MORPHOMETRICAL AND MORPHOLOGICAL VARIATIONS OF MIDDLE EAR OSSICLES IN THE NEWBORN*
Yeni doğanlarda orta kulak kemikciklerinin morfometrik ve morfolojik varyasyonları

Erdoğan UNUR[1], Harun ÜLGER[1], Nihat EKİNCİ[2]

Abstract

Purpose: *Aim of this study was to investigate the morphometric and morphologic variations of middle ear ossicles.*

Materials and Methods: *Middle ear of 20 newborn cadavers from both sexes were dissected bilaterally and the ossicles were obtained to investigate their morphometric and morphologic characteristics.*

Results: *The average of morphometric parameters showed that the malleus was 7.69 mm in total length with an angle of 137°; the manibrium mallei was 4.70 mm, and the total length of head and neck was 4.85 mm; the incus had a total length of 6.47 mm, total width of 4.88 mm , and a maximal distance of 6.12 mm between the tops of the processes, with an angle of 99.9°; the stapes had a total height of 3.22 mm, with stapedial base being 2.57 mm in length and 1.29 mm in width.*

The morphologic observations on the ossicles showed that the incus was the most stable and the stapes was the most variable of all. As a variation, one stapes did not have foramen obturatum.

Conclusion: *The knowledge of the variations of the middle ear ossicles may be helpful during ear operations to improve hearing. The morphometrical data may also be useful for the classification of middle ear ossicles.*

Key Words: *Ear ossicles, malleus, incus; Stapes*

Özet

Amaç: *Yeni doğanlarda orta kulak kemikciklerinin morfometrik ve morfolojik varyasyonlarını ortaya koymak.*

Gereç ve yöntem: *Her iki cinse ait 20 yeni doğan kadavrasının orta kulak boşluğuna girilerek elde edilen orta kulak kemikcikleri üzerinde morfometrik ve morfolojik inceleme yapıldı.*

Bulgular: *Morfometrik sonuçlar; malleus'un toplam uzunluğu 7.69 mm, manibrium mallei'nin uzunluğu 4.70 mm, caput mallei ve processus lateralis arasındaki uzaklık 4.85 mm, manibrium mallei'nin ekseni ve caput mallei arasındaki açı 137°, incus'un toplam uzunluğu 6.47 mm, toplam genişliği 4.88 mm, crus longum ve breve'nin uçları arasındaki uzaklık 6.12 mm, cruslar arasındaki açı 99.9°, stapesin toplam uzunluğu (yüksekliği) 3.22 mm, basis stapedis'in uzunluğu 2.57 mm ve basis stapadis'in genişliği 1.29 mm olarak bulundu.*

Kemikcikler üzerindeki morfolojik gözlemler varyasyon bakımından incus'un en kararlı, strapes'in ise en değişken kemikcik olduğunu ortaya koydu. Bir stapes'te foramen obturatum'un bulunmadığını tespit ettik.

Sonuç: *Kemikcikler üzerindeki varyasyonların bilinmesi orta kulağa yapılan operasyonlarda, morfometrik sonuçlar ise orta kulak kemikciklerinin sınıflandırılmasında faydalı olabilir.*

Anahtar Kelimeler: *Kulak kemikçikleri, malleus, incus; Stapes*

The tympanic cavity contains three ossicles (middle ear ossicles or auditory ossicles) in humans; the malleus, incus and stapes. These ossicles form a chain across the tympanic cavity from the tympanic membrane to the fenestra vestibuli respectively (1,2). Our knowledge about these ossicles goes back to the 15th century (3). Since that time, extensive studies have been carried out on their morphometry and morphology (4-7), anomalies (8-12), embryology (13), function and structure (14-16) as well as the surgical reconstruction (17,18). Most of these previous studies were on adult ossicles. It has been reported that these ossicles arrive at maximal size in foetal

**V. Ulusal Anatomi Kongresi, 25-30 Ekim 1999, Antalya*
Erciyes Üniversitesi Tıp Fakültesi 38039 KAYSERİ
Anatomi. Y.Doç.Dr.[1], Doç.Dr.[2].

Geliş tarihi: 12 Nisan 2001

life (19). However, two recent studies have shown that development of these ossicles continues after birth and their weight and size increase (20,21).

In this work, our aim was to study the morphometry and morphometric variation, if any, of the ossicles in the newborn. Morphological variations were also investigated in the ossicles.

MATERIALS AND METHODS

This study was performed on 40 sets of middle ear ossicles which were taken from 20 newborn cadavers of both sexes, from the Anatomy Laboratory Collection of Erciyes University. The ossicles were obtained from tympanic cavity after opening tegmen tympani. Measurements were made according to previous studies (3,9,20). The measurements were estimated with a Mitutoyo micrometer which has an accuracy of 0.01 mm. Photographs were taken with a stereoscopic microscope. The measurements of angles were estimated on the photographs. The measurements shown in figure 1 were carried out on the ossicles.

RESULTS

In this study, the data were determined in two categories; the morphometric and the morphologic. While the morphometrical data from the middle ear ossicles were given in table 1, the morphological data were based on observation.

Malleus: The free ends (distal part) of manibrium mallei showed variations between a curve anteriorly (50%) (fig.2a) and a straight line (fig. 2c). The lateral processes of mallei had a very different appearance (fig. 2a-d). Some mallei had no neck between head (caput) and manubrium and these mallei had large and long lateral processes (fig. 2c). The length of the anterior process was variable and some of the processes were quite long (fig.3).

Incus: The incus had minimum morphological variations in the ossicles. There was a notch in the inferior border of the short process (42.2%). Courses of these notches were forward (fig. 4f) or upward (fig. 4d). The angle between the short and long process of the incus was variable (fig. 4a-f). While the incus with a well-developed corpus had a wide angle (fig. 4c), the incus with a less developed corpus had a narrow angle (fig. 4e).

Stapes: Stapes had maximum morphological variations in the middle ear ossicle. The variations of stapes were in the neck, the cruses and the hole (fig. 5 and 6). The stapes had no neck (fig. 5c), a short (fig. 5a) or a long (fig. 5d) neck. The cruses of the stapes had symmetry (fig. 6a and e) or asymmetry (fig. 5a-d). The hole of stapes (foremen obturatum) was circular (fig. 6b), oval (fig. 6c), triangular (fig. 6e), tunnel shaped (fig. 6d) or without hole (fig. 6f).

It was observed that while some ossicles were well-developed morphometrically, their bone mass did not reach a sufficient size (fig. 2d and 6e).

Table I. Morphometric data of middle ear ossicles. Metric values (length and width) given in mm

Malleus (n: 40)	**Mean ± SD**	**Incus (n: 40)**	**Mean ± SD**	**Stapes (n: 40)**	Mean ± SD
Total length	7.69 0.60	Total length	6.47 0.55	Total height	3.22 0.31
Length of Manubrium	4.70 0.45	Total width	4.88 0.47	Length of basis stapedis	2.57 0.33
Length of head and neck	4.85 0.29	Distance between tips of the processes	6.12 0.43	Width of the basis stapedis	1.29 0.22
Angle	137 9.77	Angle	99.9 13.5	Index	80.06 10.04
Index	60.97 3.77	Index	79.84 6.75		

Table II. Morphometric data of middle ear ossicles from present and some previous studies. Metric values (length and width) given in mm

Malleus

Values	*Present data*	*Bouchet & Giraut, 1968*	*Masali, 1968*	*Arrensburg & Nathan, 1972*	*Harada, 1972*	*Arrensburg et al,. 1981*	*Aycan et al., 1990*
Tota length	*7.7*	*7.9*	*7.6*	*7.3*	*8.0*	*7.8*	*8.1*
Length of manubrium	*4.7*	*4.7*	*4.6*	*3.5*	*4.2*	*4.4*	*4.9*
Length of head and neck	*4.9*	*-*	*-*	*-*	*5.0*	*-*	*5.1*
Angle	*137*	*139*	*-*	*155*	*-*	*137*	*141*
Index	*61*	*-*	*-*	*-*	*-*	*56.6*	*-*

Incus

Values	*Present data*	*Bouchet & Giraut, 1968*	*Masali, 1968*	*Arrensburg & Nathan, 1972*	*Harada, 1972*	*Arrensburg et al,. 1981*	*Unur et al., 1990*
Tota length	*6.5*	*6.5*	*6.4*	*6.8*	*6.8*	*6.4*	*6.7*
Total width	*4.9*	*5.1*	*4.8*	*5.1*	*4.8*	*5.1*	*5.1*
Maximal distance top of the processes	*6.1*	*-*	*-*	*-*	*4.2*	*-*	*6.1*
Angle	*100*	*95*	*-*	*94*	*-*	*88*	*99*
Index							

Stapes

	Present data	*Bouchet & Giraut, 1968*	*Arrensburg et al, 1981*
Total height	*3.2*	*3.5*	*3.2*
Length of basis stapedis	*2.6*	*-*	*2.8*
Width of the basis stapedis	*1.3*	*-*	*1.3*
Index	*80.1*	*-*	*85.1*

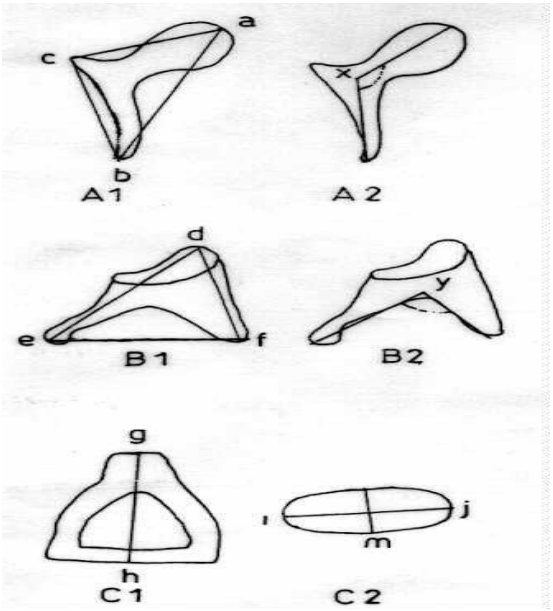

Fig. 1: Measurements of middle ear ossicles.
Fig. 1. A1 and A2 (malleus):
a-b: Total length (maximal distance between the top of the head and the end of the manubrium),
b-c: Length of manibrium mallei (distance from the end of the lateral process to the end of manibrium),
a-c: Length of head and neck (maximal distance between the top of the head and the end of the lateral process),
x: Angle (between the long axis of the neck and that of the manibrium),
Index: Length of manibrium X 100 / total length.
Fig. 1. B1 and B2 (incus):
d-e: Total length (maximal distance between the superior edge of the body and the end of the long process), **d-f: Total width** (maximal distance between the superior edge of the body and the end of the short process) **e-f:** Maximal distance between the tips of the processes, **y:** Angle between the processes, **Index:** Total width X 100 / total length of incus.
Fig. 1. C1 and C2 (stapes):
g-h: Total height (maximal distance between the top of the head and the basis stapedis),
ı-j: Length of the basis stapedis (maximal length of the long axis of basis stapedis),
m: Width of the basis stapedis (maximal width of the basis stapedis),
Index: Length of the basis stapedis X 100 / total height of stapes.

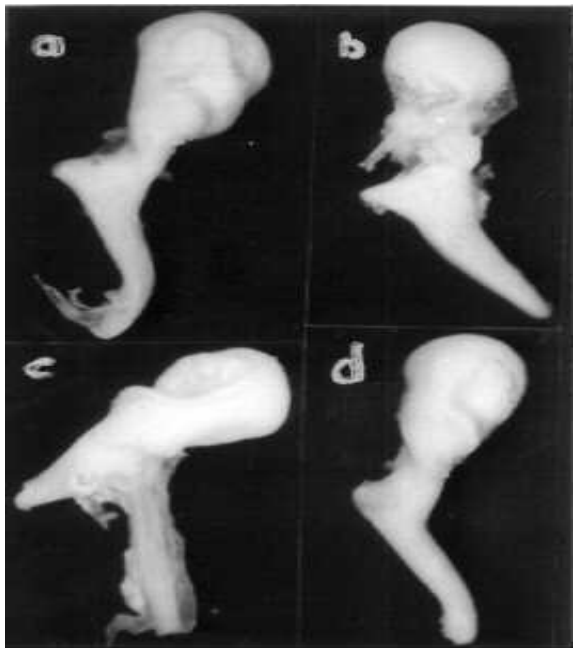

Fig. 2. The variations in the malleus. Course of the free end of manibrium mallei has a curve anteriorly (a and d) or straight (b and c).

Fig. 3. The very long anterior process of the malleus.

Table 1. *Measurements of the ossicles*

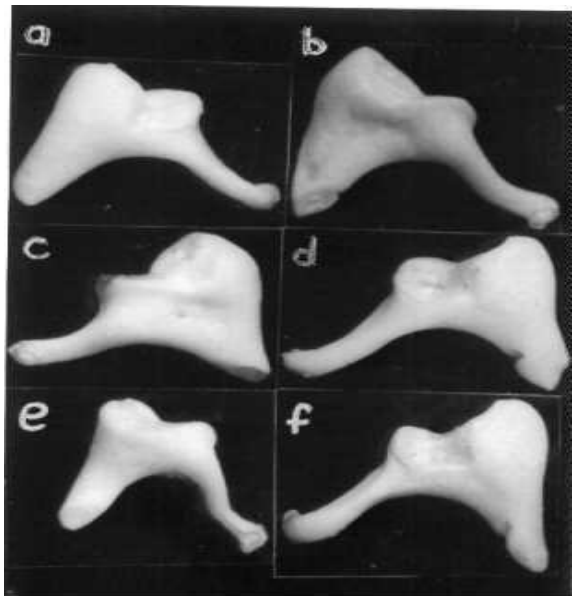

Fig. 4. The variations of the incus. The forward course (f) and upward course (d) of the notch on crus breve. The wide (c) and narrow angle (e) of incus.

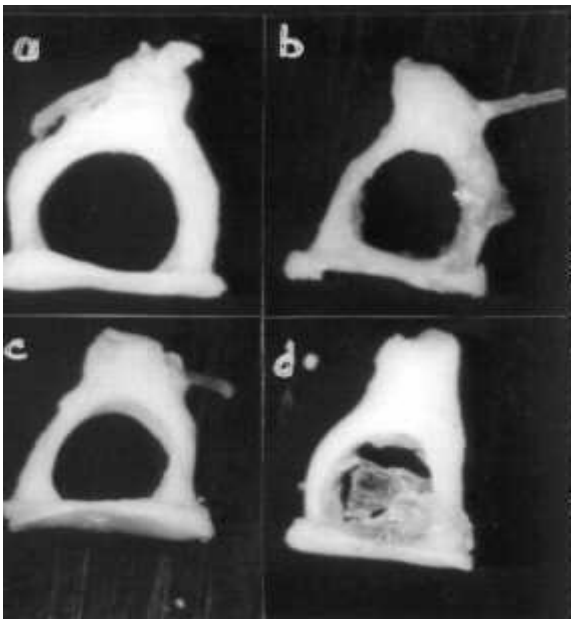

Fig. 5. The neck variations of the stapes. The stapes without neck (c) and with long neck (d).

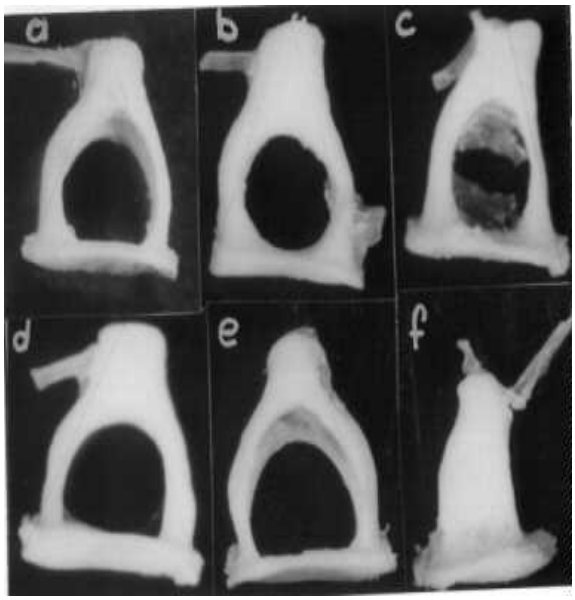

Fig. 6. The hole variations of the stapes. The circular hole (b), oval hole (c), triangular hole (e), tunnel shape (d) or without hole (f).

DISCUSSION

There are general anatomic explanations about the middle ear ossicle in anatomy textbooks. However, there are few studies in the literature on individual differences in these ossicles and these studies were on either adult or different species (3,4,6,7,9). When the present morphometric results of the malleus, incus and stapes were compared with previous results (table 2), the values were similar.

It has been reported that the anterior process was the longest process of malleus in foetal life and this process shortened after birth (22). A long anterior process was seen to exist in newborns. It is reported in the literature that the free ends of manibrium mallei curve slightly forward at a rate of 53-70% (5,6). We found it as 50% in the newborns. Incus is the most stable ossicle in variation (7). However, a notch of about 41-42% was reported on the crus breve (4). We found it as 42%. While there is information about the depth of

the notch (4), we could not find any information about their course. It was found in the present study that the course of the notch was either forward or upward. The posterior ligament of the incus connects the end of the crus breve to the fossa incudis. It has been reported that early development of the ligament in the foetus conditions the growth of the bone around it and produces the notch (4). The variations in the course of this notch could be caused by the angle between the origo and the insertio of the posterior ligament. Previous results showed that the stapes had more variations than other ossicles (5). These variations could be in the neck, the cruses and the foremen obturatum of the stapes. In addition to these variations, a stapes without the hole (foremen obturatum) was found in the present study.

As a result, it could be concluded that the stapes is the most variable and the incus is the most stable ossicle in view of morphological variations. Similar comparison of morphometric values of newborn ossicles to those of adults' values suggest that these ossicles complete their morphometric development in foetal life. However, it is possible that the development of bone mass of ossicle may not have been completed during foetal life. A study further supported this information (20, 21) .

Congenital malformations of middle ear ossicles can cause hearing problems. Wehrs (17) reported that congenital absence of the long process of the incus caused bilateral conductive hearing loss. The middle ear ossicles obtained from newborns, which are approximately the same size as the adults, might be observed in ossicle banks for future use in ossiculoplasty. In addition, these ossicles can be used as homografts to replace eroded adult middle ear ossicles.

REFERENCES

1. *Ars B, Decraemer W, Ars-Piret N. Tympano-ossicular allografts morphology and physiology. Am J Otol 1987; 8:148-154.*
2. *Williams L, Warwick R, Dyson M, Banister LH (ed): Grays Anatomy. Churchill Livingstone, Edinburg 1989, pp1226-1228*
3. *Arensburg B, Harell M, Nathan H. The human middle ear ossicles, morphometry and taxonomic implications. J Hum Evol 1981; 10:199-205.*
4. *Arensburg B, Nathan H. Observations on a notch in the short (Superior or Posterior) process of the incus. Acta Anat 1971; 78: 84-90.*
5. *Sarrat R, Guzman G, Tores A. Morphological variations of Human ossicula tmpani. Acta Anat 1988; 131:146-149*
6. *Aycan K, Unur E, Bozkır MG, et al. Anatomical study of malleus. Journal of Health Sciences 1990; 1: 152-158.*
7. *Unur E, Aycan K, Ekinci N, et al. The study of icus from morphometric view. Erciyes Medical Journal 1993; 15: 16-19.*
8. *Hough J.V.D. Congenital malformations of the middle ear. Arch Otolaryngol Head Neck Surg 1969; 78:335-343.*
9. *Harada O, Ishii H. The Condition of the auditory ossicles in microtia. Plast Reconst Surg 1972; 50:48-53.*
10. *Nomura Y, Nagao Y, Fukaya T. Anomalies of the middle ear. Laryngoscope 1988; 98:390-393*
11. *Causins Vinvent C, Milton Catherine M. Congenital ossicular abnormalities: A review of 68 cases. Am J Otol 1988; 9:76-80.*
12. *Siegert R, Weerda H, Mayer T, et al. High resolution computerized tomography of middle ear abnormalities. Laryngorhinootologie 1996; 75: 187-194.*
13. *Louryan S. Develompment of ouditory ossicles in the human embryo: correlations with data obtained in mice. Bull Assoc Anat (Nancy) 1993; 77: 29-32.*
14. *Sarrat R, Torres A, Guzman A.G, et al. Functional structure of human auditory ossicles. Acta Anat 1992; 144: 189-195*
15. *Huttenbrik K.B. The mechanics and function of middle ear. Part I: The ossicular chain and middle ear muscles. Laryngorhinootologie 1992; 71: 545-51.*

16. *Beer HJ, Bornitz M, Hardtke H.J, et al. Modelling of components of the middle ear and simulation of their dynamic behaviour. Audiol Neurootol 1999; 4: 156-162.*
17. *Wehrs RE. Congenital absence of the long process of incus. Laryngoscope 1999; 109: 192-197.*
18. *Lord RM, Mills RP, Abel EW. An anatomically shaped incus prosthesis for reconstruction ossicular chain. Hear Res 2000; 145: 141-148.*
19. *Andson BJ, Donaldson J.A. Surgical Anatomy of the Temporal Bone and Ear. WB Sounders, Philadelphia 1973, pp 37-41, 238-252*
20. *Olsewski J. Structure of the middle ear in infants. Otolaryngol Pol 1989; 43: 278-283.*
21. *Olsewski J. The morphometry of the ear ossicles in humans during development. Anat Anz 1990 ; 171:187-91.*
22. *Proop D, Hawke M, Berger G, et al. The anterior process of the malleus. The Journal of Otology 1984; 6:257-262.*
23. *Bouchet A, Giraud M. Contrubituon a l'etude morphologique et radiologique des osselets de l'ouie. Compte rendu de l' Association des Anatomists 53 Congrés 1968; 141:588-600.*
24. *Masali M. The ear bones and the vertebral column as indications of taxonomic and postural distinctions among old world primates with reference to the origin of man. Rosenberg and Sellier, Torino, 1968.*