

Can fetal ossicles be used as prosthesis in adults? A morphometric study*

Gulrez Nadeem

College of Dentistry, Ajman University of Science and Technology, Ajman, UAE

Abstract

Objectives: The tympanic cavity contains 3 small immovable bones, the malleus, incus and stapes. Extensive studies have been carried out on the morphometry of the ossicles. According to some scientists, in human beings the auditory ossicles reach their definitive size and shape in fetal periods and postnatal modifications are minimal, while there are certain studies which contradict this claim. These contradictory claims prompted us to make an endeavor to find out the growth pattern of the ear ossicles and comparing the data with adults.

Methods: Twenty-two fetal cadavers of either sex, ranging in gestational ages between 24-40 weeks, were collected from local hospitals and 15 adult formalin-fixed cadavers in age groups of 20-30 years were taken. For the study, the fetuses were kept in 2 Groups of 24-28 weeks and 36-40 weeks. From the data obtained, the mean, standard deviation and percentage gain from one group to another in different dimensions of various parts of each ossicle was calculated.

Results: The age periods between 40 weeks (full term fetuses) and adults, revealed spurt in the growth of diameter of head of malleus (3%), width of short process of incus (2.7%), width of footplate (5.2%) and height of stapes (13%). These changes were insignificant in terms of acoustic transmission.

Conclusion: It is concluded that by the end of gestation, the ear ossicles develop morphometric features comparable to adults with no appreciable changes in the post natal period. Hence, they can be used as prosthesis in adults suffering from ossicular chain malformations and can be an easy and cheap method for treatment of this type of patients.

Key words: ear ossicles; incus; malleus; morphometry; stapes

Anatomy 2012-2013;6-7:52-57, © 2012-2013 TSACA

Introduction

The tympanic cavity contains 3 small immovable bones, the malleus, incus and stapes. The auditory ossicles extend like a chain across the tympanic cavity to connect functionally the tympanic membrane with the vestibular (oval) window. The lateral ossicle is the malleus, firmly attached to the tympanic membrane, most medial is the stapes which is fixed to the vestibular window and is in direct contact with the fluid perilymph, the intermediate between the two lies the incus. These three bones are bound together by articulations, and they also effect ligamentous connections with the walls of containing cavi-

ty. The compound osseous system acts like a bent lever to connect the vibrations of the tympanic membrane into intensified thrusts of stapes against the perilymph.^[1]

Extensive studies have been carried out on the morphometry of human ossicles,^[2-5] anomalies of the ossicles,^[6-10] embryology^[11] and structure and function of the ossicles.^[12-14] Most of these studies were done on adult ossicles and have been studied on European populations, who have mesaticephalic type of skulls, but the present study has been done on Indian skulls that have dolichocephalic skulls.^[15] Thus, this is one of the aspects of justifying the utility of the study.

*Presented at the 4th International Symposium of Clinical and Applied Anatomy (ISCAA), held in Ankara, Turkey, from 28th June to 1st July, 2012.

Accordingly in human beings the auditory ossicles reach their definitive size and shape in fetal periods and postnatal modifications are minimal.^[16] Similar findings were reported that auditory ossicles reach their adult size in fetus by 6 months intrauterine length (IUL).^[17] Then some studies also documented the presence of adult sized ossicles in human fetuses of 5th month IUL and that their development is not fixed to rate of body growth in general.^[18]

However, there are certain studies which contradict this claim. A study reported that the development of auditory ossicles in humans is not completed during fetal life. The different parameters in the fetal periods increased adequately in the post natal life.^[19]

These contradictory claims prompted us to make an endeavor to find out the growth pattern of the ear ossicles and comparing the data with adults.

Materials and Methods

Material for the study comprised 22 fetal and 15 adult cadavers. This study was done in the Department of Anatomy, Jawaharlal Nehru Medical College (JNMC), Aligarh Muslim University (AMU), Aligarh, Uttar Pradesh, India. The fetuses were obtained from D/O Obstetrics and Gynecology, JNMC, AMU. The adult cadavers were obtained from the mortuary of D/O Anatomy JNMC, AMU. The ossicles were obtained from tympanic cavity by opening the tegmen tympani. The measurements were made by screw gauge (least-count-0.005). Photographs were taken by stereoscopic microscope and other guidelines for standard photography were taken.^[20]

Gestational age of fetuses was determined by crown-rump length using following the formula which states:^[15]

For the first 5 months, age of fetus in lunar months = length of fetus in cm

For the last 5 months, age of fetus in lunar months = length of fetus/5

The fetuses were divided into 2 groups (Groups I and II) of 12 and 10 fetuses in each group, respectively. Group I included fetuses of gestational age 24-28 weeks IUL and Group II contained fetuses ranging from 36-40 weeks IUL.

Formula used for calculating the percentage gain between groups is: Difference of mean value in the 2 groups / Mean value of the preceding group x100

Error of measurement

In the present study, the measurement of error is done using 2 measures. They are technical error of measure-

ment (TEM) and coefficient of reliability (R).^[21-23] The Formula for them are:

$TEM = D/2N$, where D denotes the difference between measurements (range) and N is the number of samples measured in that Group. g in this study Group I has 12 samples, Group II has 10 samples and adult group has 15.

$R = TEM/SD$, where SD is the total inter sample variance or the standard deviation in that group. It ranges between 0 and 1. This coefficient reveals what proportion of the between sample variance in a group is free from measurement error e.g. an R value of 0.9, means 90% of the variance is due to factors other than measurement error.

The following parameters of each ossicle were recorded:

Malleus

- Length of malleus (mm)
- Diameter of head (mm)
- Length of handle (mm)

Incus

- Total width of ossicle (mm)
- Length of body (mm)
- Length of long process (mm)

Stapes

- Length of base of foot plate (mm)
- Width of base of foot plate (mm)
- Height of ossicle (mm)

Results

Malleus (Tables 1-3, Figure 1)

Length of ossicle shows appreciable change during 28-36 weeks IUL of +1.3%. The ossicle attained a length of 97% of adult value at 6 months IUL and 98.2% at 9 months IUL.

Diameter of head shows fast growth rate between Groups I and II of +5.4%. It also achieved 92.5% of adult value at 6th month IUL and 97.5% at 9th month IUL.

Length of handle shows a steady growth with +1.79% gain from Groups I and II. It assumed 97.1% of adult value at 6th month IUL and 98.9% of adult value at 9th month IUL.

Incus (Tables 4-6, Figure 2)

Length of ossicle shows an increment of +5.2% between Groups I and II and this dimension achieved 92.7% of adult size at 6th months IUL and 97.6% at 9th month IUL.

Table 1
Malleus: length of ossicle (mm)

Group	Range	Mean±SD	TEM	R	% change
I	7.73-7.81	7.76±0.03	0.0030	0.90	
II	7.83-7.90	7.86±0.025	0.0035	0.86	+1.3
Adult	7.95-8.30	8.00±0.046	0.0116	0.74	+1.7

Table 2
Malleus: diameter of head (mm)

Group	Range	Mean±SD	TEM	R	% change
I	2.20-2.28	2.22±0.027	0.0033	0.87	+5.4%
II	2.31-2.36	2.34±0.02	0.0021	0.93	+2.5%
Adult	2.36-2.46	2.40±0.03	0.0050	0.83	

Table 3
Malleus: length of handle (mm)

Group	Range	Mean±SD	TEM	R	% change
I	4.43-4.48	4.45±0.02	0.0021	0.89	+1.79%
II	4.50-4.55	4.53±0.018	0.0025	0.86	+1.10%
Adult	4.51-4.63	4.58±0.015	0.0040	0.73	

Total width of ossicle shows appreciable change between Groups I and II of +3.42%. This parameter achieved 95.2% of adult size at 6th month IUL and 98.4% at 9th month IUL.

Length of long process show maximum increment between Groups I and II i.e. +2.1%, thus achieving



Figure 1. Human fetal malleus from 6th month to 9th month IUL and adult malleus.

Table 4
Incus: length of ossicle (mm)

Group	Range	Mean±SD	TEM	R	% change
I	5.83-6.05	5.92±0.027	0.0091	0.66	+5.2%
II	6.15-6.32	6.23±0.025	0.0085	0.66	+2.4%
Adult	6.32-6.44	6.38±0.036	0.0040	0.88	

Table 5
Incus: total width of ossicle (mm)

Group	Range	Mean±SD	TEM	R	% change
I	4.30-4.46	4.38±0.02	0.0066	0.66	+3.42%
II	4.51-4.55	4.53±0.016	0.0020	0.87	+1.55 %
Adult	4.54-4.64	4.60±0.031	0.0033	0.89	

Table 6
Incus: length of long process (mm)

Group	Range	Mean±SD	TEM	R	% change
I	4.43-4.50	4.46±0.024	0.0030	0.87	+2.01%
II	4.53-4.58	4.55±0.021	0.0025	0.88	+1.54%
Adult	4.58-4.66	4.62±0.042	0.0026	0.92	

96.5% of adult size at 6th month IUL and 98.4% at 9th month IUL.

Stapes (Tables 7-9, Figure 3)

Length of foot plate showed steady rise with maximum increase between 28-36 weeks IUL of +3.3%. This value



Figure 2. Human fetal incus from 6th month to 9th month IUL and adult incus.

assumed 94.5% of adult dimension at 6th months IUL and 97.6% at 9th month IUL.

Width of foot plate showed a positive increase Groups I and II of +5.5%. This dimension showed 90% of adult size at 6th month IUL & 95% of adult size at 9th month IUL.

Height of stapes showed an increment of +4.5% between 28-36 weeks i.e. Groups I and II. This parameter achieved 84.5% of adult value at 6th months IUL and 88.4% at 9th month IUL.

Discussion

The present study on human ear ossicles has given us the knowledge that different parts of each ossicle show different rate of growth during various gestational age periods. The study also showed that increase in size of fetal ossicles occurred evenly, with certain periods of most intensive growth. The study also showed the ossicles at birth are almost equal to adult's size (Figure 4)^[17,18] and there are minimal postnatal modifications.^[16] The present study has been well compared with other workers^[2,3,5,7,24-26] and they have also documented this observation, but this study is based on Indian population which is first of its kind, whereas the other workers have done in European races.

Table 10 compares the values taken in some studies of different research groups with our present study at the time of 9th month IUL. This table shows that the values of malleus for length of ossicle and length of handle are very much near to other studies except for Arrensburg and Nathan^[3] who have fewer values than the rest, similarly for incus the values for length of ossicle and total width of ossicle are on the lower end in the present study. Regarding the stapes the values are again on the lower side in relation to the height of the ossicle.

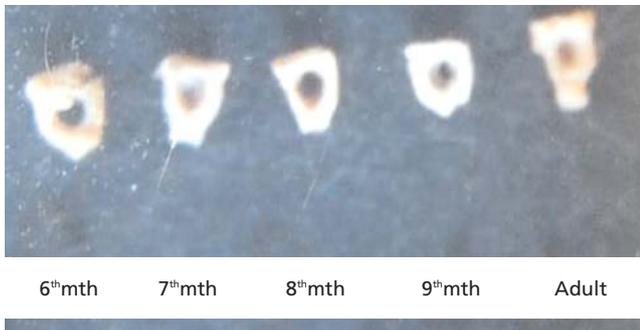


Figure 3. Human fetal stapes from 6th month to 9th month IUL and adult stapes.

Table 7

Stapes: length of footplate (mm)

Group	Range	Mean±SD	TEM	R	% change
I	2.74-2.81	2.77±0.023	0.0029	0.87	
II	2.84-2.89	2.86±0.017	0.0025	0.85	+3.3%
Adult	2.89-3.07	2.93±0.024	0.0060	0.75	+2.45%

Table 8

Stapes: width of footplate (mm)

Group	Range	Mean±SD	TEM	R	% change
I	1.40-1.48	1.44±0.025	0.0033	0.86	
II	1.50-1.55	1.52±0.018	0.0025	0.86	+5.5%
Adult	1.55-1.65	1.60±0.042	0.0033	0.92	+5.3%

Table 9

Stapes: height of ossicle (mm)

Group	Range	Mean±SD	TEM	R	% change
I	2.67-2.73	2.69±0.022	0.0025	0.88	
II	2.78-2.84	2.81±0.021	0.0030	0.86	+4.5%
Adult	3.12-3.24	3.18±0.032	0.0040	0.87	+13.1%

Hence this study assumes much importance in the field of morphometry of ossicles in Indian scenario as morphological variations of ossicles related to race has been documented.^[4] The values in the present study were little different in relation to incus and stapes although quite similar for malleus as Indian population has dolichocephalic skulls while European population has



Figure 4. Set of ear ossicles of Groups I and II, and adult ossicles.

Table 10

Morphometric data of middle ear ossicles from present and some previous studies at the time of 9th month IUL (mm).

Parameter	Present data	Unur et al., 2002 ^[2]	Bouchet and Giraut, 1968 ^[24]	Masali, 1968 ^[25]	Harada and Ishii, 1972 ^[27]	Arrensburg & Nathan, 1972 ^[3]	Arrensburg et al., 1981 ^[26]	Aycan et al., 1990 ^[5]	Unur et al., 1993 ^[27]
Malleus									
Length of ossicle	7.86	7.7	7.9	7.6	8.0	7.3	7.8	8.1	-
Length of handle	4.53	4.7	4.7	4.6	4.2	3.5	4.4	4.9	-
Diameter of head	2.34	-	-	-	-	-	-	-	-
Incus									
Length of ossicle	6.23	6.5	6.5	6.4	6.8	6.8	6.4	-	6.7
Total width of ossicle	4.53	4.9	5.1	4.8	4.8	5.1	5.1	-	5.1
Length of long process	4.55	-	-	-	-	-	-	-	-
Stapes									
Height of ossicle	2.81	3.2	3.5	-	-	-	3.2	-	-
Length of base of footplate	2.86	2.6	-	-	-	-	2.8	-	-
Width of base of footplate	1.52	1.3	-	-	-	-	1.3	-	-

mesaticephalic skulls.^[15] At the same time auditory ossicular dimensions can be used for medicolegal practice have been stated.^[28] However, it is possible that the development of bone mass of ossicles may not have been completed during fetal life as has been documented.^[19] The most important aspect of this study is that the fetal ossicles can be used as prosthesis or homografts in adults suffering from otosclerosis and ossicular chain malformations, as they have assumed adult dimensions in the last trimester of pregnancy and the post-natal modifications are minimal.^[16]

References

- Williams PL, Bannister LH, Berry MM, et al. (eds.) Gray's Anatomy. 38th ed. Edinburgh: Churchill Livingstone; 1999. p. 355-8.
- Unur E, Ülger H, Ekinci N. Morphometrical and morphological variations of middle ear ossicles in the newborn. *Erciyes Medical Journal* 2002;24:57-63.
- Arrensburg B, Nathan H. Observations on a notch in the short (superior or posterior) process of the incus. *Acta Anat (Basel)* 1971;78:84-90.
- Sarrat R, Torres A, Guzman AG, Lostalé F, Whyte J. Functional structure of human auditory ossicles. *Acta Anat (Basel)* 1992;144:189-95.
- Aycan K, Unur E, Bozkır MG. Anatomical study of malleus. *Journal of Health Sciences* 1990;1:152-8.
- Hough JV. Congenital malformations of the middle ear. *Arch Otolaryngol* 1963;78:335-43.
- Harada O, Ishii H. The condition of the auditory ossicles in microtia: findings in 57 middle ear operations. *Plast Reconstr Surg* 1972;50:48-53.
- Nomura Y, Nagao Y, Fukaya T. Anomalies of the middle ear. *Laryngoscope* 1988; 98:390-3.
- Causins VC, Milton CM. Congenital ossicular abnormalities: a review of 68 cases. *Am J Otol* 1988;9:76-80.
- Siegert R, Weerda H, Mayer T, Brückmann H. High resolution computerized tomography of middle ear abnormalities. [Article in German] *Laryngorhinootologie* 1996;75:187-94.
- Louryan S. Development of auditory ossicles in the human embryo: correlations with data obtained in mice. [Article in French] *Bull AssocAnat (Nancy)* 1993;77:29-32.
- Sarrat R, García Guzmán A, Torres A. Morphological variations of human ossicula tympani. *Acta Anat (Basel)* 1988;131:146-9.
- Huttenbrik KB. The mechanics and function of the middle ear. Part 1: The ossicular chain and middle ear muscles. [Article in German] *Laryngorhinootologie* 1992;71:545-51.
- Beer HJ, Bornitz M, Hardtke HJ, et al. Modeling of components of the middle ear and simulation of their dynamic behavior. *Audiol Neurotol* 1999;4:156-62.
- ApoorvaModi, Parikh. *Essentials of Forensic Medicine*. 3rd ed. 1992. p. 80-2.
- Lasky LE, Williams AL. Development of auditory system from conception to term. *NeoReviews* 2005;6:141-52.
- Anson BJ, Bast TM. *The temporal bone and the ear*. Charles. C. Thomas, Springfield: 1949. p. 26-38.
- Ham AW. *Hans Histology*. 7th ed. Lippincott; 1974. p. 700.
- Olszewski J. The morphometry of ear ossicles in human during development. [Article in German] *Anat Anz* 1990;171:187-91.
- Barut C, Ertlav H. Guidelines for standard photography in gross and clinical anatomy. *Anat Sci Educ* 2011; 4:348-56.
- Ulijaszek SJ, Lourie JA. Anthropometry in health assessment: the importance of measurement error. *Coll Antropol* 1997;21:429-38.
- Goto R, Mascie-Taylor CG. Precision of measurement as a component of human variation. *J Physiol Anthropol* 2007;26:253-6.
- Weinberg SM, Scott NM, Neiswanger K, Marazita M. Intraobserver error associated with measurements of the hand. *Am J Hum Biol* 2005;17:368-71.

24. Bouchet A, Giraud M. Contribution a l'etude morphologique et radiologique des osselets de l'ouïe. Comptes rendus de l' Association des Anatomistes 53 Congrès 1968;141:588-600.
25. Masali, M., 1968. The ear bones and the vertebral column as indicators of taxonomic and postural distinction among old world primates. In: Chiarelli B, ed. Taxonomy and Phylogeny of Old World Primates with References to the Origin of Man. Torino: Rosenberg and Sellier; 1968. p. 69-94.
26. Arensburg B, Harell M, Nathan H. The human middle ear ossicles, morphometry and taxonomic implications. J Hum Evol 1981;10:199-205.
27. Unur E, Aycan K, Ekinci N, et al. The study of incus from morphometric view. Erciyes Medical Journal 1993;15:16-19.
28. Kosiagina ED, Kosiagin DV. Mathematical relationship between the dimensions of the auditory ossicles and fetal age. [Article in Russian] Arkh Anat Gistol Embriol 1978;74:66-8.

Correspondence to: Dr. Gulrez Nadeem, PhD, Assistant Professor
College of Dentistry, Ajman University of Science and
Technology, Ajman, UAE
Phone: 00971501557935
e-mail: gulreznadeem@yahoo.com

Conflict of interest statement: No conflicts declared.