Original research article

A Study of Morphological and Morphometrical Variations of Human Ear Ossicles in Bihar

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Abstract

Background and Objectives: The three middle ear ossicles form an articulated chain, connecting the lateral and medial walls of the tympanic cavity. They amplify and transmit the sound vibrations to the cochlear receptors in the inner ear. Any malformations of these ossicles cause hearing problems. To study the morphometric measurements and morphological featuresof all the three ear ossicles of both the sides.

Method: 50 formalin fixed human temporal bones were dissected to remove ear ossicles for the study by dissection method. At DMCH Darbhanga.

Conclusion: The knowledge of variations of the ossicles and its morphometric data will help the otologist during reconstructive surgery and provide necessary information for the prosthesis designer. Comparisons of morphometric values of newborn ossicles with that of adult values suggest that these ossicles complete their morphometric development in foetal life. **Keywords:** Middle ear, malleus, incus, stapes, ossiculoplasty.

Introduction

The middle ear is one of evolution's greatest inventions. It explains why mammals have the sharpest hearing on earth and the greatest diversity of listening styles, writes *Natalia Angier*. The middle ear gives us our sound bite, our capacity to masticate without being forced to turn a momentarily deaf ear to the world, as most other vertebrates do. Sometimes it's the little things in life that makes all difference. In this case, the three little bones of the human body tucked in our auditory canal, just on the inner side of the ear drum, are the malleus, incus and stapes. Each mini bone, the ossicle, about the size of small fresh water pearl and jointly the basis of one of evolutions greatest inventions, in the mammalian middle ear. The middle ear also explains why mammals have the sharpest hearing on earth and the greatest diversity of listening styles, from the bats and dolphins that can detect pressure waves bouncing around at the spiky, ultrasonic end of bandwidth to the elephants and hump backed whales that can ear infrasonically, capturing the long low sound prints muttered by their pears for miles around. The human ear has a degree of complexity, probably as great as that of the eye. Understanding our sense of hearing requires familiarity with the physics of sound and its interaction with biological structures involved in hearing. The three minute bones in the middle ear, the malleus, incus and stapes form articulated chain across the tympanic cavity transmits the vibrations of tympanic membrane to the cochlea where the sensory receptor for hearing is situated. Our current knowledge of sound transmission started in the

sixth century B.C, when the Pythagoras, the Greek mathematician, introduced the concept that sound was a vibration in air. Seven centuries later, in 175 A.d., Galen, the Greek physician, recognized that the sensation of sound was transmitted to the brain via nerves. The gap in knowledge between Pythagoras's sound as air vibration and Galen's nerves transmitting sound to the brain was filled in 1543 by the Belgian anatomist Andreas Vesalius, who discovered the malleus and incus. Seven years later in 1546, Ingrassias discovered the third ossicle, the stapes[1]. To restore appropriate sound transmission, ossicular chain reconstructions (ossiculoplasty) is performed. several factors have to be considered when selecting the material to use for ossiculoplasty. These include availability, stability, biocompatibility and cost effectiveness[2]. Congenital malformations of middle ear ossicles like absence of long process of incus and capitulum of stapes will cause hearing problems. In this case ossicular reconstruction can be carried out using incus long process homograft[3]. Human beings are individualistic creature and this is reflected in the human anatomy, which is subjected to a large number of anatomical variations. Hence in the present study an attempt is made to study the morphological and morphometrical variations of ear ossicles. The cavity is bounded laterally by tympanic membrane and medially by the lateral wall of internal ear, it communicates posteriorly with mastoid antrum and mastoid air cells and anteriorly with nasopharynx via pharyngotympanic tube[4]. At about eighth month the loose mesenchymal cells around the three ossicles disintegrate. Later the mucous lining of the primitive tympanic cavity extends upwards and envelops ossicles, muscles, nerves and blood vessels. The extensive cavity thus formed persists as definitive tympanic cavity, lying lateral to the otic capsule. Further extension of the tympanic cavity grows backwards and forms mastoid antrum. Mastoid air cells however, sprout from the antrum about second year after birth[5].

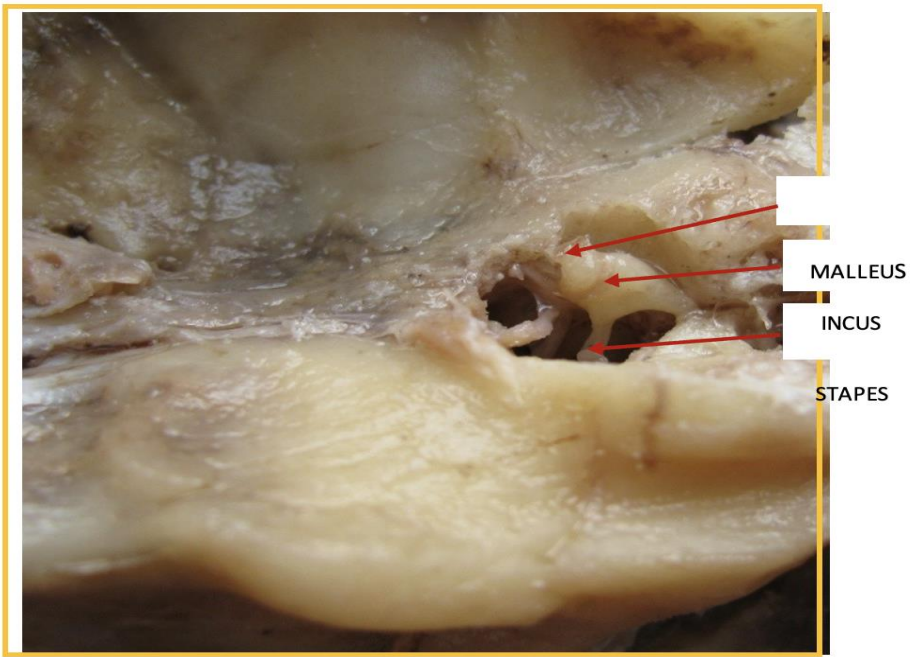
Objectives

To study the morphometric measurements. It includes various dimensions and weight of all the three ear ossicles of both rightand left sides

To study the morphological features and any variations present (shape, size, nodule etc.) of all the three ear ossicles of both right and left sides.

Material and Method

50 formalin fixed human temporal bones were dissected to remove ear ossicles for the study by dissection method. At Darbhanga Medical College and Hospital Darbhanga, Laheriasarai Bihar. Study duration of Two years. Fifty sets of ear ossicles, twenty five sets from right side and twenty five sets from left side was collected. Each set containing malleus, incus and stapes.1 set of both right and left side was collected from fetus of less than 6 month old. 1 set from newborn cadaver. Remaining 23 sets from adult cadaver. Specimens were collected from formalin fixed temporal bones. The cranial cavity and the middle cranial fossa were properly exposed after removing brain and the duramater. The portion of arcuate eminence and thin plate of tegmen tympani of petrous part of temporal bone was chipped off with the help of fine edged chisel and hammer till the ear ossicles were clearly visualized. The displacement of the tegmen tympani enabled easy access to the removal of malleus and incus; both could be extracted intact by a gentle manipulation and pull applied through the forceps. The stapes had to be retrieved only by careful and bimanually assisted isolation of the ossicle from the chipped off block of temporal bone using hacksaw blade. Care had to be taken while removing stapes as its foot plate and cruses are very thin and delicate. All the three ossicles removed were washed with hydrogen peroxide solution to remove stains if any. Ossicles of one side were stored in the small clean glass bottles and the specimen number and side to which it belongs to was labeled on it.



Cadaveric Temporal bone showing middle ear cavity exposing all threeossicles

The collected ear ossicles were placed individually on a graph paper (which had large square measuring 1cm x 1 cm, this is further divided in to 100 small squares, each small square measure 1mm x 1mm), this graph paper was a guide for the measurement. All the ossicles were kept in same attitude and were photographed (malleus was photographed by keeping the articular facet on its head facing upwards) to avoid any error. The measurements on the footplate was taken by keeping stapes in inverted manner using needle and photographed. This image was transferred to the computer and magnified.

M_1: Total length – from the top of the head to lower end of handle
M_2: Length of maubrium or handle – from the end of lateral process to theend of handle
M_3: Width of head- maximum distance between the two lateral marginsof the head
I_1: Total length –distance between upper edge of the body and the end of the longprocess.
I_2: Width of the body distance between the anterior end of the body and the end of short process.
I_3 : Length of the long process- distance between the lower edge of the body and the end of long process.

Total height –distance between top of the head to the undersurface of stapesfootplate
S_2: Length of footplate – maximum length of long axis of footplate
S_3: Width of footplate – maximum width of the footplate
S_4: Length of anterior crus – from shoulder to the upper surface of footplate
S5: Length of posterior crus – from shoulder to the upper surface of footplate

Results
In the present study the following metrical variations are noted for theindividual ossicles.

MALLEUS
The total length of malleus ranged from 6.50 mm – 8.36 mm and an average of 7.65mm. Average on right side was 7.69 mm and 7.61 mm on left side. The length of the manubrium ranged from 2.91 mm – 4.43 mm and an average of 3.52mm. Average on right side was 3.64

mm and 3.41 mm on left side. The maximum width of head ranged from 1.83 mm – 2.80 mm and an average of 2.37mm. Average on right side was 2.36 mm and 2.37 mm on left side. The weight ranged from 13.5 mg – 25.4 mg and an average of 20.90 mg. Average on right side was 21.2 mg and 20.6 mg on left side.

INCUS

The total length of the incus ranged from 5.46 mm – 6.96 mm and an average of 6.32mm. Average on right side was 6.32 mm and 6.31 mm on the left side. The total width of the body ranged from 3.31 mm – 4.96 mm and an average of 4.41mm. Average on right side was 4.38 mm and 4.43 mm on left side. The length of long process ranged from 2.63 mm – 4.43 mm and an average of 3.48mm. Average on right side was 3.46 mm and 3.50 mm on left side. The weight of the incus ranged from 11.10 mg – 33.70 mg with an average of 23.82mg. Average on right side was 23.25 mg and 24.39 mg on left side.

STAPES

The total height of the stapes ranged from 2.41 mm – 3.43 mm and an average of 3.11 mm. Average on right side was 3.12 mm and 3.11 mm on left side.
The length of footplate ranged from 2.41 mm – 3.57 mm and an average of 3.12 mm. Average on right side was 3.18 mm and 3.05 mm on left side.
The width of footplate ranged from 1.25 mm – 1.80 mm with an average of 1.51 mm.

Average on right side was 1.52 mm and 1.49 mm on left side. The length of anterior crus ranged from 1.27 mm – 2.76 mm and an average of 1.93 mm. Average on right side was 1.93 mm and 1.94 mm on left side. The length of posterior crus ranged from 1.36 mm – 2.76 mm and an average of 2.04 mm. Average on right side was 2.01 mm and 2.07 mm on left side. The length of anterior crus and posterior crus is same in specimen no 1 on right side and specimen no 13 on left side. The length of anterior crus is more than the posterior crus in specimen no 9 and 16 on right side and in the remaining specimens the posterior crus is longer than the anterior crus. The width of head ranged from 0.78 mm – 1.42 mm and an average of 1.08 mm. Average on right side was of 1.07 mm and 1.10 mm on left side. The weight ranged from 1.00 mg – 4.80 mg and an average of 2.23 mg. Average on right side was 2.18 mg and 2.27 mg on left side.

Statistical analysis of malleus (total)

Total (Malleus)	**Total length**	**Length of manubrium**	**Max width of Head**	**weight**
N	50	50	50	50
Mean	7.6554	3.5288	2.3718	20.9080
Standard deviation	.37156	.37768	.18523	2.98088
Range	1.86	1.52	.97	11.90
Minimum	6.50	2.91	1.83	13.50
maximum	8.36	4.43	2.80	25.40

Statistical analysis of incus (total)

Total (Incus)	Total Length	Total width of the body	Length of long process	Weight
N	50	50	50	50

Mean	6.3208	4.4132	3.4814	23.8220
Standard Deviation	.33887	.35502	.33065	4.70108
Range	1.50	1.65	1.80	22.60
Minimum	5.46	3.31	2.63	11.10
maximum	6.96	4.96	4.43	33.70

Statistical analysis of stapes (total)

Total	Total Height	Length of footplate	Width of footplate	Length of Posterior Crus	Length of Anterior Crus	Width of Head	Weight
N	50	50	50	50	50	50	50
Mean	3.1188	3.1210	1.5120	1.9396	2.0482	1.0896	2.2320
Standard Deviation	.26719	.19921	.13280	.26076	.24110	.14512	.76570
Range	1.16	.93	.55	1.49	1.40	.64	3.80
Minimum	2.41	2.72	1.25	1.27	1.36	.78	1.00
Maximum	3.57	3.65	1.80	2.76	2.76	1.42	4.80

*In Malleus, the length of manubrium showed statistical difference between right and left side with a P value of 0.027 with right side having higher mean value. Other parameters showed no significant difference between right and left side.
*In Incus, the parameters showed no significant difference between right and left side.
*In Stapes, the length of footplate showed statistical difference between right and left side with a P value of 0.024 with right side having higher mean value. Other measurements showed no significant difference with P value > 0.05.

Discussion

The three middle ear ossicles form an articulated chain, connecting the lateral and medial walls of the tympanic cavity. They amplify and transmit the sound vibrations to the cochlear receptors in the inner ear. Any malformations of these ossicles cause hearing impairment. In India, 5.9% of the population, estimated as 60 million, has disabling hearing impairments and associated moderate or worse hearing impairment in the better ear. It has been estimated that large segment of the deaf in developing countries requires 32 million hearing aids per year[6]. Reconstructive procedures for sound conduction in the middle ear have advanced substantially since 1950s. With advances in instrumentation and technology, newer and better techniques of surgeries are available. Increasingly otologic surgeons are performing surgeries for deafness like, ossicular replacements and ossiculoplasty. A resultant achievement of good hearing following surgery, particularly in the presence of disease or malformations is one of the greatest challenges to the otologists. Successful ossicular repair depends on precise dimensions of implants. Hence the present study was undertaken to study the morphological and morphometrical analysis of ear ossicles.

Comparison of morphometry of malleus with other studies.

Authors	Total Length	Length of Manubrium
Unur, Ulger & Ekinki 2002	7.7 mm	4.7mm
Ayean et al.1990	8.1mm	4.9mm

Arrensburg et al. 1981	7.8mm	4.4mm
Arrensburg & Nathan 1972	7.3mm	3.5mm
Harada. 1972	8.0mm	4.2mm
Masali 1968	7.6mm	4.6mm
Bouchet & Giraut. 1968	7.9mm	4.7mm
Present Study	7.6 mm	3.5mm

The same study was mentioned to be 5mm which is slightly higher than the present study[7]. According to Anson and Bast the width of incus varied from 3.36 – 4.09mm, which is almost similar to the present study, and reported the length of long process as 4.27- 5.55mm which is higher compared to the present study[8].

Comparison of morphometry of Incus with other studies.

Authors	Total length	Total width
Unur, Ulger & Ekinki 2002	6.5mm	4.9mm
Unur et al.1990	6.7mm	5.1mm
Arrensburg et al. 1981	6.4mm	5.1mm
Arrensburg & Nathan 1972	6.8mm	5.1mm
Harada. 1972	6.8mm	4.8mm
Masali 1968	6.4mm	4.8mm
Bouchet & Giraut. 1968	6.5mm	5.1mm
Present Study	6.3mm	4.4mm

In the present study the morphometric data of stapes showed that the total height of stapes varied from 2.41 – 3.43mm with an average of 3.11mm. According to Anson and Bast the total height of the stapes varied from 2.50 –3.78mm with an average of 3.26mm which is almost similar compared to the present study[8].

Comparison of morphometry of stapes (total height, length and width of footplate) with other studies.

Authors	Total Height	Length of footplate	Width of footplate
Bouchet & Giraut 1968	3.5mm	-	-
Arrensburg et al 1981	3.2mm	2.8mm	1.3mm
Unur, Ulger, Ekinki 2002	3.2mm	2.6mm	1.3mm
Present study	3.1mm	3.1mm	1.5mm

From the above table we know that the total height of the stapes and width of footplate is similar in measurements compared to other studies, length of footplate was found to be slightly higher compared to other studies. In the present study, of the 50 stapes specimens, the length of anterior and posterior crus were equal in 2 specimens and anterior crus was longer than the posterior crus in 2 specimens. The remaining specimens had longer Posterior crus than the anterior crus. Wadhwa S, Kaul J M, and Agarwal A K in their study on 10 stapes reported that in all the bones, the posterior crus were longer than the anterior crus[6]. Unur, Ulger & Ekinki in their study on 40 sets of ear ossicles, obtained from 20 newborn cadavers have observed similar morphological variations. According to their study they have concluded that the stapes was most variable and incus was most stable morphologically. As a variation one stapes had no obturator foramen [9]. Prabhu L, Saralya V, Kumar A have reported almost similar observations on stapes which exhibited a high

number of anomalous features in the head, crural region and in the footplate area. They have also reported that the malleus was most morphologically stable of all the ossicles which disagree with our study[10].

Conclusion

The knowledge of variations of the ossicles and its morphometric data will help the otologist during reconstructive surgery and provide necessary information for the prosthesis designer. Successful ossicular repair remains a challenge. This success depends on precise dimensions of implants. Comparisons of morphometric values of newborn ossicles with that of adult values suggest that these ossicles complete their morphometric development in foetal life. The ossicles obtained from newborns, which are approximately the same size as that of adults might be preserved in ossicle banks for future use in ossiculoplasty. These ossicles can be used as homografts to replace the eroded adult middle ear ossicles.

References

1. Afifi, Adal K, Bergman, Ronald A. Functional neuroanatomy; Text and Atlas. 2nd ed: Mc. Graw Hill; 2005: 316.
2. Bharathi MB. Recent trends in ear ossicle transplantation: approach to anatomy. Anatomica Karnataka. 2008; 3(2): 8-9.
3. Wehrs RE. Congenital absence of long process of incus. Laryngoscope. 1990; 109:192- 197.
4. Berkovitz BK. External and Middle ear. Gray's Anatomy. Standring, 39th ed; Elsevier Churchill Livingston; 2005: 649-661.
5. Datta AK. Essentials of Human Embryology. Organs of special senses: Ear.5th ed: Current Books International; 2005: 284 -289.
6. Rodriguez K, Shah KR, Kenna M. Anomalies of the Middle and Inner Ear. Otolaryngologic Clinics of North America. 2007; 40: 81- 96.
7. Lempert J, Wollf D. Histopathology of incus and the head of the malleus in cases of stapedial ankylosis. Archives Otolaryngology. 1945; 42: 339-367.
8. Wolff D, Belluci RJ. The human ossicular ligament. Annals Otol rhinol laryngol. 1956; 65: 895 - 910.
9. Praphu L, Saralaya V, Kumar A. Morphometrical observations on the middle ear ossicles. Indian Journal of Otology. 2004; (10): 24 – 27.
10. Wadhwa. S, Kaul JM, Agarwal. AK. Morphometric study of stapes and its clinical implications. Journal. Anat Soc India 2005; 54 (2): 1-9.