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Case Report

Uniqueness of External Ear: A Test in Genetic Relations

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Abstract

In recent times various human morphological features are used for establishing identity of an individual. One of the essential properties of any trait to be used for personal identification is it should be 'Unique' in every individual. External ear is a new entrant in this field. It is a fact that every morphological feature is under genetic influence and may be assumed that it will exhibit similarity among genetically related individuals than population at large. In this study an attempt has been made to estimate the extent of closeness of the ear structure in genetic relations and also to determine whether it altered the 'unique' nature of the individual ear. The study sample included members of 90 general and 27 tribal families of Central India. A validation study was performed on members of 48 North Indian families. The closest of genetic relation, monozygotic twins (Fifty three pairs) were also examined. Seventeen linear distances were measured on image of ear and each ear was represented as a feature vector in 17 dimensional feature space. Every ear pattern was paired and compared with its genetic relative. The dissimilarity in the ear pattern was measured by Euclidean distance between members of the pair. During analysis it was found that every ear pattern was distinct in its morphology. Among various genetic relations the ear patterns exhibited maximum dissimilarity between grandparent and grandchild and were most similar among monozygotic twin pairs.

INTRODUCTION

With the advent of electronic revolution in the last forty years, widespread use of digital technology has stormed the centre stage and the pace of innovation and refinement of these gadgets is astounding. Such a revolution has also added a new dimension to forensic investigation. The widespread use of digital camera, camera phone, closed circuit television etc. has widened the scope of '*Evidence*' capturing (digital imaging) capabilities like never before. The 'Information age' has also ushered the techniques of personal identification to a more accurate, automatic and secure world of 'Biometrics'. This method of identification based on ones physical or behavioural characteristics uses various morphological traits like face, hand, iris, fingerprint etc. External ear is a new entrant in this field. The ear pattern consisting of features which show great variation in their shape and size together give a complex structure to it. Like fingerprint with variable ridge characteristics, the external ear with its variable morphological features may be used as a Biometric trait.

Any trait used for establishing personal identity must possess few essential properties, one of which is being '*unique*' in all individuals. Though the study of ear patterns, characters and differences has been a matter of observation and study for over a century [1-3], till date there is no study with empirical data to establish the '*uniqueness*' of external ear pattern among genetically related persons.

It is a fact that various features of external ears are under multiple genetic controls [4-6]. Hence it is expected that these features will exhibit (phenotypic expression) more similarity among genetically related persons than population at large.

Various studies on 'Ear Biometrics' are being carried out on the premise that ear commands as much authenticity as fingerprints. The present study investigates this premise among family members to measure the degree of similarity/dissimilarity existing in the ear structure and to determine whether the similarity among genetic relations affect the uniqueness of the individual ear. However any study in the field of personal identification should be approached keeping the ultimate purpose i.e. its legal application in mind. The present study was planned to give the evidences related to external ear enough scientific backing to be admitted as credible evidence in the Court of Law.

MATERIALS AND METHODS

Theoretical background

It is a known fact that any pattern appears in different shapes and sizes in photographs taken from different camera alignments or position [7]. So, a photo–anthropometric comparison between different pairs of samples of ear pattern must ensure that all the photographs have been acquired under identical conditions of camera alignment and position. But, doing so is a formidable task, especially for a large sample size, while identical perspectives of ear patterns can only be considered for a faithful comparative study. This problem may be solved by the following device.

A rectangular scale (60mm width and 80mm height) be affixed beside the ear of each subject (Figure 1) such that,

(i) It is a common tangent to the convex curvature prominences of both temporal and zygomatic bones and

(ii) Horizontal midline of the rectangular scale is parallel to the line joining orbitale and tragion.

Profile view facial image may be taken by a digital camera from a distance large compared to the depth of features of the nearly flat ear pattern - but, details of ear pattern should be clear and sharp for precise measurements. While taking such photographs for a large sample size at different times, some variations in camera alignments or positions cannot be avoided. So, before conducting any anthropometric measurement all the images must be so processed as to reconstruct identical perspectives of ear patterns which are to be compared amongst themselves.

The size and shape of the same rectangular scale, as appearing in different sample images will depend on the camera distance and its alignment [7]. In fact, the rectangular scale will not appear as an accurate rectangle in the photographic images, unless the camera is so aligned that its focal plane is precisely parallel to the plane of the rectangle. So, each photograph should be digitally processed by a photogrammetric rectification procedure by considering the four corners of the rectangular scale as pass-points (Figure 1). For a 60mm*80mm rectangular scale, the aforesaid pass-points may be mapped on to an accurate rectangle of size 300*400 pixels in the rectified image. Such rectification for all the images will make them so appear such that they were snapped from identical camera distances and the camera focal plane was precisely aligned as parallel to the plane of the rectangular scale each time. Since, the scale was fitted on a fixed alignment with respect to the head, the images rectified with respect to the scale as above can be considered as identical perspectives of ear patterns. Such processed digital images of ear patterns are suitable for a comparison by digital photo-anthropometric measurements with an accuracy limit of 1 pixel width, which according to the above mapping amounts to 0.2mm only.

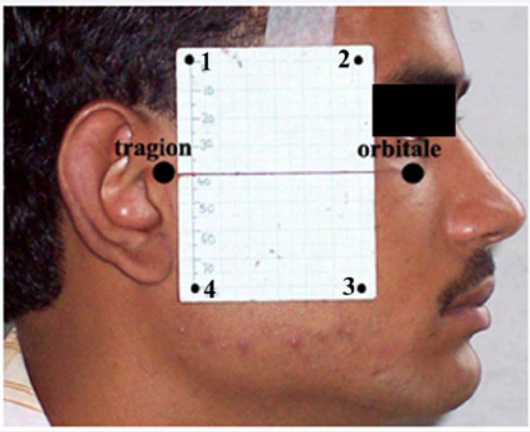

Figure 1 Rectangular scale affixed on face for photography. Points 1,2,3,4 are pass points of scale for photogrammetric rectification.

In order to retain the clarity and sharpness of the original image undisturbed in the processed image, the width and height of the rectangular scale, as appearing in the original image, should not be less than 300 and 400 pixels respectively. But, as noted already, the camera distance must be much larger than the depths of the nearly flat ear patterns. So, the camera position should be so adjusted that it is as large as possible, while the above resolution for the rectangular scale is ensured. Optical zooming may be done for best results.

METHOD OF COMPARISON

All human ear patterns, as visible in a profile view facial image, belong to a class of patterns presumably with some subtle differences amongst themselves in spite of their common class characteristics [7-8]. The present problem is to study whether such differences are detectable by the suggested metric analysis and whether each ear pattern may be ascribed a unique character suitable for personal identification.

In order to extract distinguishing ear features, a feature vector has been defined. The principle of the same has been explained in earlier work [9]. Altogether ten prominent landmarks have been selected on each ear pattern. The coordinates of such landmark points P_i (i=1 to 10) have been recorded to the nearest pixel through an interactive point selection procedure. Altogether 17 inter-landmark distances for a particular ear pattern, P_1P_j (j=2 to 10) and P_2P_j (j=3 to 10) have been evaluated as X_i (i=1 to 17) that act as different components of a feature vector representing the ear pattern.

The ear landmarks superauarale and subaurale have been chosen as P_1 and P_2 respectively. Thus, a 17-dimensional feature-space may be formed from ten precisely located landmarks and each ear pattern will be represented as a feature-point in that feature-space with co-ordinates X_i (i=1 to 17). Let AX_i (i=1 to 17) represent the ear pattern 'A' in such a 17-dimensional feature-space. Any other ear pattern, say, 'B' will also have a similar representation. In case the ear patterns A and B are distinguished, their representative feature-points in the feature space must be separated from each other and a numerical measure of this separation is the Euclidean distance between A and B in the 17-dimensional feature space. The squared Euclidean distance between A and B is as follows.

$$D^2 = (AX_1 - BX_1)^2 + (AX_2 - BX_2)^2 + \dots + (AX_{17} - BX_{17})^2$$

Thus, computation of the Euclidean distances for all possible pairs of the samples of ear patterns will lead to a faithful comparison procedure. The distribution of such distances for a large sample size will give a quantitative indication of the nature of variations of ear patterns amongst different persons. This will throw light on the uniqueness of human ear patterns.

However, all possible aspects of an ear pattern have not been reflected in ear features as defined. In fact, a true comparison between two ear patterns in both holistic as well as feature wise manners can be done by direct superimposition. But for a large sample size comparison by direct superimposition for each pair is obviously a formidable task. Thus a comparison by direct superimposition may be undertaken only for those ear patterns which are not well distinguished on the basis of ear features considered here.

Imaging of external ear

Bilateral profile view facial images were collected from subjects. While acquiring image, the subject was positioned at a distance of 1.10 metres from the camera with his/her head in Frankfurt horizontal plane (FH plane is a line joining orbitale and tragion is parallel to the floor). A rectangular scale (60*80 millimetres) was so affixed in front of the ear that its horizontal midline was parallel to the FH plane (Figure 1). During photography the focal plane of the camera was parallel to the plane of the rectangular scale. The camera was fixed on a tripod (Flaxzy SW-F705A) so that it could be elevated to the level of ear of the subject. To ensure least movement of the head and face a 'Chin stand' was fabricated. The stand has an attachable flat horizontal platform on which the chin of the subject rested. Profile images were acquired with Kodak Easy Share CX7330, 3.2 Mega Pixel digital cameras using 3X Optical zoom.

Interactive landmark identification

The devised programme allowed for interactive clicking with the mouse of any point on the ear image and highlights it for verification. Ten anatomical landmarks (Figure 2) were identified on each ear pattern after photogrammetric rectification. Due care was exercised to select those landmarks which were least ambiguous, easily visible in image, distributed all over the ear pattern and were located on the prominent features of ear. They are as follows:

1. Superaurale P_1,	2. Subaurale P_2,
3. Intertragica inferior P_3 ,	4. Protragion P_4,
5. Antitragus superior P_5,	6. Incisura anterior auris posterior P_6,
7. Concha superior P_7	8. Posterior most point on the antihelical curvature P_8,
9. Postaurale P_9 and	10. Lobule posterior P_{10}

The location of the above mentioned landmarks have been identified on the ear on the basis of the definition prescribed by Martin and Saller [10] (for P_1 and P_2), Farkas [11] (for P_9) and Knußmann [12] (for P_3, P_4 and P_8).

Four landmarks, antitragus superior (P_5), incisura anterior auris posterior (P_6), concha superior (P_7) and lobule posterior (P_{10}) were found suitable and defined by the author. The definitions of landmarks P_6, P_7 and P_{10} are given elsewhere [9] while antitragus superior (P_5) is defined as the tip of the antitragus (Figure 2).

Seventeen distances were computed using the ten above mentioned anatomical landmarks. With P_1 (superaurale) and P_2 (subaurale) as primary landmarks their distances from others (P_3 through P_{10}) were computed. The distances are as follows:

1. P_1P_2	2. P_1P_3	3. P_1P_4	4. P_1P_5	5. P_1P_6
6. P_1P_7	7. P_1P_8	8. P_1P_9	9. P_1P_{10}	10. P_2P_3
11. P_2P_4	12. P_2P_5	13. P_2P_6	14. P_2P_7	15. P_2P_8
16. P_2P_9	17. P_2P_{10}			

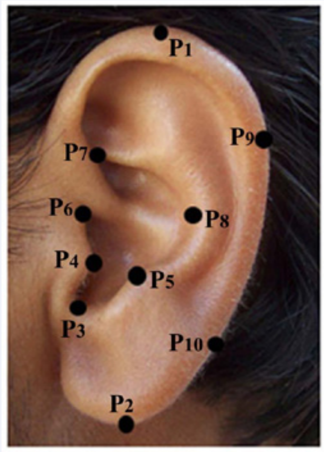

Figure 2 Anatomical landmarks of external ear.

Errors in landmark identification

It may be noted that if a particular ear pattern is repeated in a sample study, the computed distance between the feature-points of the repeated patterns will give a measure of experimental error limit and the final results should be judged on that basis. Thus independent intra and inter-observer tests were performed on ear patterns to measure the experimental error that is likely to occur while marking the location of the anatomical landmarks on an image. This also checked the objectivity/ambiguity and reliability of the set of anatomical landmarks selected for the present study [13-15]. For intra-observer study the exercise was repeated on ten ear images (5 males and 5 females) in ten sessions (i.e. F_{1-1} –F_{1-10}, . . ., F_{5-1}–F_{5-10}, M_{1-1} – M_{1-10}, . . ., M_{5-1} – M_{5-10}), with inter-session interval of 2 to 4 days (Table 1, columns 3 through 5). For each subject, 45 possible pair combinations from 10 observations could be made (e.g. F_{1-1} and F_{1-2}, F_{1-1} and F_{1-3}, . . ., F_{1-1} and F_{1-10}). In inter-observer study ten observers (students of master of anthropology) were recruited to undertake the test. Each observer was given ten images to mark the locations of the landmarks (Table 1), columns 6 through 8). The Euclidean distances between the respective feature points were estimated. The maximum intra-pair distance in 10 subjects varied from 1.9mm to 3.5mm and 3.1mm to 5.1mm. in intra- and inter-observer tests respectively. The highest value of maximum inter-pair distance was used to set the threshold limit for the present study. In other words ear patterns for which the intra-pair distance was less than 5.1mm could not be distinguished by a representation in the present 17-dimensional feature space. These ear patterns were further compared by direct superimposition technique using Symmetry Perceiving Adaptive Neuronet (SPAN) [7].

METHOD OF ANALYSIS

Independent tests were performed for each family. While judging the distance between members the Euclidian distance in feature space between the feature points was computed. The smaller the distance (quantitatively), the more the resemblance of the ear pattern with its respective member pair.

The greatest dissimilarity in ear pattern between paired

Table 1: Observer tests : Intra pair distances of ear patterns in feature space.

Subjects	Side	Max. intra pair distance (mm)	No. of paired combinations within 0-2mm	> 2mm	Max. intra pair distance (mm)	No. of paired combinations within 0-2mm	> 2mm
Intra-Observer					*Inter-Observer*		
F_1	L	2.5	43	2	4.1	42	3
F_2	L	2.9	44	1	3.9	43	2
F_3	R	3.3	44	1	**5.1**	42	3
F_4	L	**3.5**	44	1	4.9	41	4
F_5	R	2.3	44	1	4.3	40	5
M_1	R	2.6	42	3	3.6	39	6
M_2	R	2.1	44	1	3.5	43	2
M_3	L	2.8	43	2	3.4	40	5
M_4	R	1.9	45	0	3.1	42	3
M_5	L	3.2	44	1	4.1	44	1

members was represented by maximum distance and minimum intra pair distance represented the most similar ear patterns. The genetic relations which showed maximum similarity/dissimilarity in their ear form were identified. Independent analysis was conducted for two and three generation families and general and tribal population groups.

Subjects

The study was conducted in Central India covering the districts of Sagar, Raisen and Ujjain. The study covered all cross section of people (general) and few tribal (Bhil and Saura) groups. In total, images were procured from 96 families belonging to general population and 34 families from tribal groups. While finalising the data some of the members were found missing in few families, and hence were removed from the final analysis. The final sample for family study comprised of 90 and 27 families belonging to general and tribal populations respectively. Out of 90 families, 55 families included members from three generations while 35 families were restricted to two generations only. Similarly, among tribal groups 12 were three generation families and 15 families had members from two generations. Most of the families mentioned above were joint families. In total 648 members of general and 243 members of tribal families took part in the study. All the subjects were normal and healthy. None of them suffered from any auricular (congenital or traumatic) or maxillofacial deformity.

As a validation test the same study was carried out in Hamirpur district of Himachal Pradesh in North India. 33 three-generation and 18 two-generation families were photographed, out of which 32 three-generation and 16 two-generation families including 423 members finally formed the test sample.

In the present report the result of paired comparison of only left ear features in various genetic relations (except twins) is presented. The result of right ear follows similar trend. Due consent was sought from the subjects before acquiring images. The study conformed to the guidelines set by the Ethical committee of Indian Council of Medical Research, New Delhi.

In order to study the similarity/differences in ear pattern among closest genetic relations fifty three monozygotic twin pairs (identical genetic constitution) were examined. As suggested by Kings et al. [16] zygosity of the twins was assessed by questionnaire, similarity method (anthropometric measurements) and confirmed by blood group testing on the twins and their parents. Majority of the data was acquired from Mohammadpur, Umri and the adjacent areas in Northern India.

RESULTS

The study pursued two objectives, the first to test whether genetic relatives have identical ear pattern i.e. testing uniqueness. The second was a corollary of the first, identifying the genetic relations having the most dissimilar and similar ear patterns. In the uniqueness test, it is interesting to note that a negligible number (less than 0.2%, Table 2) of the paired relations fell below the threshold limit. The distribution of intra-pair distance showed a peak between 10 to 20mm distance in all the samples (Figure 3). Though intra-pair distance varied from 3.5mm to 70mm, 78% to 85% of the pairs were separated by 10 to 40mm distance and only a negligible number crossed over 50mm.

An interesting observation was made among families belonging to tribal group. The average Euclidean distance between relatives in tribal families is much smaller than general populations of Central India (10.8mm on left & 6.4mm on right ear of tribal group as against 12.1 mm on left & 18.3mm right ear of general population) and North India. This peculiar phenomena seems to point towards two possibilities,

- either generations of inbreeding (intra tribe marriage) would have resulted in more genetic similarity or
- smaller size of sample (27 families in tribes and 90 families in general population) could be the reason.

Analysis of monozygotic twins brought out certain interesting observations. The degree of similarity in the ear form of the twin pair was apparent from the small average intra pair Euclidean distance and more number of pairs falling below threshold limit (Table 3). Supporting this observation it was found that in most cases the pairs were separated from their counterpart by a narrow range of distance measuring between 5 to 20mm (Figure 4).

Table 2: Metric assessment of 'Uniqueness' of ear patterns among family members.

Sample	Sample Size (Families)	Total paired relations analysed in families	Range of average distance between pairs (mm)	Dissimilarity / Maximum intra-pair distance (mm)	Closeness/ Minimum intra-pair distance (mm)	No. of pairs below threshold level	No. of pairs above threshold level
Central India							
General	90	1699	17.769-29.78	62.218	4.583	2 (0.118%)	1697 (99.88%)
Tribal	27	683	16.049-26.839	42.389	5.79	1 (0.146%)	682 (99.85%)
Northern India	48	1593	13.689-28.058	55.552	5.569	2 (0.126%)	1591(99.45%)

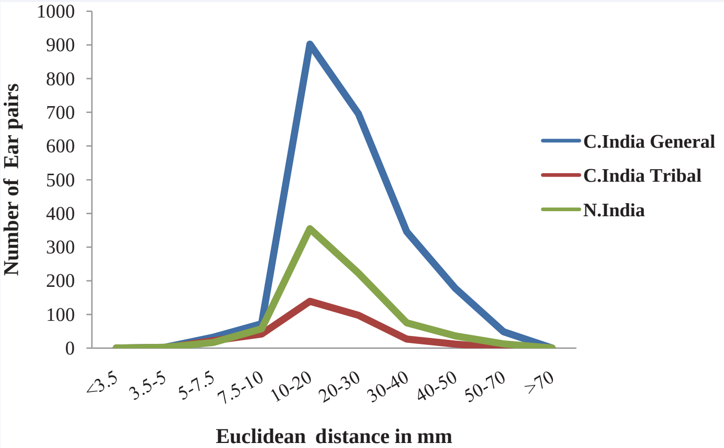

Figure 3 Distribution of intra pair Euclidean distance between left ear pairs of genetic relations in 17 dimensional feature space.

Table 3: Metric assessment of variation in ear pattern among monozygotic twins.

Side	Sample Size	Pairs analy-sed	Average intra-pair distance (mm)	Dissimilarity/ Maximum intra-pair distance (mm)	Closeness/ Minimum intra-pair distance (mm)	No. of pairs falling below threshold level	No. of pairs above threshold level
Left	106	53	10.69	22.82	2.96	2 (3.78%)	51 (96.23%)
Right	106	53	11.61	34.86	5.07	1 (1.9%)	52 (98.1%)

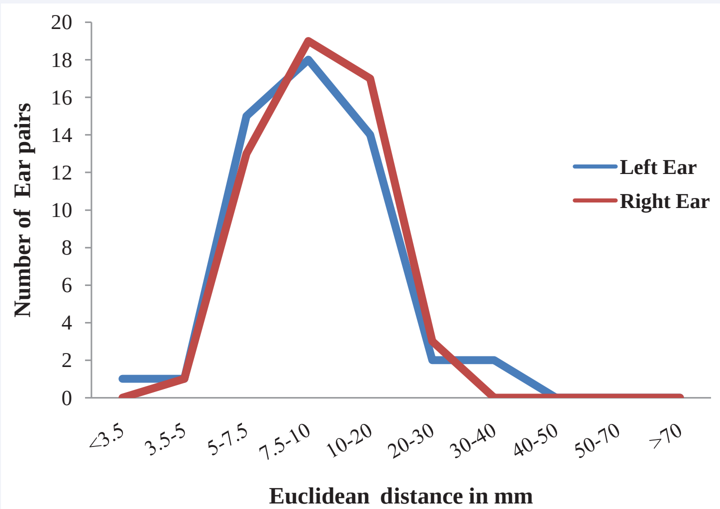

Figure 4 Distribution of intra pair Euclidean distance between ear pairs of Monozygotic twins in 17 dimensional feature space.

Superimposition of undistinguished images

As mentioned earlier for cases falling below threshold limit only a direct superimposition could give the final verdict, but conducting such a test for a large sample size was a formidable task. So having come to the conclusion that most of ears (96%-99%) in the genetic gradient are clearly distinguishable using metric assessment, the study needed to be narrowed down to confirm whether the remaining cases where pairs falling below threshold level were distinguishable or not. For these cases, a more detailed method of direct superimposition of their images was undertaken. As such, the majority of ear pattern pairs were eliminated from this final test. To acquaint one with the method of superimposition a monozygotic twin ear patterns has been described and illustrated in the following paragraphs.

Figure 5 shows the results of direct superimposition for the most closely matching left ear patterns of monozygotic twin pair. The pair (Figure 5 A&B) was separated by a Euclidean distance of 2.96mm and hence failed to cross the accepted threshold limit of intra-pair ear pattern distance. One horizontal and one vertical strip-wise composite images were reconstructed from the super imposable images produced by SPAN [17], so as to bring out the distinctions with more clarity. The prominent points of alignment and misalignment have been identified and marked on the images. The horizontal strip-wise composite (Figure 5C) showed mismatching in helical (points 1-7) and lobular borders (points 9, 10), crux of helix (point 8), at the hump of tragus (point 12) and anti tragus (point 11). The conchal border of the two ear patterns at point 13 are in complete alignment. The misalignments in the helical (points 1 to 7) and lobular borders (point 12), tragus (point 11) and anti tragus (point 10) are again depicted in vertical strip-wise comparison (Figure 5D). Also the upper conchal border (points 8, 9) shows misalignment. The inner and outer helical borders at points 13 and 14 are in complete alignment.

For identifying the genetic relation exhibiting most similar and dissimilar ear patterns, the analysis was performed separately for three and two generation families. In three-generation families the ear patterns was mostly found to be dissimilar between grandparent and grandchild (80%-92% families, Tables 4 &6). The other genetic relation parental siblings-nephew/niece also showed dissimilarity though in less number and even few families registered incidences of maximum dissimilarity in parent-child relation.

An interesting observation was made in the above analysis. The greater the genetic distance in relation, larger was the range of Euclidean distance, e.g. the Euclidean distance between grandparent-grandchild varied between 26.9 to 62.2mm (35.3mm), while parental sibling-nephew/niece relation had range between 29.5 to 49.9mm (20.4mm). The closest relation among the three i.e. parent-child had the smallest range, 16.5 to 30.5mm (16.5mm) (Table 4).

In two generation families nearly three-fourth (71%) of families had most dissimilar ears in parental sibling-nephew/niece relation; an appreciable percentage was also found in parent-child pairs and only negligible among siblings (Tables 4). Tribal families presented slightly different picture. While the dissimilarity was nearly equal in parent-child and parental sibling-nephew/niece relations, in 13% of families siblings exhibited maximum dissimilarity in ear pattern. North Indian test sample presented similar trend as tribal group except that there was no family exhibiting sibling dissimilarity (Table 6).

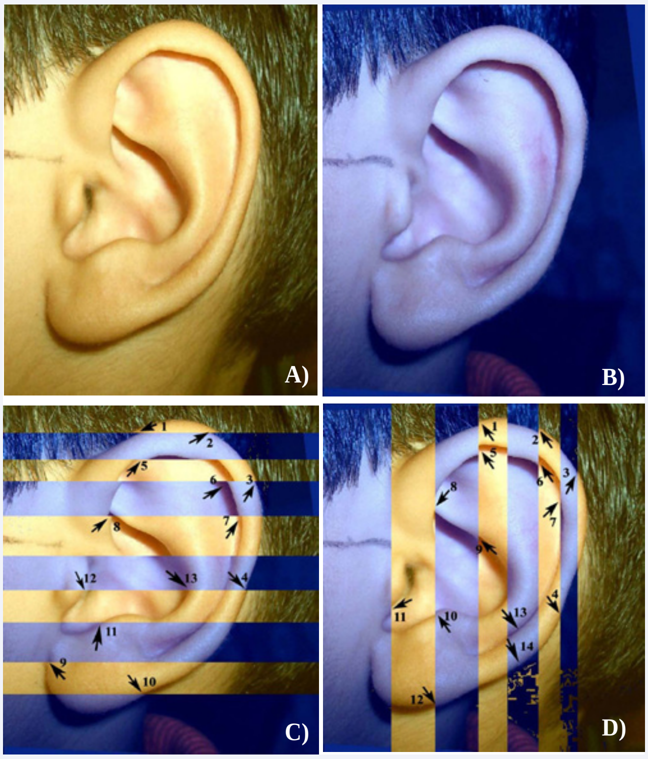

Figure 5 Superimposition of left ear patterns of monozygotic twin pair
(a) Ear pattern A,
(b) Ear pattern B,
(c) Horizontal strip-wise superimposition
(d) Vertical strip- Wise superimposition

Closeness of the ear pattern between members of family was determined by minimum Euclidean distance. Nearly in all families similar ears were found among siblings and in parent-child relations though the frequency was more common among siblings (58% to 87% of families, Table 5). This was supported by the fact that even the range of Euclidean distance between siblings was smaller than parent-child relation. 3% of the families in general population had similar ears among first cousins. In North Indian families though the trend was similar, more similar ears were found in parent-child relation.

DISCUSSION

The question of proving 'uniqueness' of forensic trait/evidence continues to be a controversial issue. On one hand professionals [18-21] claim that the issue has been neglected and never rigorously pursued by Forensic Scientists. While Page et al. [22] believe that 'uniqueness is impossible to prove, and is not anywhere near as relevant as some may claim.... There are few valid reasons to claim uniqueness, or to continue this fruitless search for what remains a philosophical ideal.'

Following the recent Court ruling [*1,2] for more rigorous

Table 4: Metric assessment of dissimilarity (maximum distance in 17 dimensional feature space) of ear pattern among family members in Central India.

Relation among family member	General population				Tribal population			
	3 Generation families		2 Generation families		3 Generation families		2 Generation families	
	No. of families	Range of maximum intra-pair distance (mm)	No. of families	Range of maximum intra-pair distance (mm)	No. of families	Range of maximum intra-pair distance (mm)	No. of families	Range of maximum intra-pair distance (mm)
Grandparent-grand child	44 (80%)	26.94-62.22	-	-	11 (91.7%)	35.43-49.13	-	-
Parent-child	5 (9.1%)	16.54-30.51	8 (22.9%)	24.09-47.54	-	-	6 (40%)	16.19-32.67
Parental sibling-Nephew/Niece	6 (10.9%)	29.54-48.97	25 (71.4%)	28.11-66.71	1 (8.3%)	19.26	7 (46.7%)	36.98-61.97
Among sibling	-	-	2 (5.7%)	27.16-33.48	-	-	2 (13.3%)	19.9-21.26

Table 5: Metric assessment of closeness (minimum distance in 17 dimensional feature space) of ear pattern among family members in Central India.

Relation among family member	General population				Tribal population			
	3 Generation families		2 Generation families		3 Generation families		2 Generation families	
	No. of families	Range of minimum distance (mm)	No. of families	Range of minimum distance (mm)	No. of families	Range of minimum distance (mm)	No. of families	Range of minimum distance (mm)
Parent-child	23 (41.8%)	6.67-16.36	13 (37.1%)	7.02-21	4 (33.3%)	6.42- 13.65	2 (13.3%)	13.59-17.45
Among cousins	-	-	1 (2.9%)	16.65	-	-	-	-
Among sibling	32 (58.2%)	4.44- 12.4	21 (60%)	4.58-15.24	8 (66.7%)	4.98-10.41	13(86.7%)	7.19- 12.09

Table 6: Validation study: Metric assessment of dissimilarity and closeness (distance in 17 dimensional feature space) of ear Pattern among family members in Northern India.

Relation among family member	Dissimilarity				Closeness			
	3 Generation families		2 Generation families		3 Generation families		2 Generation families	
	No. of families	Range of maximum distance (mm)	No. of families	Range of maximum distance (mm)	No. of families	Range of minimum distance (mm)	No. of families	Range of minimum distance (mm)
Grandparent-grand child	26 (81.2%)	27.52-69.22	-	-	-	-	-	-
Parent-child	2 (6.3%)	25.74-36.13	7 (43.8%)	15.88-22.1	18 (56.3%)	5.79-19.42	7 (43.8%)	9.35-17.83
Parental sibling-Nephew/Niece	4 (12.5%)	23.33-33.9	9 (56.2%)	19.69-43.8	-	-	-	-
Among sibling	-	-	-	-	14 (43.7%)	4.3-11.76	9 (56.2%)	4.76-10.81

admittance of forensic evidence, Scientists have undertaken empirical studies to prove the '*uniqueness*' of various traits e.g fingerprint [23], documents [24] etc. Working on the same line it was felt necessary to undertake a similar exercise on external ear too. Balding [25] claim that it is impossible to prove any human characteristic to be distinct in each individual without

[1*] **Frye v. United States** decided 1923: *Expert opinion based on a scientific technique is inadmissible unless the technique is generally accepted as reliable in the relevant scientific community.*

[2*] **Daubert, et al. v. Merrell Dow Pharmaceuticals** *decided June 28, 1993: To admit expert opinion based on scientific technique in court, the technique needs to be established based on testing, peer review, error rates, and acceptability.*

Checking every individual. But undertaking such formidable tasks of testing every living person on earth is not feasible. So a large representative sample can work as substitute data [19] for the test as a small step towards investigating uniqueness.

Though few attempts have been made to prove uniqueness of ear pattern in the unrelated individuals in population [9,26] no empirical study was ever undertaken to investigate the same in genetic relations. Every morphological structure is monitored by its genetic constitution and external ear is no exception. Hence it was thought necessary to investigate into whether the similarity in ear structure would preclude its uniqueness in genetic relatives.

During analysis when various genetic relations are compared on the basis of metric assessment all but a negligible number (0.2%) of the pairs were found to be distinct. The observation in fact is quite interesting as the intra pair members are genetically related (sharing some common genes depending on the degree of closeness in the relation). Though the metric analysis may not completely assess the morphology of ear structure but it seems the array of measurements so selected in the study could bring out the differences even in closely related member pair. The direct superimposition technique could complete the remaining task of distinguishing every person from the other.

Investigating closeness/dissimilarity in genetic relations

The role of genes in determining ear structure was claimed as early as 1854 when Armede Joux commented that 'there is no other organ that can identify a father and son, authenticity of descent or unfaithfulness of a wife' He made his comments in "Gazette des hopitaux de Paris 1854" [3]. On the other hand Iannarelli [2] with experience of analyzing more than 10,000 ears found all ears are distinguishable from each other. He observed closeness of ear structure among family members but did not provide any empirical data in support of his observations. When ear pattern was examined for its suitability as a tool for establishing personal identification, it was felt necessary to investigate into/resolve the above controversy.

In three generation families, the grandparent-grandchild relation takes the lead in dissimilarity (Tables 4,6) though few cases of parental sibling-nephew/niece and parent-child were also found. The parental sib-nephew/niece relation is high on the dissimilarity scale in two generation families (Table 4,6). It is followed by parent-child relation and few cases of sibling relations also exhibit dissimilarity. So it can be inferred that the second degree relations (sharing 25% of genes) are most distant in likeness of ear structure in two generation families. The complete absence of cousins who are genetically most distant of all the relations considered is quite intriguing and remains unexplained.

When the closeness/likeness in ear structure was investigated among family members, the siblings show maximum similarity (58%-67% in 3 generation and 60%-87% in 2 generation families). A strong parent-child bondage as witnessed in ear structure is seen in 13% to 42% families. The occurrence of similar ear structure among cousins in 3% of families again remains unexplained. But one may say that it is difficult to furnish any scientific reason for the aberrant/unusual behavior of the 'cousin' category in similarity/ dissimilarity test.

Based on his study of ear photograph of parents and their children Iannarelli [2] commented that '*there was no appreciable similarity of ear configuration between the child and the parent. Though ...., there was some likeness of ear form between children of the same parent.*' The outcome of the present study also finds that the siblings exhibited maximum closeness in ear structure though parent and child too exhibit similarity to some extent as empirically proved above. It is pertinent to mention here that the closeness in the ear structure among siblings did not preclude the uniqueness of individual ear.

CONCLUSIONS

The present study undertook to test the 'uniqueness' on sample of genetically related individuals. None of the ear patterns of any person was found to be identical in morphology when compared with his/her genetic relatives, not even monozygotic twins. Hence, one can presume that, external ear pattern could be used as a '*unique*' feature for personal identification.

Though the conclusions drawn are based on Indian population sample, the results suggest that similar outcome may be expected from other populations as well.

Limitations of the study

The ear has nearly coplanar/flattened structure. With vertical or horizontal rotation of head the shape of various ear features may not be visible in the image for a faithful analysis. So it is necessary to undertake the imaging of external ear by the standard method suggested in the study.

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