ORIGINAL ARTICLE

MORPHOMETRIC DIMENSIONS OF HUMAN EAR OSSICLES OF MALES

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ABSTRACT

Introduction: The otologic surgeons need to be fully conversant with the anatomical details of middle ear and its bones so as to perform microsurgical maneuvers successfully. In India, data on normal anatomical parameters of the ossicles is limited. The present study attempts to provide the anatomical details of the three ossicles in North Indian Population in males and compare the parameters with those reported from different parts of the world.

Methodology: The study was carried out on 100 sets of middle ear ossicles collected from adult male cadavers from the Department of Anatomy of various colleges of North India. The various measurements were taken with the help of digital verneir caliper

Results: Our study reveals no significant difference between morphometric measurements of the bones of right and left side except Incus in males

Conclusion: The precise measurements of the ossicles have been reported in the study in North Indian Population (males), which would be very helpful in designing the prosthesis in ossicular chain pathology in North Indians.

Keywords: Otology, Ossicles, Measurements

INTRODUCTION

The tympanic cavity contains a chain of three movable auditory ossicles in humans – Malleus, Incus, Stapes. These ossicles form a chain across the tympanic cavity from tympanic membrane to fenestra vestibule. These bones are bound together by articulations and have ligamentous connections with the walls of middle ear cavity. These ossicles transmit the sound waves smoothly from the tympanic membrane and amplify them towards the surface of oval window [1]. Many congenital malformations of the middle ear ossicles have been reported to cause hearing problems [2,3,4]. Globally, 250 million people are suffering from hearing loss, which is more than 4% of the world's population; out of which 165 million people live in developing countries. So, the developing countries need more than 32 million hearing aids per year[5].

The ossicular chain reconstruction by the otolaryngologists can bring a significant improvement in conductive hearing loses due to ossicular erosion[6]. The materials used in reconstruction of ossicular chain are autografts, homografts and allografts [7]. To achieve good postoperative results in patients who require middle ear surgery and to perform these microsurgical maneuvers, the otologic surgeons need to be fully conversant with the anatomical details of the ossicles of the middle ear.

The present study was undertaken to provide the valuable parameters of the three ossicles in North Indian Population for designing and constructing the implants by using their precise measurements.

METHODOLOGY

The study has been carried out on 100 sets of middle ear ossicles from adult male cadavers from the Department of Anatomy of various colleges of North India.

The calvaria was removed with the help of electric bone cutter and the brain was taken out to expose the petrous part of temporal bone. The duramater was stripped off. The temporal bones were removed en block with the help of hammer and chisel, a small aperture was made by removing tegmen tympani to expose the roof of the middle ear. The rounded head

of the malleus articulating with the incus in epitympanum were identified and were taken out with forceps after fine manipulations. Later to expose the stapes, a diagonal section of the temporal bone was taken through arcuate eminence. Then the stapes was removed with the help of fine forceps. This way, all the three ossicles were safely removed. These bones were cleaned (removal of any tissue attachment) and dried. The bones thus obtained were put into plastic satchel bags with zip locking mechanism. These pouches were assigned the serial number, side and gender.

The following measurements were taken with the help of digital verneir caliper with the least count of 0.01 mm. Each bone was weighed on Metledo weighing machine with least count of 0.01mg.

1) Measurements of Malleus (Fig1)

a) Total length: maximum distance between top of the head and the end of the manubrium (M1 in mm)
b) Length of manubrium: distance from the end of the lateral process to the end of manubrium (M2 in mm)
c) Length of head and neck: maximal distance between the top of the head and the end of the lateral process (M3 in mm)
d) Index: length of manubrium x 100/ total length
e) Weight of Malleus(in mgs)

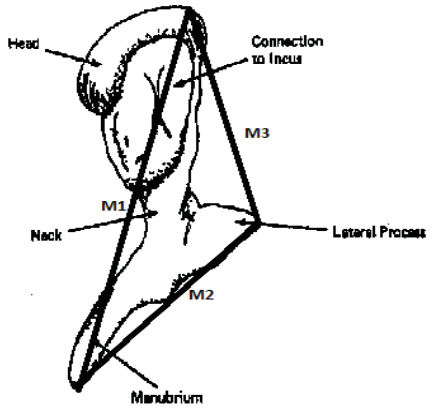

Figure 1: Shows various measurements of Malleus

2) Measurements of Incus (Fig 2)

a) Total length: maximal distance between the superior edge of the body and the end of the long process (I1 in mm)
b) Total width: maximal distance between the superior edge of the body and the end of the short process (I2 in mm)
c) Maximal distance between the tips of the processes (I3 in mm)
d) Index: Total width X 100/ total length of incus
e) Weight of Incus (in mgs)

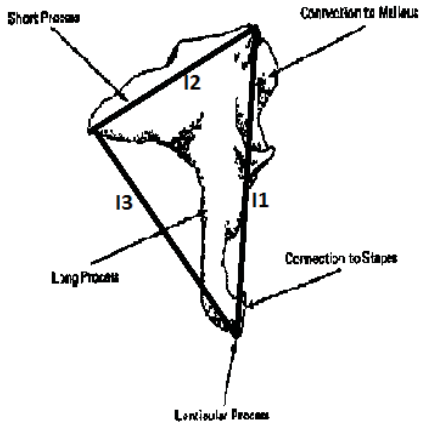

Figure 2: Shows various measurements of Incus

3) Measurements of Stapes (Fig 3)

a) Total height: maximal distance between the top of the head and the foot plate (S1 in mm)
b) Length of foot plate: maximal length of the long axis of foot plate (S2 in mm)
c) Width of foot plate: maximal width of the foot plate (S3 in mm)
d) Index: Length of foot plate X 100/ total height of stapes
e) Weight of Stapes(in mgs)

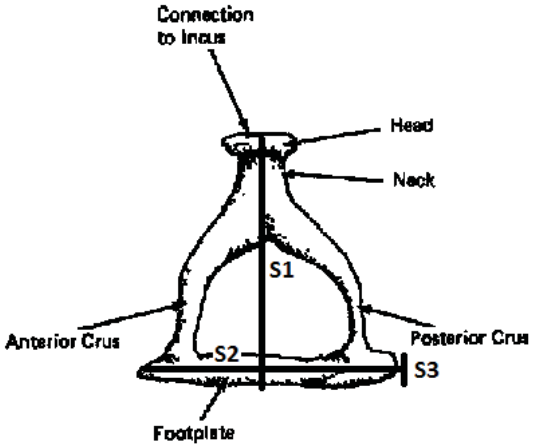

Figure 3: Shows various measurements of Stapes

The data has been statistically treated using SPSS software version 20.0

RESULTS

All the parameters of the three bones of both sides (right and left) were analyzed statistically by applying Independent Sample T test / Mann Whitney Test (after the data analysis for assumption tests). All the statistical calculations were performed using the software SPSS version 20. The following parameters were recorded:

Table 1: Descriptive analysis of Malleus (n=50)

Malleus	Range		Minimum		Maximum		Mean		SD	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Total length (mm)	1.45	3.14	7.10	6.04	8.55	9.18	7.87	7.80	0.37	0.54
Length of Manubrium(mm)	2.14	1.78	3.23	3.52	5.37	5.30	4.47	4.42	0.41	0.42
Length of Head and Neck (mm)	2.43	2.31	3.30	3.53	5.73	5.84	4.70	4.68	0.43	0.41
Weight (mgm)	18.54	22.20	11.67	9.30	30.21	31.50	22.41	21.54	4.19	4.79

Index on right side was calculated to be 56.77% and on left side was 56.78%

Table 2: Descriptive analysis of Incus (n=50)

Incus	Range		Minimum		Maximum		Mean		SD	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Total length(mm)	1.43	2.01	5.56	5.32	6.99	7.33	6.465	6.48	0.36	0.42
Total Width(mm)	2.19	2.09	3.67	3.67	5.86	5.76	4.834	4.93	0.44	0.40
Two processes distance(mm)	1.86	1.87	4.32	4.42	6.18	6.29	5.396	5.23	0.40	0.44
Weight (mgm)	23.75	26.42	10.35	7.03	34.10	33.45	23.561	24.20	5.87	6.19

Index on the right side was calculated to be 74.87%and on left side was 76.04%

Table 3: Descriptive analysis of Stapes

Stapes	Range		Minimum		Maximum		Mean		SD	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Total height (mm)	1.31	1.16	2.59	2.91	3.90	4.07	3.38	3.39	0.25	0.26
Length of Footplate (mm)	0.82	0.96	2.53	2.17	3.35	3.13	2.82	2.79	0.19	0.19
Width of footplate (mm)	0.86	0.45	0.98	1.14	1.84	1.59	1.37	1.36	0.14	0.11
Weight (mgm)	2.93	3.05	0.89	0.98	3.82	4.03	2.51	2.60	0.65	0.68

Index on the right side was calculated to be 83.70% and on the left side was 82.74%

On comparison of right side of each parameter with its left side of respective bone, no statistical significant difference was observed in case of malleus, incus and stapes except in one of the parameters of incus i.e distance between long and short processes. Right side values were significantly at higher levels than left side (p=0.047). The reason is difficult to comment at this point of time. However this has not been reported in literature earlier.

The correlation between the morphometric measurements of the three bones were also studied using Pearson correlation test. A positive correlation was found between total length of malleus with total length of incus (p=0.005, r= 0.69) as well as with total height of stapes,on left side(p=0.014, r=0.34). Whereas, total length of incus showed positive correlation with total height of stapes on both sides (right side p=0.024, r= 0.312), (left side p=0.004, r=0.39) .

Pearsons correlation test was also applied on the weight of three bones and a positive correlation was seen among the weights of all the three bone with each other on both sides.

DISCUSSION

The ear ossicles were first described in 16th century . Hast and Garrisson [8] stated that Vesalius described incus and malleus in 1543 in his monumental work "De Humani Corporis Fabrica" whereas Ingrassia and Eustachius[9] were the first to describe Stapes in 1546.

According to Lempert and Wolff[10], the ear ossicles possess unique features in the form of : miniature size, adult state of which is attained during fetal life, isolated position in the middle ear, complete envelopment of mucosa which is continuous with mucosa of tympanic cavity and their constant involuntary activity.

Though these bones attain full adult size during fetal life but continues to undergo changes throughout life, so the variations of the size and morphology of these bones are expected [11]

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 past 50 years as reported from the different regions of the world.(table 7,8,9)

When compared with the international studies, the average dimensions of malleus were almost similar to South Africa subjects, but were on higher side to that of Turkey subjects and lower side to that of Colombia and Isreal subjects. With in India, the dimensions

were at higher side to that of South population. But when compared to regional areas, the values were similar to Gujrati population but were at little lower level to Rajasthan, Rohtak and Uttar Pardesh population and at higher side to Jaipur subjects.

In case of incus, the average dimensions are almost identical to Isreal and Turkey subjects. With in India, the dimensions were again at higher side to that of South population (Mangalore, Mysore, Andhra Pradesh) and at lower level to regional studies (Rajasthan , Rohtak) and higher to that of Jaipur and Uttar Pradesh.

In case of Stapes, the values of the present study are at higher side to International studies (Turkey, Iran, Switzerland, Israel). With in India, the dimensions were again at higher side to that of South population but at little higher level to regional studies of Patiala,Jaipur and UP and at the lower level to studies conducted in New Delhi. Values were very close to studies conducted at Jamnagar.

Such a comparison of the observations on weight and dimensions of bones with those other workers confirm that the adult bones show marked morphometric variations.

Table 7: Comparison between morphometric data of Malleus with previous studies

Author	Population	Sample Size	Mean of Total Length	Mean Of Length Of Manubrium	Mean of Head & Neck	Weight	Index
Harneja (1973)[11]	Jaipur	50	7.15	4.22	--	23.65	--
Arrensburg (1981)[13]	Israel	31	7.8	4.4	--	--	56.6
Oschman (1991)[14]	South Africa	90	7.84	4.39	--	.22gm	--
Bhatnagar (2001)[15]	Punjab	60	8.36	4.65	--	25.99	--
Unur (2002)[16]	Turkey	40	7.69	4.70	4.85	--	60.97
Natekar (2010)[17]	Goa	--	--	--	--	--	56.05
Jyoti (2011)[18]	Mysore	50	7.65	3.52	2.37	20.90	--
Kamal (2012)[19]	Rohtak	120	7.94	4.76	5.23	22.92	56.05
Gulrez (2013)[20]	Aligarh UP	30	8.00	4.58	--	--	--
Ramirez (2013)[21]	Colombia	23	8.53	4.91	--	--	--
Vinayachandra (2014)[22]	Mangalore	50	7.45	--	--	18.26	--
Padmani (2014)[23]	AP	100	5.54	3.03	2.79	--	54.73
Mogra (2014)[24]	Rajasthan	66	8.53	5.20	4.72	--	61.01
Rathava (2015)[25]	Jamnagar	60	7.81	4.59	5.00	--	--
Present Study	North India	100	7.83	4.44	4.68	21.97	56.77

Table 8: Comparison between morphometric data of Incus with previous studies

Author	Population	Sample size	Mean of Total Length	Mean of Total Width	Mean Of Distance between two processes	Weight	Index
Haneja (1973)[11]	Jaipur	50	3.14	1.82	--	25.06	--
Arrensburg (1981)[13]	Isreal	22	6.4	5.1	--	--	80.1
Unur(2002)[16]	Turkey	40	6.47	4.88	6.12	--	79.84
Natekar (2006)[17]	Goa		6.52	5.06	5.86	20.74	--
Jyothi (2011)[18]	Mysore	50	6.32	4.41	--	23.82	--
Gulrez(2013)[20]	Aligarh	30	6.38	4.60	--	--	--
Padmini(2014)[23]	AP	100	5.13	3.47	4.5	--	67.75
Mogra (2015)[26]	Rajasthan	66	7.26	5.95	6.80	--	82.41
Kamal (2016)[27]	Rohtak	120	6.67	5.04	6.01	26.30	75.71
Present study	North India	100	6.47	4.88	5.31	23.88	75.45

Table 9: Comparison between morphometric data of Stapes with previous studies

Author	Population	Sample Size	Mean of Total Height	Mean of Length of Footplate	Mean of Width of Footplate	Weght	Index
Dass (1966)[28]	Patiala	165	3.29	2.79	1.43	3.02	--
Dass (1969)[29]	Patiala	100(fetal)	3.32	2.82	1.41	--	--
Harneja (1973)[11]	Jaipur	50	3.12	2.68	1.26	3.17	--
Arrensburg (1981)[13]	Isreal		3.2	2.8	1.3	--	85.1
Awenger (1995)[30]	Switzerland	10	--	2.48	--	--	--
Unur(2002)[16]	Turkey	40	3.22	2.57	1.29	--	80.06
Wadwa (2005)[31]	New Delhi	17	3.41	2.97	0.38	--	--
Farahani (2008)[32]	Iran	12	3.28	2.99	1.43	--	--
Jyoti (2011)[18]	Mysore	50	3.11	3.12	1.51	2.23	--
Gulrez (2012)[20]	Aligarh	30	3.18	2.93	1.60	--	--
Padmini (2014)[23]	AP	100	2.71	2.36	--	--	87.2
Rathava(2014)[33]	Jamnagar	60	3.33	2.78	1.34	--	--
Present study	North India	100	3.38	2.80	1.36	2.55	83.22

CONCLUSION

The three ossicles are morphometrically similar in both the ears except Incus, which showed the significant difference in left and right side. A positive correlation was found between the weights of three bones in right as well as left side and also between total length of malleus with total length of incus and total length of malleus with total height of stapes on left side. Total length of incus was positively correlated with total height of stapes on both sides.

The precise measurements of the ossicles have been reported in the study in North Indian Population (males), which would be very helpful in designing the prosthesis in ossicular chain pathology in North Indians. The variations seen in the dimensions of the ossicles with other studies confirms that the adult bones show marked morphometric variations or it may be due to racial differences or regional population difference. This variability should be a strong reminder, that sculpting an ossicle for ossiculoplasty or reconstruction,must be customized to a particular ear. Even the implantable hearing aids may yield better performance if they are customized to variations in ossicle masses and linear dimensions.

REFERENCE

1. Standring, Gray's Anatomy, 40th Ed; Elsevier Churchill Livingston; 2005: 627-630.
2. Werhs F. Congenital absence of long process of Incus. The Laryngoscope, vol 109(2):192-197.
3. Evcimik MF, Ozkurt FE, Ahmet K. the morphological findings of malleus and incus in a case of Marfan's syndrome. The laryngoscope,2012; 122: 389-392.
4. Bruintje TD. The auditory ossicles in human skeletal remains from a leper cementry in Chichester, England. Journal of Arch Sci, 1990;17(6):627-633.
5. Kumar S. WHO tackles hearing disabilities in developing world. Lancet,2001;3, 58:219
6. Prendergast PJ, Ferris P, Ric HJ. Vibroacoustic modeling of the outer and middle ear using the nite element method. Audiology and Neuro-otology,1999; 4:185-191.
7. Zenev I, Zenev E, Sopundzhiev N. Scanning electron microscopy of auditory ossicles. Journal of otology,2006; 3:112-116.
8. Hast MH, Garrison DH. Vesalius on the variability of human skull: Book I chap V of De Humani Corporis Fabrica. Clin Anat, 2000;13(5): 311-320.
9. Francesco C, Aldo G, Giovanni Z. Giovanni Filippo Ingrassia: a Five Hundred Year Long Lesson. Clinical Anatomy, 2010; 23: 743-749.
10. Lempert J, Wolff D. histopathology of incus and head of malleus in cases of stapedial ankylosis. Arch Otolaryng, 1945; 42: 333-367.
11. Harneja NK, Chaturvedi RP. A study of human ear ossicles. Indian journal of otology,1973;25: 154-160.
12. Harada O, Ishii H. The condition of auditory ossicles in microtia: findings in 57 middle ear operations. Plastic reconstruction surgery, 1972; 50: 48-53.
13. Arrensburg B, Harell m, Nathan H. the human middle ear ossicles, morphometry and taxonomic implications. Journal of human Evolution,1981;10:199-205.
14. Oschman Z, Meiring JH. A morphometric and comparative study of the malleus. Acta Anat,1991; 142:60-61.
15. Bhatnagar DP, Singal P, Thapar SP. Anatomy of malleus – A human ear ossicle; Anthropologists, 2001; 3(2): 139-141.
16. Unur E, Ulger H, Ekinci N. Morphometrical and morphological variations of middle ear ossicles in the new born. Erciyes Medical Journal, 2002; 24(2):57-63.
17. Natekar P, De Souza M. Indices of malleus in reconstructive surgery. Indian journal of Otology, 2010; 16: 36-40.
18. Jyoti KC, Shama SN. A study of morphological and morphometrical analysis of human incus. Int J of Current Research,2015; 7(5): 16102-104.
19. Singh K, Chhabra S, Sirohiwal BL et al. Morphometry of malleus, a possible tool in Sex Determination. J Forensic Res, 2012; 3(6): 152-154.
20. Gulrez N. Can fetal ossicles be used as prosthesis in adults? A morphometric study. International Journal of Experimental and Clinical Anatomy, 2013; 6-7: 52-57.
21. Ramirez LM, Ballesteres LE. Anthropometry of Malleus in Humans: a direct anatomical study. International Journal of Morphology, 2013;31(1): 177-183.
22. Vinayachandra PH, Viveka S, Sudha MJ. Morphometry and variations of malleus with clinica correlations. Int J of Anat Res, 2014; 2(1):191-94.
23. Padmani MP,Rao NB. Morphometry of human fetal ear ossicles: a human cadaveric study. British journal of Medicine and Medical Research, 2014; 4(9): 1873-1882.
24. Mogra K,Gupta S, Chauhan S. Morphological and morphometrical variations of malleus in human cadavers. International Journal of Healthcare and Biomedical Research, 2014; 2 (3):186-192.
25. Rathava J, Trivedi P, Kukadiya U. Morphometric study of malleus in gujrati population. International journal of Advanced Research, 2015; 3(3): 306- 310.
26. Mogra k, Panwar L, Shekhawat S. Morphological and morphometrical variations of Incus in human cadavers. International Journal of Medical Research prof, 2015; 1(2): 11-13.
27. Singh K,Rohilla A,Jyoti. Incus morphometry : a possible tool in sex determination. Journal of Forensic Research, 2016; 7: 320.
28. Dass R, Grewal B.S,Thapar S.P. Human stapes and its variations I General Features. Journal of Laryngology and Otology,1966; 80(1): 11-25.
29. Dass R, Thapar S.P, Makhni S.S. Feotal stapes I General features. Journal of Laryngology and Otology1969; :101-117.
30. Awenger D.F. Measurements of the stapes superstructure. Ann Otol Rhinol Laryngol, 1995;104: 311-316.
31. Wadhwa S, Kaul JM, Agarwal AK. Morphometric study of stapes and its clinical implications. Journal of Anatomical Society of India, 2005; 54(2):1-9.
32. Farahani RM, Nooranipur M. Anatomy and Anthropometry of human stapes. American journal of otolaryngology- Head & Neck Medicine and Surgery, 2008;29: 42-47.
33. Rathava JK, Gohil DV, SataparaVK. Osteometric dimensions of stapes. Journal of Res Med Den Scien, 2014; 2(2): 30-33.
34. Natekar PE, De Souza FM. A morphometric study of malleus and incus and its clinical implications. Indian J Otol,2006; 12: 6-9.