



Original Research Article

Morphometric study of stapes and its variation in Eastern Indian population

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ABSTRACT

Background: For audiological prosthesis surgery morphometry of stapes is of utmost importance. Previous studies were mainly based on foreign and northern Indian population. Hence the present study.

Aims: To measure the morphometric parameters of stapes and compare the same with the previous studies.

Materials and Methods: This cross sectional observational study, performed on the ear ossicle, stapes obtained from 26 cadaveric heads. A total of $(26 \times 2) = 52$ sets of stapes were taken out for the study. Measurements of various parameters of the ossicles were done with micrometer. Comparison among them with respect to sex, laterality and race were made. Age variation was not considered as the ossicles reach their full size at birth.

Result: Statistically significant difference in the total height of stapes was observed between male and female ossicles, but no such disparity was found between ossicles of the two sides. Height of stapes in males (mean: 3.35mm) was found to be significantly higher (p value: 0.00001) as compared to females (mean: 3.18mm) in this present study. In surgeries for otosclerosis, the stapes superstructure is removed and replaced by a prosthetic 'piston', the selection of which is determined by the distance between the lenticular process of incus and the footplate of stapes, which in turn corresponds to the height of stapes superstructure. This measurement is vital for a properly fit piston and thus to the outcome of the surgery in terms of hearing improvement and lack of complications like expulsion of the piston, intractable vertigo, etc. When the mean values found in this study were compared with those of previous foreign and Indian studies, some of the values were found to be similar.

Conclusion: The height of stapes was shorter in our study as compared to studies based on North Indian population. These differences might point towards geographic or ethnic variations in the stapes which might call for further research work into this topic.

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1. Introduction

Stapes is the smallest bone in the body measuring in average about 3-5 mm in height. It helps to transmit the vibrations from the incus to the inner ear (scala vestibuli) lying beyond the oval window. This bone looks exactly like a miniature stirrup¹ consisting of a head, neck, two crura and a foot plate. The head articulates with the lenticular process to

form a synovial ball and socket type 'incudo-stapedial' joint. Neck receives posteriorly the insertion of the stapedius muscle. The rocking movement of the footplate helps to set the inner ear fluids into motion.

For proper conduction of sound waves, an intact ossicular chain is required. The ossicular chain also has a contributory effect in the direct reduction of the impedance mismatch caused as a result of sound waves traversing through different media before stimulating the auditory hair cells.²

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Since this study is based on Eastern Indian population, the data obtained will help to design various ossicular prosthesis like the ‘Piston’³ which is widely used in stapedectomy, specially designed and customised for the said Population. It is also hoped that this study will help the oto-surgeons in their various microsurgical manoeuvres and manipulations in the limited working space of the middle ear.

Otosclerosis is an autosomal dominant hereditary osseous dysplasia of petrous temporal bone, confined to bones derived from the embryonic otic capsule.⁴ It affects mostly women between twenty to forty years of age. Here the normal bone is replaced by immature spongy bone with increased cellularity and vascularity alongside areas of fibrous replacement and sclerosis. The most common site for otosclerotic focus is the area anterior to the oval window leading to ankylosis of the stapes footplate.⁴ This hampers the rocking movement of the stapes as it becomes fixed in the oval window resulting in deafness. The stapes, particularly the superstructure, may also be eroded in infective diseases of the middle ear like the CSOM.⁵

Surgical treatment in otosclerosis includes ‘Stapedectomy’ or ‘Stapedotomy’, which involves placing a prosthesis ‘piston’ after perforating the footplate of stapes, fracturing it and then removal of the stapes superstructure. The motto of stapes surgery is to transmit the sound vibration from incus to the scala vestibuli of the inner ear directly through this prosthesis.² For this, precise measurement of the ‘piston’ which ought to fit snugly in the gap between incus long process and the foot plate is required.³ In order to provide maximum audiological benefit the such prosthesis should be adjusted in shape, dimensions and angles before insertion into the middle ear of a particular patient.⁶ Therefore proper measurement of the ossicles and their variations need to be recorded for reference.

The present work is based on the morphometric measurements of the stapes in cadavers and aimed towards finding out any differences between male and female ossicles and ossicles of the two sides of an individual. Our data may help in designing different ossicular prosthesis for the two sexes, used in oto-surgeries.

2. Materials and Methods

The study was performed on 52 sets of mallei which were taken from 26 cranial parts of adult cadavers, obtained from the department of Anatomy, Medical College & Hospital, Kolkata, after dissecting them under the operating otolaryngological microscope with the help of micro-surgical forceps and knives and micro-drill set. Those ossicles which showed morphological alterations were excluded, so finally, a total number of 52 mallei were studied, out of which 32 were from male cadavers and 20 were from female cadavers. Since the auditory ossicles reach their adult size even during

the prenatal period,⁵ and we performed this study on adult cadavers only, therefore age as a parameter of variations amongst the ossicles has not been considered.

A micrometer (accuracy 0.01mm) was used to measure the mallei and the angle was measured from the photographs of the mallei taken.

First, each head was placed under the operating microscope. A standard post aural incision was made. The incision was deepened to reach the periosteum, which was then lifted off the underlying mastoid bone. The pinna was retracted anteriorly with a mastoid retractor to expose the posterior wall of the external auditory canal. An incision was made on the cartilage part of the canal at the osteo-cartilagenous junction and the pinna was retracted more anteriorly to have a proper view of the external auditory canal and tympanic membrane. A transmeatal incision was made from 5 O’clock position to 12 O’clock position on the skin of the canal wall with a side-knife. The large postero-superior tympano-meatal flap was elevated from the underneath bone along with the annulus and tympanic membrane. The handle of malleus remaining embedded in the tympanic membrane, was freed by means of sickle-knife. The elevated tympano-meatal flap was reflected anteriorly to enter the middle ear (technique similar to anterior tympanotomy).⁷

The handle of malleus and long process of incus were visualised. The fold of mucous membrane containing tensor tympani muscle was cut. To expose the head of malleus, body and short process of incus the attic needed to be opened up. For this, the micro-drill was used to drill out the posterior bony canal wall. Subsequently, on drilling out the lateral wall of the epitympanum, the head of malleus, body of incus were seen. On further drilling posteriorly across the aditus towards the mastoid antrum, the fossa incudis with the short process of incus were visualized. The ligaments of these ossicles which attach them to the walls of tympanic cavity were cut.

First the malleus was disarticulated from the body of incus by holding it with alligator forceps and gently twisting it. The incudo-stapedial joint was divided by the tip of a short hook which was placed medial to the long process of incus. The stapes was seen postero-medially. The stapedial tendon was cut. The mucus membrane covering the footplate was removed by a curved hook and the footplate was mobilised and freed from the annular ligament. Next with the help of the curved hook, introduced in the foramen obturatum the stapes was brought out.

Thus, 52 intact stapes were taken out from the middle ear cavities of both sides, properly labelled according to the sex of the individual and laterality of the malleus. They were then measured by a micrometer (accuracy 0.01mm)

2.1. Inclusion criteria for selection of samples

1. Samples with intact temporal region.

2. Samples having intact ossicular chain with no discontinuity or erosion.
3. Samples of both sexes and all ages.

2.2. Exclusion criteria

1. The ossicles which were eroded as a consequence of CSOM or other diseases.
2. Ankylosis of head of malleus.
3. Stapes footplate fixation as in Otosclerosis.

2.3. Parameters of stapes studied (Figure 1)

1. Total height (a-b) [maximal distance between the top of head & the base of stapes].
2. Length of footplate of stapes (c-d) [maximal length of the long axis of the footplate].
3. Width of footplate of stapes (w) [maximal width of the footplate].

3. Results

The study could finally be conducted on 52 sets of malleus, incus and stapes, of which 32 belonged to males and 20 belonged to females. 26 sets of ossicles were right sided and 26 sets were left sided. The morphometric differences for the chosen parameters of stapes depending on sex (Table 1), their statistical significance (Table 2), and their comparative analysis Figure 1).

3.1. Morphometry of the male and female stapes

The average (mean) Total height of male stapes is 3.35mm $\pm$ 0.17 (max-3.72, min-3.08), whereas that of female stapes is 3.18mm $\pm$ 0.08 (max-3.48, min-3.1).

The average (mean) Length of footplate of male stapes is 2.73mm $\pm$ 0.19(max-3.01, min-2.38), whereas that of female stapes is 2.67mm $\pm$ 0.16 (max-2.9, min-2.39).

The average (mean) Width of footplate of male stapes is 1.35mm $\pm$ 0.09 (max-1.51, min-1.06), whereas that of female stapes is 1.32mm $\pm$ 0.13 (max-1.54, min-1.04).

The total height of male stapes is significantly higher than that of female stapes (p-Value-0.00001), whereas no significant difference is found among other parameters of stapes (p-Value>0.05).

3.2. Morphometry of right and left stapes:-

The average (mean) Total height of left stapes is 3.28mm $\pm$ 0.17 (max-3.68, min-3.08), whereas that of right stapes is 3.29mm $\pm$ 0.16 (max-3.72, min-3.1).

The average (mean) Length of footplate of left stapes is 2.70mm $\pm$ 0.19 (max-2.98, min-2.39), whereas that of right stapes is 2.69mm $\pm$ 0.18 (max-3.01, min-2.38)

The average (mean) Width of footplate of left stapes is 1.34mm $\pm$ 0.11 (max-1.5, min-1.04), whereas that of right stapes is 1.35mm $\pm$ 0.1 (max-1.54, min-1.06).

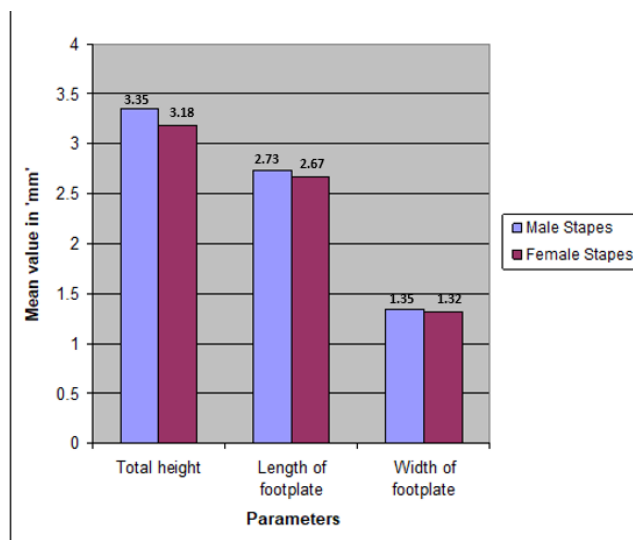


Figure 1: Bar diagram showing comparison between Stapes obtained from male and female cadavers

No significant difference exists in the parameters of left and right stapes (p-Value >0.05 in all parameters).

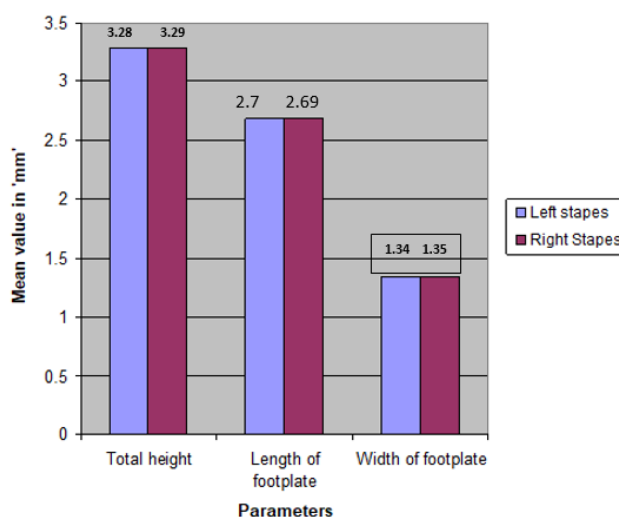


Figure 2: Bar diagram showing comparison between stapes obtained from left and right sides

4. Discussion

The middle ear ossicles form a semi rigid chain in the middle of the ear for conduction and amplification of sound waves from the tympanic membrane to the inner ear. Diseases of the middle ear like CSOM, cholesteatoma, otosclerosis etc. often involve the ossicular chain, leading to hearing loss and disability for the patient. Eastern India is no exception to it and huge numbers of people affected by these diseases need medical help. Due to the advent

Table 1: Showing morphometric data of all specimens of stapes classified according to sex (Metric values given in mm)

Male stapes (n=32)				Female stapes (n=20)			
S.No.	Total height	Length of Footplate	Width of Footplate	S.No.	Total height	Length of Footplate	Width of Footplate
1	3.41	2.9	1.25	1	3.15	2.56	1.21
2	3.56	2.74	1.38	2	3.36	2.87	1.36
3	3.67	2.83	1.47	3	3.1	2.67	1.2
4	3.58	2.47	1.51	4	3.48	2.9	1.04
5	3.29	2.79	1.06	5	3.18	2.52	1.12
6	3.08	2.99	1.41	6	3.15	2.6	1.3
7	3.12	2.83	1.39	7	3.16	2.58	1.14
8	3.43	2.84	1.28	8	3.18	2.9	1.35
9	3.51	2.78	1.31	9	3.15	2.89	1.38
10	3.59	2.89	1.45	10	3.19	2.83	1.38
11	3.46	2.53	1.49	11	3.19	2.74	1.27
12	3.34	2.84	1.1	12	3.17	2.68	1.32
13	3.14	2.89	1.36	13	3.12	2.67	1.54
14	3.18	2.95	1.38	14	3.15	2.51	1.38
15	3.28	2.47	1.35	15	3.17	2.47	1.42
16	3.28	2.57	1.34	16	3.16	2.84	1.45
17	3.15	2.89	1.38	17	3.14	2.61	1.49
18	3.41	2.73	1.45	18	3.17	2.48	1.37
19	3.31	3.01	1.41	19	3.2	2.39	1.48
20	3.18	2.86	1.29	20	3.13	2.79	1.39
21	3.24	2.39	1.33				
22	3.38	2.55	1.42				
23	3.19	2.83	1.38				
24	3.48	2.79	1.41				
25	3.24	2.98	1.5				
26	3.27	2.83	1.34				
27	3.24	2.81	1.3				
28	3.3	2.48	1.31				
29	3.21	2.76	1.36				
30	3.33	2.44	1.29				
31	3.68	2.38	1.32				
32	3.72	2.43	1.35				
Mean	3.35	2.73	1.35		3.18	2.67	1.32
SD	±0.17	±0.19	±0.09		±0.08	±0.16	±0.13

Table 2: p-Value of parameters of stapes classified according to gender and their significance by student 't' test

Parameters	P Value	Significance
Total Height	0.00001	Significant
Length of Footplate	0.266	Not significant
Width of Footplate	0.422	Not Significant

of powerful operating microscopes, micro-instruments and various ossicular prosthesis, reconstruction of the lost or diseased ossicular elements are now-a-days possible, thereby opening up new horizons where researchers may go hand in hand with the oto-surgeons, to contribute to the welfare of patients.

Studies were conducted earlier on morphometry and morphological variations of middle ear ossicles particularly in countries abroad. In India, however detailed morphometric studies on middle ear ossicles were lacking till the beginning of 20th century⁸ when a number of

informative research works by Indian researchers were published.

In the present study, total height of stapes in male shows statistically significant higher values (p-Value- 0.00001) than that of female in our study [Figure 1, Tables 1 and 2]. But the dimensions of the footplate do not show statistically significant disparity between the two sexes. The clinical significance of this finding lies in the fact that, the height of stapes is an important parameter for selection of the piston used in stapedectomy.⁹ An accurate length of piston is required to bridge the gap between the long process

Table 3: Showing morphometric data of all specimens of stapes classified according to laterality (Metric value given in mm & angle in degree)

Serial no. of cadaveric heads	No.	Left Stapes (n = 26)			No.	Right Stapes (n = 26)		
		Total Height	Length of Footplate	Width of Footplate		Total Height	Length of Footplate	Width of Footplate
1	s-1	3.15	2.67	1.2	s-1	3.1	2.56	1.21
2	s-2	3.36	2.9	1.04	S-2	3.48	2.87	1.36
3	s-3	3.41	2.84	1.28	s-3	3.43	2.9	1.25
4	s-4	3.56	2.78	1.31	S-4	3.51	2.74	1.38
5	s-5	3.67	2.89	1.45	s-5	3.59	2.83	1.47
6	s-6	3.58	2.53	1.49	S-6	3.46	2.47	1.51
7	S-7	3.29	2.84	1.1	s-7	3.34	2.79	1.06
8	s-8	3.08	2.89	1.36	s-8	3.14	2.99	1.41
9	s-9	3.12	2.95	1.38	s-9	3.18	2.83	1.39
10	s-10	3.18	2.58	1.14	s-10	3.16	2.52	1.12
11	s-11	3.15	2.9	1.35	S-11	3.18	2.6	1.3
12	s-12	3.28	2.39	1.33	s-12	3.24	2.47	1.35
13	s-13	3.28	2.55	1.42	s-13	3.38	2.57	1.34
14	s-14	3.15	2.83	1.38	s-14	3.19	2.89	1.38
15	s-15	3.41	2.79	1.41	s-15	3.48	2.73	1.45
16	s-16	3.31	2.98	1.5	s-16	3.24	3.01	1.41
17	s-17	3.18	2.83	1.34	s-17	3.27	2.86	1.29
18	s-18	3.16	2.39	1.4	s-18	3.19	2.43	1.34
19	s-19	3.24	2.75	1.36	s-19	3.21	2.81	1.3
20	s-20	3.3	2.44	1.29	s-20	3.33	2.48	1.31
21	S-21	3.19	2.68	1.32	s-21	3.17	2.74	1.27
22	s-22	3.68	2.43	1.35	s-22	3.72	2.38	1.32
23	S-23	3.12	2.61	1.49	S-23	3.14	2.67	1.54
24	s-24	3.15	2.48	1.37	s-24	3.17	2.51	1.38
25	s-25	3.17	2.39	1.48	s-25	3.2	2.47	1.42
26	s-26	3.16	2.79	1.39	s-26	3.13	2.84	1.45
Mean		3.28	2.7	1.34		3.29	2.69	1.35
SD		± 0.17	± 0.19	± 0.11		± 0.16	± 0.18	± 0.1

Table 4: p-Value of parameters of Stapes classified according to Laterality and their significance by student 't' test

Parameters	P Value	Significance
Total Height	0.806	Not Significant
Length of Footplate	0.914	Not significant
Width of Footplate	0.922	Not Significant

Table 5: Morphometric data of middle ear ossicles from present and some previous foreign studies

	Total height	Length of foot plate	Width of foot plate
Present study	3.29	2.7	1.35
Urbantschitsch	3.7	3	1.5
Anson	NA	2.47	1.5
Bast & Anson	3.06	2.99	1.41
Bouchet & Giraust	3.5	NA	Na
Arensburg et al	3.2	2.8	1.3
Unur et al	3.2	2.6	1.3

Table 6: Morphometric data of middle ear ossicles from present study and some previous Indian studies

Stapes Parameters	Present Study	Dass et al (1966)	Wadhwa et al (2005)	Kumar et al (2008)
Total Height	3.29	3.29	3.41	3.45
Length of footplate	2.7	2.79	2.97	2.75
Width of footplate	1.35	1.43	NA	1.3
NA- Not available				

of incus and stapes footplate created after fracturing the stapes superstructure which in turn depends upon the height of stapes. So, the detailed knowledge of the stapes super-structure is essential for designing of electromagnetic middle ear implants.

According to our study, as the height of stapes in male is significantly higher than in female, it can be projected that the choice of appropriate size of piston for stapedectomy will differ according to the sex of the patient in Eastern Indian population. These findings might also help in manufacture of ossiculoplasty prosthesis customised for male and female patients. Such pre-fabricated implantable devices having specific shapes and dimensions not only decrease the operating time for the otosurgeon,¹⁰ improve the outcome of the surgical procedures.

However, in our study, no significant morphometric variations were found when the stapes of both sides of each cadaver were compared (Figure 2 /Tables 3 and 4), suggesting that in Eastern Indian population, variation of ossicles according to laterality might not exist.

4.1. Comparison between present study & previous foreign studies

Not many studies are found describing the difference in ossicles according to sex and laterality. However, a study by Oschman and Meiring¹¹ stated that there were no differences between ossicles obtained from male and female cadavers but there was significant difference between right-sided ossicles and left sided ones. But in our study population, the opposite findings were seen.

Urbantschitsch in his study gave the values of various dimensions of stapes (total height of stapes: 3.7 mm, length and width of footplate: 3 mm and 1.5 mm respectively). Due to lack of requisite data (standard deviation), a statistical comparison was not possible, none the less, values in this present study tallied closely with the findings of Arensburg et al¹² and Unur et al.¹³

Congenital malformations of middle ear ossicles can cause hearing problems.¹⁴ Among the ossicles, the malleus and stapes are the most variable ones as stated by Sarrat et al.¹⁵ Unur et al in 2002 also concluded that stapes is the most variable ossicle so far as their morphological variations are concerned (Table 5), thus emphasising on the importance of this study and its application in the field of

otosurgery.

Wadhwa et al¹⁶ from Maulana Azad Medical College, New Delhi concluded that no significant difference in the height of the stapes in the Indian population was present except for existence of significantly slender Indian stapedial crura compared to their Western counterparts.

If we compare studies of Indian researchers like Dass et al,¹⁷ Kumar et al¹⁸ with some prominent Western studies, we do not find much difference between them. In most of the Indian studies, however, there was a deficiency in relevant data,¹⁹ so a proper statistical comparison was not possible.

In the following table, the mean morphometric values of some previous foreign and Indian studies have been given. It shows the similarity of values of different parameters and no major differences among some prominent Indian and Western studies.

4.2. Comparison between present study and previous Indian studies

The values we found in stapes morphometry matches very closely with those found by Dass et al.¹⁷ However the total height of stapes as found by Wadhwa et al¹⁶ and Kumar et al¹⁸ are a little higher than those found in the present study, which might point towards ‘taller stapes’ among North Indians as compared to the East Indian population.

Except for the height of stapes, our values closely matched that of other previous Indian researchers like Wadhwa et al,¹⁶ whose research was based on North Indian population. It may be possible to infer here that the height of stapes in Northern Indian population is higher than those found in Eastern India. These differences in dimensions of the stapes in different geographic locations within the same country may have surgical implications in reconstructive operative procedures on the ossicles, thereby influencing the design of locally manufactured prosthesis to suit different populations within India.^{20,21}

However, further studies comparing the parameters of ossicles between different populations of the world are required to prove any racial or geographical variation.

5. Limitations

Thickness of the stapes footplate is an important parameter for placing the ‘Piston’ during stapedectomy⁷ since one end of the piston remains embedded within the thickness

of the footplate. This parameter was not determined in our study. So, this study leaves a window of opportunity to assess the thickness of stapes footplate, and to provide valuable information, which would help oto-surgeons in their manoeuvres to improve hearing.

6. Conclusion

Since involvement of stapes in otosclerosis leads to debilitating hearing loss and tinnitus, often requiring surgery and use of prosthesis, this study is an attempt to provide base line information that may be used to evaluate the variations and morphometry of stapes, the smallest of the middle ear ossicles. Though there are a few studies done in India on this topic, studies involving Eastern Indian population is lacking. Although minor differences have been observed between past and present studies, knowledge from the present study, highlighting the morphometric variations of stapes will be helpful in the pre-surgical evaluation of patients undergoing surgeries involving these ossicles.

7. Conflicts of Interest

None.

8. Source of Funding

None.

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