the variations of the size and morphology of these bones are expected.¹⁹

The mean weight of the malleus obtained in this present study was different from Sodhi et al¹² and Jyoti et al²⁵. Harneja et al¹⁹, Bhatnagar et al²² and Singh et al²⁶ tend to have higher values. The mean length of malleus in this study was in support of the report from Oschman et al²¹. The dimensions of malleus were comparatively low to South Africa, Mysore, Rohtak, Colombia, Jaipur, Israel, North India, AP and Turkey populations, but were on the higher side to that of Punjab, Rajasthan subjects (Table 7).

Table 7. Comparison between Morphometric Data of Malleus with Previous Studies

Author	Population	Sample Size	Mean Length	Mean Length Manubrium	Mean Head and Neck	Wt	Index
Harneja et al ¹⁹	Jaipur	50	7.15	4.22	--	23.65	--
Arrensburg et al ²⁰	Israel	31	7.8	4.4	--	--	56.6
Oschman et al ²¹	South Africa	90	7.84	4.39	--	22	--
Bhatnagar et al ²²	Punjab	60	8.36	4.65	--	25.99	--
Unur et al ²³	Turkey	40	7.69	4.70	4.85	--	60.97
Natekar et al ²⁴	Goa	--	--	--	--	--	56.05
Jyoti et al ²⁵	Mysore	50	7.65	3.52	2.37	20.90	--
Singh et al ²⁶	Rohtak	120	7.94	4.76	5.23	22.92	56.05
Gulrez ²⁷	Aligarh UP	30	8.00	4.58	--	--	--
Ramirez et al ²	Colombia	23	8.53	4.91	--	--	--
Vinayachandra et al ²⁸	Mangalore	50	7.45	--	--	18.26	--
Padmani et al ²⁹	AP	100	5.54	3.03	2.79	--	54.73
Mogra et al ³⁰	Rajasthan	66	8.53	5.20	4.72	--	61.01
Rathava et al ³¹	Jamnagar	60	7.81	4.59	5.00	--	--
Sodhi et al ¹²	North India	100	7.83	4.44	4.68	21.97	56.77
Present Study	Nigeria	94	8.02	4.93	4.99	22.04	61.54

Wt=Weight of Malleus

Table 8. Comparison between Morphometric Data of Incus with Previous Studies

Author	Population	Sample Size	Mean Length	Mean Width	Mean of Distance between Two Processes	Wt	Index
Harneja et al ¹⁹	Jaipur	50	3.14	1.82	--	25.06	--
Arrensburg et al ²⁰	Israel	22	6.4	5.1	--	--	80.1
Unur et al ²³	Turkey	40	6.47	4.88	6.12	--	79.84
Natekar et al ²⁴	Goa	--	6.52	5.06	5.86	20.74	--
Jyoti et al ²⁵	Mysore	50	6.32	4.41	--	23.82	--
Gulrez ²⁷	Aligarh	30	6.38	4.60	--	--	--
Padmani et al ²⁹	AP	100	5.13	3.47	4.5	--	67.75
Mogra et al ⁹	Rajasthan	66	7.26	5.95	6.80	--	82.41
Singh et al ³²	Rohtak	120	6.67	5.04	6.01	26.30	75.71
Sodhi et al ¹²	North India	100	6.47	4.88	5.31	23.88	75.45
Present Study	Nigeria	70	6.73	4.12	6.07	27.02	61.86

Wt=Weight of Incus

Table 9. Comparison between Morphometric Data of Stapes with Previous Studies

Author	Population	Sample Size	Mean Height	Mean Length of Footplate	Mean Width of Footplate	Wt	Index
Dass et al ³³	Patiala	165	3.29	2.79	1.43	3.02	--
Dass et al ³⁴	Patiala	100 (fetal)	3.32	2.82	1.41	--	--
Harneja et al ¹⁹	Jaipur	50	3.12	2.68	1.26	3.17	--
Arrensburg et al ²⁰	Isreal	--	3.2	2.8	1.3	--	85.1
Awengen et al ³⁵	Switzerland	10	--	2.48	--	--	--
Unur et al ²³	Turkey	40	3.22	2.57	1.29	--	80.06
Wadwa et al ³⁶	New Delhi	17	3.41	2.97	0.38	--	--
Farahani et al ³⁷	Iran	12	3.28	2.99	1.43	--	--
Jyoti et al ²⁵	Mysore	50	3.11	3.12	1.51	2.23	--
Gulrez ²⁷	Aligarh	30	3.18	2.93	1.60	--	--
Padmini et al ²⁹	AP	100	2.71	2.36	--	--	87.2
Rathava et al ³¹	Jamnagar	60	3.33	2.78	1.34	--	--
Sodhi et al ¹²	North India	100	3.38	2.80	1.36	2.55	83.22
Present Study	Nigeria	27	3.20	1.94	2.88	3.34	61.19

Wt=Weight of Stapes

The mean weight of the incus obtained from this study was higher with the reports from Harneja et al,¹⁹ Natekar et al,²⁴ Jyoti et al,²⁵ Sodhi et al¹⁷ and Singh et al²⁶. The mean length of incus in this present study was different from the report from Natekar et al²⁴ but in support of the works from Sodhi et al,¹⁷ Singh et al,²⁶ Unur et al²³ and Mogra et al³⁰. The dimensions obtained in incus were at variance with North India, AP and Jaipur, Rohtak Aligarh populations. The dimensions were on the higher side to that of Rajasthan and similar to Goa, Turkey and Israel Subjects (Table 8).

In the case of stapes, the value of the mean weight obtained in this study correlates with the work of Harneja et al,¹⁹ and Dass et al³³ but is slightly lower than the reports from Jyoti et al²⁵ and Sodhi et al¹⁷. The mean length of the footplate in stapes in this present study was lesser than the reports from Sodhi et al,¹⁷ Rathava et al,³¹ Padmani et al²⁹ and Gulrez²⁷. Jyoti et al,²⁵ Farahani et al,³⁶ Wadhwa et al³⁷ and Unur et al²³ values. In addition, the mean width of the footplate in stapes in this present study was higher than the reports from Sodhi et al,¹⁷ Rathava et al³¹ and Gulrez²⁷. The dimensions of stapes when compared with Patiala, Jaipur, New Delhi, and Uttar Pradesh were higher. Values were also lower than in studies conducted at Jamnagar, Israel, Turkey and Switzerland (Table 9).

In this study, the morphometric values of right and left auditory ossicles were compared; the differences were not statistically significant ($p > 0.05$) except for malleus which showed statistical significance with the index. It was in contrast with the report from Sodhi et al¹⁷ which revealed no significant difference between morphometric measurements of the bones of the right and left side in malleus, incus, and stapes except in the maximum distance between long and short processes. The right-side values were significantly higher than the left-side ($p = 0.047$). It was also in contrast with Vinayachandra et al²⁸ they reported that the left-sided malleus dominated the right-sided ones in both length and weight. Ravindra et al⁴⁰ also reported that no significant difference was found

between the right and left malleus in both males and females. Jyothi et al²⁵ also reported no significant difference between right and left incus on comparing the parameters.

The variations observed in the morphometric dimensions of the human male auditory ossicles could be due to racial or regional factors as the values from these published authors are from Asian and Caucasian populations.

The study has some limitations. These include:

1. There was an incomplete set of the ossicle bones in different bodies, this account for different numbers of the ossicles harvested.
2. Due to the miniature size and fragility of the ossicles especially the stapes, it was difficult to harvest many as most of it was broken in some part or whole.

CONCLUSION

The three auditory ossicles are morphometrically identical in both ears except the malleus. The precise measurements of the ossicles have been reported in this study among adult male Nigerian population which would be very helpful in forensic study. Variations were observed in the dimensions of the ossicles when compared with previous studies which may be due to racial or regional factor as the values from published authors are from Asian and Caucasian populations.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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