Original Article

Anthropometric measurement and cross-sectional surveying of ear pinna characteristics in Northern India

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Abstract

Background: Pinna is a part of external ear. Its lateral surface shows various depressions and elevations, which makes it irregularly concave. Variations in ear proportions during growth, aging, and according to sex were reported. These differences were noticed in diverse ethnic groups such as Italian, European, Caucasian, Turkish, Dutch German, North American, and other countries. However, literature regarding the morphometry of pinna in Indians is lacking. **Materials and Methods:** Four hundred subjects (200 males and 200 females) between 10 and 50 years of age were selected for the study. According to age, the subjects were divided into four groups (A–D). For the purpose of study, unique digital signal processing technology, the megapixel camera was used to enable high-resolution system. Various anthropometric parameters of the external ear including total length of ear, total width of ear (TWE), total lobule length (TLL), and total lobule width (TLW) were measured by indirect method, and variations according to age and sex were studied. **Results:** All parameters of the cohort for both left and right ears showed an increase in values with increasing age, but this growth was statistically insignificant. Differences in three parameters of the pinna (TWE, TLL, and TLW) were statistically significant ($P < 0.05$) in both the sexes. Two important indices (auricular and lobule) were calculated in both the sexes. In males, the right lobule index was found to be statistically higher ($P = 0.01$) as compared to left one. However, it was not so in females. **Conclusion:** These parameters become a mainstay for plastic reconstructive surgeries. Besides this, the designing of hearing instruments also requires the information regarding anthropometry of ear in different ethnic groups. Ear dimensions exhibit significant effect of gender also.

Key words: Anthropometry, ear pinna, gender, hearing aids

INTRODUCTION

Anthropometry refers to the study of dimensions of different parts of the human body which shows variation according to age, sex, and race. Thus, the study of these physical variations plays an important

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role in establishing the identity of individual as well as holds importance in plastic surgeries and prosthesis development (Deopa *et al*., 2013).

The identification of an individual by age and sex possesses difficulty in revealing its identity. Various parameters have been used to establish the identification of individuals. Anthropometry of external features of the pinna is one of them (Brucker *et al*., 2003). Different studies proved that variations in ear proportions during growth, aging, and according to sex were reported. These differences were noticed in diverse ethnic groups such as Italian, European, Caucasian, Turkish, Dutch German, North American, and other countries (Ferrario *et al*., 1999; Gualdi-Russo 1998; Sforza *et al*., 2005; Sforza *et al*., 2009; Bozkir *et al*., 2006; Kalcioglu *et al*., 2006). Extensive MEDLINE search revealed limited literature regarding morphometry of the pinna in North India (Deopa *et al*., 2013; Kalra *et al*., 2015).

Pinna is a part of external ear. Its lateral surface shows various depressions and elevations, which makes it irregularly concave (Sinnatamby, 2000). According to some studies, the irregularities on the surface of pinna can be considered for the identification of the individual. Abeysekera and Shahnavaz reported in their study that the earpiece designed for males of the United States fitted only in 95% Germans, 75% Frenchmen, 60% Italians, 45% Japanese, and 10% Thais (Abeysekera and Shahnavaz, 1989). The size and shape of pinna differ in people of different nations was also reported (Deopa *et al*., 2013; Ferrario *et al*., 1999; Gualdi-Russo 1998; Abeysekera and Shahnavaz, 1989). Besides this, some studies reported that not only ethnic group but also age and sex are the determinants of ear anthropometry (Agnihotri and Singh, 2007; Azaria *et al*., 2003). The medial surface shows irregularities which correspond to its lateral surface and thus also shows ethnic, age, and sex variations (Agnihotri and Singh, 2007).

Yellow elastic cartilage folding gives the characteristic shape to the pinna. However, the part of pinna called as lobule is simply a skin fold containing fibro-fatty tissue. Embryologically, the human pinna develops in the 4th and 6th weeks of gestation. Neural crest tissues of the first and second branchial arches combine with surface ectoderm of corresponding arches. From this tissue, six auricular hillocks are derived. These hillocks fuses to form pinna, which finally shifts posteriorly and superiorly to attain the actual location of ear on the face (Wang *et al*., 2011).

According to some authors, the size, shape, and position of the auricle are one of the five chief features of the human face and influence the individual's appearance and beauty. Malformed and malpositioned auricle can fetter one's appearance. Because the architecture of the pinna is highly multifarious, plastic surgeons need in-depth information about its various dimensions for construction, location, and orientation of the auricular framework (Patel *et al*., 1992; Purkait and Singh, 2007).

The parameters generated in the study will provide a baseline data to help surgeons in the constructive and periauricular surgeries of the external ear. It will also prove to be helpful in industries involved in designing of ear prosthesis. Our study also facilitates the identification of an individual by forensic experts and anthropologists. This study was conducted to identify various morphological features of the pinna among the North Indian population.

MATERIALS AND METHODS

This was a cross-sectional study conducted between February 2013 and August 2015. Four hundred subjects (200 males and 200 females) between 10 and 50 years of age were selected for the study. According to age, the subjects were divided into four groups (A–D) [Table 1].

Individuals with positive history of congenital ear disease, craniofacial injury, infectious ear disease and those who have undergone surgery of the ear were excluded from the study. Subjects who lie in the age group of 10–50 years, have normal ear morphology, and belong to Indian ethnicity were included in the study. Informed verbal consent explaining the purpose and method of the study was obtained from the study subjects while the same was taken from the parents if the subject's age is <16 years.

For the purpose of this study, unique digital signal processing technology, the megapixel camera was used to enable high-resolution system. The subject was made to sit comfortably on a chair in such a way that the subject looked straight forward keeping the face in Frankfurt plane, i.e., the inferior borders of orbit and center of external auditory meatus lies in the same horizontal plane.

Lateral surface of the auricle was photographed in such a way that mid-vertical grid line of the camera aligned to pass through the mid-sagittal plane of the face while the mid-horizontal pass through the Frankfurt horizontal plane [Figure 1]. Posterior view of the auricle

Table 1: Distribution of age and sex in the study

Genders	Age group (years)				
	Group A (11-20)	Group B (21-30)	Group C (31-40)	Group D (41-50)	Total
Males	40	58	56	46	200
Females	36	60	58	46	200
Total	76	118	114	92	400

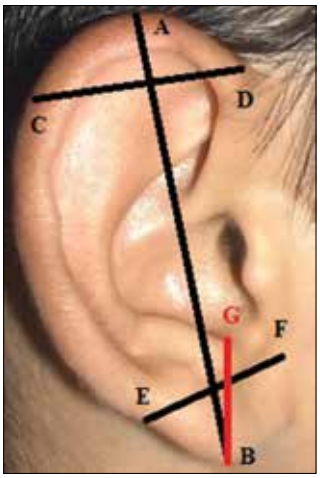

Figure 1: Lateral Surface of the ear. AB - Total length of ear, CD = Total width of ear, BG - Total lobular length, EF - Total lobular width

Figure 2: Medial surface of the ear

is photographed by aligning the mid-vertical grid line of the camera to pass through the base of the auricle coming in contact with the mastoid prominence while the mid-horizontal passes through the tragal level [Figure 2].

Ear features are captured using a digital camera. Digital images are transferred to a computer and the images are analyzed with Adobe Photoshop software (version 7.0, Adobe Systems, San Jose, California). First of all, various soft tissue landmarks are tagged on the subject's ear photograph and then different parameters were measured by Image J 1.48 software ImageJ (v 1.48 Java 1.6.0_20 64 bits).

The following anthropometric parameters of the external ear were measured by indirect method and variation according to age and sex were studied:

a. Total length of ear (TLE)
b. Total width of ear (TWE)
c. Total lobular length (TLL)
d. Total lobular width (TLW)
e. Auricular index (AI): Width of auricle/length of the auricle × 100
f. Lobular index (LI): Lobular width/lobular length × 100.

TLE was calculated as the measurement from the highest point of the pinna (A) to the lowest point of the pinna. Distance between the anterior and posterior points of the external ear was considered as TWE. The TLL was considered as the measurement from the midpoint of base of the intertragic notch to the lowest point of the lobule. LW was measured as the transverse distance of the ear lobule passing through the center of the length of lobule. AI was calculated as auricular width/auricular length × 100. LI was measured as lobule width/lobule length × 100.

The results were calculated as mean ± standard deviation. The Pearson correlation was used to institute the association between age, sex, and external ear anthropometry. The data were analyzed using BM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp., and $P < 0.05$ was considered as level of significance.

RESULTS

In our study, Table 2 shows values of different morphometric parameters of both ears according to age groups. All parameters of the cohort for both left and right ears showed increase in values with increasing age, but this growth was statistically insignificant.

Table 3 depicts the values of ear parameters according to sex, and three of them (TWE, TLL, and TLW) were statistically significant ($P < 0.05$). In this study, we analyzed our interpretation by means of statistical parameters (mean [standard deviation], mode, median, and range) to get better accuracy for the pinna measurements. The standard deviation predicts the variability in the values. The range depends on the number of subjects and the dispersion of values. Such statistical parameters provide evidence to information in deciding the actual value of distance during surgical interventions. The mode enables us to know the most frequent value of the parameter in that ethnic group.

Two important indices (AI and LI) were calculated in both the sexes. In males, the right LI was found to be statistically higher ($P = 0.01$) as compared to left one [Table 4]. However, it was not so in females. Combined results of males and females also showed significantly ($P = 0.03$) higher value of right LI as compared to males.

DISCUSSION

The knowledge of morphometric parameters of different landmarks on the face in relation to different age groups and

gender has become essential in the modern era for accurate plastic reconstruction and forensic purposes (Ekanem *et al*., 2010; Sharma *et al*., 2007). The anthropometry of external ear is also very important for the companies involved in designing of earphones. The present study determined the anthropometric size of TEL, TEW, TLL, and TLW of both sides. A similar study has been done in Northern Nigeria, in which all these parameters showed the lower values as compared to the present study (Ekanem *et al*., 2010). Thus, it proves that ethnic variation exists in the anthropometry of external ear. Hence, the study of morphometry of the pinna becomes essential among Indians.

Lobule length and width in our study are found to be statistically higher in females as compared to males. This fact is supported by another study done on Urhobo people of South Nigeria (Eboh, 2013). In contrast to this, Wang *et al*. (2011) suggested that lobule dimensions are not significantly different in two genders. All the values of pinna dimensions are higher in males as compared to females was proved by Ekanem *et al*. (2010) in their study. Some other studies have also reported that males had larger ears than females. Agnihotri and Singh (2007) found in their study significantly big ears in Indian boys than the girls at the time of birth. However, it was interesting to find in our study that although ear dimensions were higher in males, lobule was larger in females.

When right and left sides were compared, the recent study showed no statistically significant asymmetry in the ear. Bozkir *et al*. (2006) also determined the morphometric measurements from right and left ears among 341 healthy young adults (150 women and 191 men) and also observed similar symmetry among them.

A study conducted by Liu (2006) reported that no significant changes in the parameter of pinna were found in different age groups. Similar to this study, the present one also found no significance in changes in the morphometry of pinna with advancing age. Sforza *et al*. (2009) conducted a similar study in Italian Caucasians to determine the age- and sex-related changes in the normal and healthy human ear. They observed

Table 2: Different morphometric measurements of pinna in relation to age

Side	Parameter (cm)	Age group (years), mean±SD			
		Group A	Group B	Group C	Group D
Right ear	TLE	5.21±0.41	5.86±0.38	6.05±0.35	6.5±0.36
	TWE	2.06±0.21	2.9±0.24	3.42±0.31	3.58±0.31
	TLL	1.59±0.18	1.64±0.16	1.77±0.15	1.92±0.15
	TLW	1.92±0.14	1.95±0.17	1.99±0.15	2.06±0.15
Left ear	TLE	5.32±0.41	5.8±0.35	6.03±0.37	6.71±0.31
	TWE	2.07±0.2	2.9±0.24	3.39±0.33	3.56±0.34
	TLL	1.57±0.19	1.63±0.15	1.75±0.15	1.91±0.13
	TLW	1.9±0.12	1.94±0.17	1.96±0.15	2.03±0.14

TLE - Total length of ear, TWE - Total width of ear, TLL - Total lobule length, TLW - Total lobule width

Table 3: Different morphometric parameters of pinna in relation to sex

Parameters (cm)	Side	Sex	Mean±SD	*P*	Median	Range	Mode
TLE	Right	Male	5.43±0.31	0.13	5.04	4.76-6.35	5.31
		Female	5.49±0.47		5.09	4.81-6.41	5.37
TLE	Left	Male	5.37±0.51	0.37	5.01	4.61-6.27	5.24
		Female	5.41±0.39		5.05	4.65-6.32	5.27
TWE	Right	Male	2.89±0.26	0.01*	2.57	2.05-3.79	2.68
		Female	2.81±0.40		2.49	2.00-3.68	2.63
TWE	Left	Male	2.84±0.33	0.15	2.35	2.02-3.95	2.73
		Female	2.79±0.37		2.41	1.98-3.90	2.59
TLL	Right	Male	1.34±0.21	0.001*	1.30	0.92-1.83	1.25
		Female	1.52±0.19		1.42	1.06-2.11	1.47
TLL	Left	Male	1.37±0.17	0.001*	1.32	0.97-1.89	1.22
		Female	1.53±0.18		1.44	1.03-2.15	1.43
TLW	Right	Male	1.42±0.23	0.001*	1.33	1.02-2.22	1.29
		Female	1.56±0.21		1.47	1.13-2.39	1.42
TLW	Left	Male	1.40±0.21	0.001*	1.35	1.01-2.03	1.28
		Female	1.59±0.17		1.49	1.17-2.48	1.42

*$P \leq 0.01$. TLE - Total length of ear, TWE - Total width of ear, TLL - Total lobule length, TLW - Total lobule width, SD - Standard deviation

Table 4: Different indices of ear pinna

Indices	Side	Male (*n*=200)		Female (*n*=200)		Combined (*n*=400)	
		Mean±SD	*P*	Mean±SD	*P*	Mean±SD	*P*
Auricular index	Right	53.22±4.23	0.41	51.18±4.02	0.34	52.19±4.18	0.001*
	Left	52.89±3.87		51.57±4.19		50.78±4.03	
Lobule index	Right	105.97±15.94	0.01*	102.63±12.74	0.32	105.35±14.81	0.03*
	Left	102.19±13.72		103.92±13.45		102.34±13.67	

*$P \leq 0.01$. SD - Standard deviation

that with age, all linear distances were influenced. Similarly, another study done on Northern Chinese by Wang *et al*. (2011) revealed that length and width of the auricle as well as lobule increase significantly with age in both genders. In the present study, we found no statistically significant changes in the dimensions of ear with increasing age. The reason behind this is that before three years of age, 90% of the enlargement of the ear occurs, with the remaining 10% before 20 years of age. After 20 years of age, the changes in appearance of pinna occur due to rearrangement of elastic fibers (Adamson *et al*., 1965). The changes in size of lobule are mainly seen after 45 years of age due to gravitational forces and also secondary to wearing of ornaments by females (Barut and Aktunc, 2006). Limitation of this study is that age group selected for morphometry was from 10 to 50 years of age. When we compare our study with previous researches, various disparities in auricular morphology are found which changes with age and sex. Different factors which attribute to these variations are geographical locations, ethnic group, genetics, and sex.

CONCLUSION

The anthropometric data of the external ear have impending implications in the identification of congenital deformities, various syndromes affecting external ear, and traumatic deformities. Thus, these parameters are supposed to be helpful for plastic reconstructive surgeries. Besides this, the designing of hearing instruments also requires the information regarding anthropometry of ear in different ethnic groups. The different parameters of the ear exhibit significant effect of gender, and so, the prosthesis of ear should be manufactured according to the sex variation observed in the study.

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Conflicts of Interest
There are no conflicts of interest.

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