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Dentistry Section

Morphological Variations and Biometrics of Ear: An Aid to Personal Identification

PRADHUMAN VERMA[1], HARPREET KAUR SANDHU[2], KANIKA GUPTA VERMA[3], SHARRY GOYAL[4], MADHU SUDAN[5], AMIT LADGOTRA[6]

ABSTRACT

Introduction: The morphological characteristics and dimensions of external ear vary in different human ethnic races which can be utilized in forensics for personal identification of living or deceased.

Aim: To determine uniqueness of morphological and biometric variations of both ears for individualization among North East (NE) and North West (NW) subpopulation of India.

Materials and Methods: The study was conducted on randomly selected 80 students, 40 from each subgroup. Nine ear parameters were recorded twice using digital Vernier's caliper by single investigator and two indices (Ear Index and Lobule Index) were calculated for both the ears. Morphological ear shapes and lobule attachment were also noted. Pearson's coefficient correlation test was performed on cross-tabulations to evaluate significant relationship between different variables.

Results: Of the total 35% free and 65% attached ear lobes were noted in both population groups. Oval ear shape was most commonly noted followed by triangular, rectangular and round in both populations. On comparing anthropometric measurements of ears in two populations it was found that except the tragus length and lobule index all other values were noted more in NW population. No statistical difference was found in ear and lobular indices of males and females although the left ear index and lobule index were found to be higher than right in both populations except in NW females where right lobule index was recorded more than left.

Conclusion: The results obtained can be used in anthropological and forensic sciences for the inclusion and exclusion of persons for identification on the basis of ear variations.

Keywords: Ear lobule attachment, Ear measurements, Ethnic races, Ear shapes, Forensics

INTRODUCTION

The use of ear as a tool for human identification started since late 19th century when Alphonse Bertillon utilized it as one of eleven anthropometric measurements for his manual system of identifying individuals [1]. The ear consists of a single piece of fibrocartilage with a complicated relief on the anterior, concave side and a fairly smooth configuration on the posterior, convex side. The fetal development of ear starts shortly after conception and by the 38th day some of its features are recognizable. The ear moves to its definitive position on 56th day and the shape of ear can be recognized on the 70th day. The shape is fixed from then on and never changes from birth until death [2]. The human ear is divided into external, middle and internal parts. Auricle and external acoustic meatus form the external ear which is utilized in the forensic sciences for individual identification and authentication. Also the auricle is one of the five primary features of the human face and is particularly influential in determining its appearance [3]. The lateral surface of the auricle is irregularly concave, faces slightly forward and displays many eminences and depressions, which can make contact with various surfaces and can produce a print like a rubber stamp. Ear prints are found predominantly on surfaces where an individual has been listening to determine whether or not premises could be occupied during burglary. This occurs generally at doors or windows [4]. The biometrics of ear is a very interesting issue as during crime scene investigation, ear marks and measurements are often used for identification in the absence of valid fingerprints. Ear biometrics can positively identify an individual using comparative analysis of the human ear and its morphology. The dimensions of the pinna have been found to vary among different ethnic groups [5]. Many studies have been conducted regarding morphological variations of human ears but the data for variations between inter-ethnic groups was lacking, which is essential for the personnel identification in forensic sciences [6,7]. Imhofer also stressed the possibility of using ear characteristics for assessing familial relationships, as the morphology of ears tends to be hereditary [8]. The pattern of the free lobule was proposed by Altmann to be a dominant trait with the attached lobule representing the recessive trait [9]. Oepen studied the external ear from an anthropological point of view and gathered data from the ears of 500 male and 500 female subjects [10]. Alfred V. Iannarelli in 1989 worked on 10,000 human ear patterns and found that they all were different [11]. The identity of Verrappan body, a famous sandal wood smuggler from Indian subcontinent was confirmed by his ear morphology and biometrics measurements in 2004 [12]. Jung and Jung conducted a survey and confirmed the age, gender and ethnic variations of ears among Koreans [13]. According to Hammer, the probability for the random occurrence of four concordant features of ear was estimated to be one in 7800 [14].

AIM

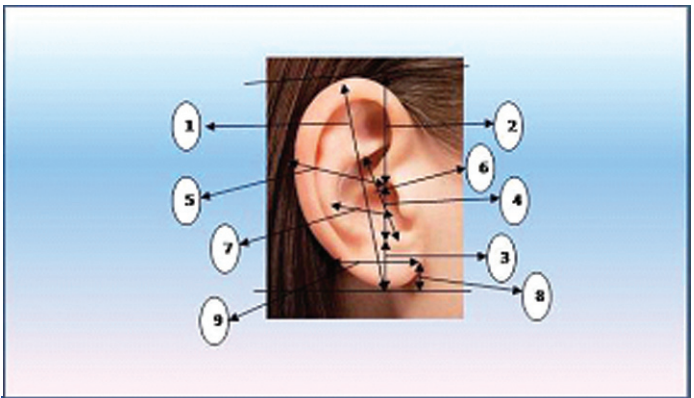
With this background the present study was undertaken to compare the external ear morphological variations and biometrics among both genders of North-East (NE) and North-West (NW) subgroups of Indian population.

MATERIALS AND METHODS

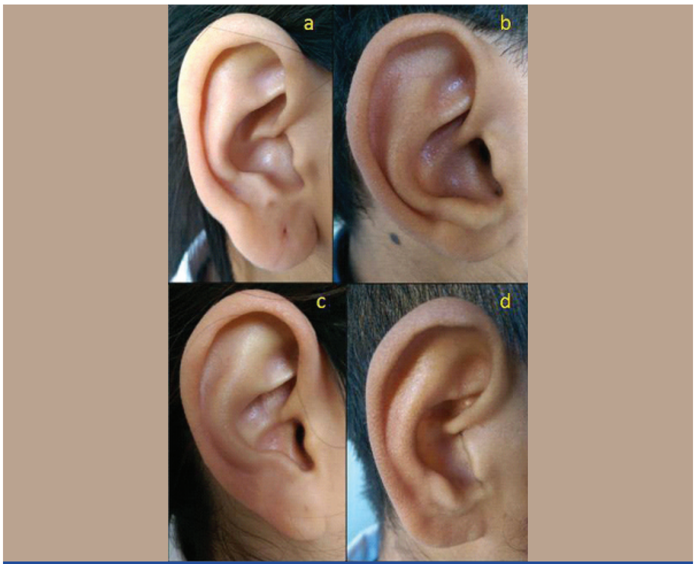
The present longitudinal randomized study was carried on randomly selected 80 dental students, 40 from North-East (NE) and 40 from North-West (NW) population zone of India in Surendera Dental College and Research Institute, Sriganganagar Rajasthan from December 2014 to March 2015. The study sample included subjects aged 18 to 25 years, of which 33 subjects were males and 47 were females. All the subjects were briefed about the purpose of the study and written informed consent was obtained after their racial confirmation. The study approval was obtained from the institutional ethical committee. Thorough clinical examination was done and subjects with history of craniofacial trauma, ear diseases, congenital abnormalities or surgery of the ear, piercing of ear lobule were excluded from the study. The anatomical landmarks used for ear biometrics of both sides were – 1) Total Ear Length (TEL): the distance between superior most pinna point to inferior most point of lobule. 2) Ear length above tragus: distance between superior point of ear to tragion. 3) Ear length below tragus: distance between intertragic incisure to lower most lobule point. 4) Tragus length: distance between tragion to intertregic incisures. 5) Ear breadth: distance between maximum convexity of the helix and the root of ear. 6) Concha length: distance between intertragic incisures and cymba concha. 7) Concha breadth: distance between maximum concavity of the antihelix and posterior margin of tragus. 8) Lobule height: distance between inferior most point of external ear attachment head up to the free margins of ear lobe. 9) Lobule width: distance between outermost maximum transverse width of ear lobule and caudal most attachment of ear lobule [Table/Fig-1]. All the measurements were done on both ears using standard digital Vernier's caliper with measuring capability to the nearest 0.1mm by single investigator. The measurements were carried out for each subject twice to get accuracy and mean of two measurements was considered for each dimension. Also Ear Index (ear width/ ear height x 100) and Lobule Index (lobule width/lobule height x 100) were calculated for each subject [15]. The four basic ear morphological shapes considered were Oval, Rectangular, Triangular and Round [1]. Also, the ear lobule attachment was noted as attached or free. [Table/Fig-2].

STATISTICAL ANALYSIS

The collected data was statistically analyzed using SPSS Version 20.0 (Microsoft Corperation Inc., Chicago, IL, USA). The cross-tabulations were made and Pearson's correlation coefficient tests were performed on cross tabulations to evaluate significant relationship between both genders in two populations.



[Table/Fig-1]: Biometric measurements of external ear. 1 Total ear length 2.Ear length above tragus 3.Ear length below tragus 4.Tragus length 5.Ear breadth 6. Concha length 7. Concha breadth 8. Lobule height 9. Lobule width.



[Table/Fig-2]: Morphological shapes of ears a. Oval b. Round c. Triangular d. Rectangular.

RESULTS

The percentage of free and attached ear lobe attachments was noted (35% free and 65% attached) in both population groups. Also the attached ear lobes percentage was noted more among both genders of two populations except male NE population where the free and attached ear lobe attachments were equally distributed [Table/Fig-3].

Complete 100% symmetry was noted regarding shapes of ears in NW population whereas one case of asymmetrical ears was noted among NE population. Most commonly oval shape of ears was noted followed by triangular, rectangular and round in both populations [Table/Fig-4].

The measurements and comparison of results for the right and left ears among both genders of NW population in the study are shown in [Table/Fig-5]. The mean TEL, ear length above tragus, ear length below tragus, ear breadth, concha breadth, concha length, lobule height and lobule width was noted more in males on both sides. The tragus length was equal among both genders on both sides. The ear index was noted more in males on both sides whereas lobule index was more in females on both sides. Also the ear index was found higher on left side for all NW subjects whereas lobule index was noted higher on right side among females. Highly

Population	Mean Age (yrs)		Gender			Ear Lobe Attachment											
	Male	Female	Male (M)	Female (F)	Total (T)	Right						Left					
						M		F		T		M		F		T	
						F	A	F	A	F	A	F	A	F	A	F	A
North West	19.39	21.79	21 (52.5%)	19 (47.50%)	40	8	13	6	13	14 (35%)	26 (65%)	10	11	7	12	17 (42.5%)	23 (57.5%)
North East	21.5	20.29	12 (30%)	28 (70%)	40	6	6	8	20	14 (35%)	26 (65%)	6	6	8	20	14 (35%)	26 (65%)

[Table/Fig-3]: Distribution of patterns of ear lobe attachment.

Population	Ear Symmetry						Shapes											
	Sym			Asym			Oval			Round			Triangular			Rectangular		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
North West	21 (52.5%)	19 (47.5%)	40	0	0	0	7R 7L	9R 9L	16R# 16L^	1R 1L	1R 1L	2R 2L	9R 9L	3R 3L	12R 12L	4R 4L	6R 6L	10R 10L
North East	12 (30.76%)	27 (69.23%)	39	0	1	1	9R 9L	9R 8L	18R 17L	0R 0L	2R 2L	2R 2L	2R 2L	13R 14L	15R 16L	1R 1L	4R 4L	5R 5L

[Table/Fig-4]: Distribution of morphological shapes of ears and symmetry.
#Right; ^Left

significant difference was found for TEL in both genders on both sides (p≤0.001) whereas significant difference was noted for ear length above tragus, concha length, lobule height and lobule width on both sides for both genders (p<0.05).

The biometric results for the right and left ears among both genders of NE population in the study are shown in [Table/Fig -6]. The mean TEL, ear length above tragus, tragus length, ear breadth, concha

North West									
Parameters	Sides	Male Population Measurements (in mm)				Female Population Measurements (in mm)			
		Calculated Range	Mean ± SD	t-test	p-value	Calculated Range	Mean±SD	t-test	p-value
Total Ear length	Left	54.59-72.35	61.11±4.65	4.089	0.001*	51.8-62.63	58.16±3.39	4.281	<0.001*
	Right	55.22-70.69	63.74±4.66			52.1-63.27	58.90±3.27		
Ear length above tragus	Left	23.29-41.18	28.33±3.79	3.165	0.005**	22.34-30.18	27.09±1.69	2.838	0.011**
	Right	25.33-38.03	30±4.92			25.59-30.62	28.79±3.02		
Ear length below tragus	Left	11.18-28.14	20.36±5.10	2.108	0.048**	13.83-29.5	19.27±4.69	0.608	0.551***
	Right	12.95-27.89	21.30±4.51			13.95-30.62	19.40±4.29		
Tragus length	Left	6.2-21.35	14.9±5.07	-2.186	0.041**	2.97-18.16	14.4±3.21	-1.939	0.068***
	Right	2.31-20.20	13.74±4.59			5.86-17.13	13.26±4.44		
Ear breadth	Left	26.96-40.48	32.19±2.42	0.199	0.844***	26.86-33.44	29.13±2.19	0.710	0.487***
	Right	27.09-35.60	32.30±4.41			26.28-35.02	29.48±1.48		
Concha length	Left	21.61-31.43	26.01±2.38	2.579	0.018**	19.36-26.86	24.11±1.83	2.626	0.017**
	Right	22.96-30.30	26.70±2.66			21.68-27.74	25.24±2.09		
Concha breadth	Left	12.9-26.00	18.28±12.85	1.115	0.278***	15.14-20.94	17.42±1.74	-1.835	0.083***
	Right	11.5-75.3	21.40±3.12			14.33-20.74	17.06±1.31		
Lobule height	Left	0-14.17	5.68±6.56	-0.551	0.588***	0-13.12	2.85±3.65	-2.280	0.035**
	Right	0-16.5	5.36±5.76			0-10.14	2.17±4.57		
Lobule width	Left	12.74-24.79	19.39±2.95	-2.462	0.023**	13.71-27.12	19.17±3.75	-2.212	0.040**
	Right	12.49-22.99	18.02±3.92			12.47-23.17	17.96±3.47		
Ear index	Left	43.2-60.77	52.64±3.79	-2.063	0.052**	46.44-59.26	50.24±3.34	-0.167	0.869***
	Right	42.96-55.53	50.80±5.56			43.97-55.35	50.10±3.90		
Lobule index	Left	147.27-535.98	242.34±147.99	-0.949	0.371***	161.43-541.76	333.52±157.46	1.580	0.175***
	Right	112.72-521.31	221.62±144.80			195.75-530.48	357.05±174.05		

[Table/Fig-5]: Biometric ear measurements in both genders among North-West Indian sub-population.
*p-value ≤ 0.001 is highly significant; **p-value < 0.05 is significant; ***p-value > 0.05 is insignificant

North East									
Parameters	Sides	Male Population Measurements (in mm)				Female Population Measurements (in mm)			
		Calculated Range	Mean ± SD	t-test	p-value	Calculated Range	Mean±SD	t-test	p-value
Total Ear length	Left	55.4-67.55	60.03±3.64	4.206	0.001*	48.18-63.4	57.51±3.93	6.555	<0.001*
	Right	56.64-68.09	61.58±3.93			52.15-67.84	59.38±3.67		
Ear length above tragus	Left	22.79-28.13	25.93±1.96	6.962	0.000*	22.63-30.94	25.01±2.52	5.897	<0.001*
	Right	23.5-31.08	28.06±1.67			21.18-30.95	27.13±2.40		
Ear length below tragus	Left	15.34-23.9	18.11±2.23	1.212	0.251**	13.37-22.03	18.01±2.56	1.509	0.143**
	Right	15.57-22.64	18.47±2.64			13.90-23.25	18.39±2.23		
Tragus length	Left	9.93-23.16	15.99±4.48	-0.375	0.714**	9.97-18.09	14.48±2.05	-1.432	0.163**
	Right	11.74-28.29	15.71±3.74			10.59-17.94	13.89±2.24		
Ear breadth	Left	28.27-32.54	30.72±2.31	1.737	0.110**	23.63-31.89	27.97±2.83	5.032	<0.001*
	Right	26.9-35.47	31.46±1.44			24.63-35.02	29.48±2.61		
Concha length	Left	22.73-29.45	24.96±2.33	0.492	0.632**	18.65-28.16	24.16±2.17	.976	0.338**
	Right	22.26-29.67	25.20±1.96			19.62-28.48	24.47±2.34		
Concha breadth	Left	16.22-19.85	16.80±1.04	-3.232	0.008***	10.48-21.08	17.05±2.29	0.943	0.354**
	Right	15.61-18.15	17.65±1.32			12.81-21.84	17.32±1.96		
Lobule height	Left	0-9.1	3.37±3.16	-2.342	0.039***	0-8.34	1.86±2.88	-1.479	0.151**
	Right	0-8.50	2.78±3.63			0-9.09	1.74±3.04		
Lobule width	Left	15.51-21.34	17.90±2.38	3.292	0.007***	9.67-21.97	16.45±3.20	-0.953	0.349**
	Right	16.22-22.1	18.92±2.24			9.07-21.38	16.13±2.97		
Ear index	Left	46.12-55.16	51.31±3.13	-0.265	0.796**	43.24-57.57	48.63±4.14	2.015	0.054***
	Right	43.61-56.34	51.12±3.12			45.25-62.17	49.68±3.38		
Lobule index	Left	189.56-379.04	273.02±138.89	2.796	0.038***	228.84-406.7	300.05±68.58	0.433	0.678**
	Right	201.17-591.64	372.95±75.38			231.61-389.84	305.84±62.49		

[Table/Fig-6]: Biometric ear measurements in both genders among North-East Indian sub-population.
*p-value ≤ 0.001 is highly significant; **p-value > 0.05 is insignificant; ***p-value < 0.05 is significant.

length, lobule height and lobule width was noted more in males on both sides. The ear length below tragus and concha breadth was noted nearly equal among both genders on both sides. The ear index was noted more in males on both sides while lobule index was noted more in females. Highly significant difference was found for TEL, ear length above tragus, ear breadth in both genders on both sides ($p \leq 0.001$) whereas significant difference was noted for ear length above tragus, concha length, concha breadth lobule height and lobule width on both sides for both genders ($p<0.05$).

DISCUSSION

Knowledge about the normal human ear dimensions and morphological features of various populations can be helpful from anthropological and forensic point of view to provide data procedures for the inclusion and exclusion of persons for identification on the basis of ear variations collected from criminals. The purpose of conducting present ear biometric study was that the variation in shape, size, features and no effect of expression change on ears makes it richer biometric tool than face in forensic sciences. Also the ear dimensions are important in the diagnosis of congenital malformations, acquired deformities, syndromes and in the treatment plannings. The study would also prove helpful to plastic surgeons to reproduce an anatomically correct ear during its reconstruction. Johann Casper Lavater first reported the study of human earology while Haken Jorgensen established the system of recording the ear morphology using ear biometrics and ear moulds [6].

Bhasin stated that ear lobule attachment was found to be an interesting marker in population genetics [16]. In present study both population showed more percentage of attached ear lobe (65%). The results were in accordance with Sharma A et al., who conducted a study on northwest Indian population and contrary to the Verma.K et al., study among the rickshaw drivers of central India were 66.46% ears lobe is free and 33.53% is attached [6, 17]. Lai and Walash found the frequency of attached ear lobule among Japanese subjects is 67% and in Chinese subjects it is 64.3% [18]. This might be due to different ethnic and genetic backgrounds of study populations. Gates observed that the attached ear lobule is possibly an African character with recessive inheritance pattern [19]. When both sides were compared for shape; symmetry was noted in most of the subjects of two populations. The results were in accordance with Kumar P et al., and Bozkir et al., [5,20].

The TEL is important in the evaluation of congenital anomalies (Down Syndrome), facial reconstruction and in forensic purposes. The ear reaches its mature height at 13 years in males and at 12 years in females. In present study the mean TEL was found more among males in both NE (60.03mm left side mm; 61.58mm right side) and NW (61.11mm left side; 63.74mm on right side) populations. The results were comparative with the studies done by Purkait R., Bozkir et al., and Asai Y et al., where the TEL of left ear in men was found to be 62.4mm, 63.1mm and 61.4mm respectively [12,20,21]. The release of more growth hormone in males than females during this age group supports the results. Also the TEL was noted more in NW population compared to NE among both genders. The genetic and racial background differences between two populations may be the reason.

Also most of other anthropometric dimensions of ear in present study (ear length above tragus, ear length below tragus, ear breadth, concha length, concha breadth lobule height, lobule width) were noted significantly higher in males than females in both populations. The results were in accordance with Ekanem et al., Eboh DEO and Deopa D et al., [15,22,23] [Table/Fig-7]. Wang et al., in a Northern Chinese study revealed that length of auricle, width of auricle, lobule length and lobule width was significantly more in males than females [24]. It has been opined that beyond 20 years of age, the size increase is basically attributable to secondary elongation of the earlobes due to gravitational forces. It was observed that auricular measurements increased significantly with age in both genders. The authors posited that these changes were associated with changes with the elastic fibers which are noted faster in males than females [25].

The ear biometric measurement comparison of both ears in two sub-populations showed that except lobule index and tragus length, all values were noted more in NW subjects in both genders. The ethnic and genetic background difference supports the results and was in accordance with the Sharma A et al., studies [16].

Ferrario et al., found that the ear indices of both sides in males were significantly higher than females [26]. Barut and Aktunc observed insignificantly higher right ear indices and significantly higher left ear indices in males [27]. The present study does not show any statistical difference in ear and lobule indices between two genders although left ear and lobule index were noted higher than right side in both population subjects except in NW where right lobule index was recorded more than left.

Source	Year	Population Studied	Male Ear Length (in mm)	Lobule Width (in mm)
Dreyfus [28]	1967	American	63.5	18.7
Burkhand and Sachs [29]	1975	American	68.5	20.4
Purkait and Singh [3]	2007	Central India	57.7	18.0
Chattopadhyay and Bhatia [7]	2009	Eastern India	62.5	-
Dinker and Sambyal [30]	2012	Goan (India)	61.4	-
Eboh DEO [22]	2013	Urhobo (Nigeria)	56.7	21.1
Deopa D [23]	2013	Haldwani, Uttarakhand (India)	61.0	19.6
Vermak et al., [6]	2014	Greater Noida, Uttar Pradesh (India)	64.2	18.6
Our study		North East Indian population North West Indian population	61.5 63.7	18.3 19.4

[Table/Fig-7]: Previous studies of ear biometrics.

LIMITATION

The limitations of the present study were the small study sample considered and the age related changes on ear biometrics were not noted among study populations.

CONCLUSION

The present study results of morphological examination and morpholometric variations of human ears can be used as supportive evidence as having a role in forensic field by the identification of landmarks variations in different ethnic groups.

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PARTICULARS OF CONTRIBUTORS:
1. Reader, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.
2. Post Graduate Student, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.
3. Reader, Department of Pedodontics & Preventive Dentistry, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.
4. Post Graduate Student, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.
5. Post Graduate Student, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.
6. Post Graduate Student, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Pradhuman Verma,
Reader, Department of Oral Medicine & Radiology, Surendera Dental College & Research Institute
H.H Gardens; Power House Road, Sriganganagar, Rajasthan-335001, India.
E-mail: pradhuman_verma@rediffmail.com

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