Morphologic and Morphometric Analysis of External Ear: A Preliminary Study on Monozygotic Twins for Personal Identification

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ABSTRACT

Introduction: Monozygotic twins have remained a mystery for researchers since their discovery in the early twentieth century. As a result of the same set of genetic materials, monozygotic twins share almost similar morphological features. Hence, distinguishing monozygotic twins based on their physical appearance remains a formidable challenge for criminal investigators. The ear is one of the unique features of the human body.

Aims: Previous researchers explored numerous features of the external ear for personal identification in different populations but no studies are available on the comparative analysis of identical twin’s external ear. The present study investigates the morphologic and morphometric features of monozygotic twins.

Methodology: Samples under the study were collected randomly from 37 pairs of monozygotic twins from central India. Different morphological features were recorded by keeping the previous literature as references. Vernier calliper is used to measure the length and breadth of the ear.

Result: Oval shape and round-shaped ears are most and least frequent, respectively. Arch and triangular-shaped ear lobules have the highest and lowest frequency, respectively. The length and breadth of the right and left ears of the twin pairs have depicted a very high correlation. Observed results of the present study revealed precisely that selected features of the external ear of the corresponding sides in both individuals of each twin pair have no significant difference.

Conclusion: This study concluded that the ears of monozygotic twins are morphologically identical. Although they have some minor morphometric variations, they can potentially distinguish them from each other.

Key Words: External ear, Monozygotic twins, Morphological features, Morphometric variation, Criminal investigation Personal identification

INTRODUCTION

Twins and issues inextricably related to them are consistently capturing severe attention towards the scientific research community from the last century. In the late 19th century J Matthews, a Scottish obstetrician first recognized two specific types of twins. But, Francis Galton was the first person to coin the distinct possibility of applying twins for the comparison of hereditary and environmental contributions.1,2 Twins are typically classified into two specific categories i.e., monozygotic (Identical: naturally divided from a single fertilized egg) and dizygotic (Fraternal: formed by two independently fertilized eggs by two different sperms).3,5 Monozygotic twins are virtually identical because they universally share the same chromosomal sequence4 except for very few rare mutations.3 Individualization of monozygotic twins without modern genetic sequencing techniques in common remain a critical task as they naturally possess almost identical phenotypic appearance.5,7 They easily hide or swap their distinctive identity by exploiting the key advantage of striking similarity to voluntarily commit crimes. The distinct population of monozygotic twins is gradually increasing around the globe and including India in the last few decades. In 2013, a high frequency of twins was observed during a health camp in Kodinhi, a village in Kerala, by the members of Yenepoya Dental College, Mangalore, Karnataka. A further survey revealed that there was a ratio of 35 twins out of every 1,000 individuals.3 Personal identification plays a vital
role in the field of forensic sciences. The modern Biometric system is most reliable to positively establish the personal identity based on the morphological and behavioural characteristics of an individual.\textsuperscript{8,9} Ear biometrics is undoubtedly an emerging technique in the field of personal identification. The science of human identification from ear impressions or prints is called Forensic Otoscopy.\textsuperscript{10} It possesses several overwhelming advantages as a biometric feature due to its stability (mostly invariable during various facial expressions and poses) and peculiar structure. The remarkable peculiarity of the external ear comprises several anatomical features i.e., auricle shape, earlobe shape (Lobule), attachment of the earlobe (Lobule), helix shape and tragus shape.\textsuperscript{10,11} Figure 1 demonstrates the various morphological characteristics of the ear. The oily and waxy surface of the external ear (Pinna or auricle) is responsible for the Ear prints on a contrasting surface.\textsuperscript{10,11} Ear prints are found in cases where a criminal try to overhear the private conversation behind the other side of the door or window.\textsuperscript{10} The first direct involvement of the ear in a forensic issue dated in 1910. In that case, the distinctive identity of a prisoner was scientifically proved with the help of the remarkable peculiarity of his ear.\textsuperscript{11} It can also be a vital feature for personal identification in the case of the mutilated body or in a circumstance where the alleged suspect has gone through plastic surgery. In recent years, crimes often been recorded in overhead CCTV cameras. A considerable chance of excellent visibility of a person’s pinna in raw CCTV footage can be properly investigated and identified with a forensic expert.\textsuperscript{10} In previous studies on ear patterns or prints, researchers proved its uniqueness in every person and no two individuals can have the same set of morphological characteristics on the external ear.\textsuperscript{10-19} Preliminary research was also conducted on the variations of external ear prints of monozygotic twins.\textsuperscript{20} But, no studies are present on the morphologic and morphometric similarities and dissimilarities of identical twins’ external ears. A present study is a preliminary approach aimed at the comprehensive examination of the morphological features and differences of external ears among monozygotic twins.

**METHODOLOGY**

The present study has been conducted to carefully analyse the morphology and morphometry of the external ear of monozygotic twins. A total of 37 pairs (74 subjects) of monoyzygotic twins aged between 5 to 40 years was examined in this study. All the samples were randomly collected from three different regions of central India i.e., Jhansi, Bhopal, and Shivpuri. A valid written informed consent was obtained from the parents of the subjects under the age of 18 years as well as from the adult subjects before the study. All the subjects were properly informed about the specific purpose and fundamental nature of the experiment.

**RESULTS**

The present study was carefully conducted to study the morphological and morphometric features of the external ear of monozygotic twins. The study shows that all the selected morphological features were the same in a twin pair. Figures 4.a and 4.b show the right ear of two individuals of a twin pair. Although the length and breadth of each ear slightly differ between the individuals of a twin pair.

The distribution of auricle shape among all the twin pairs shows that the oval-shaped ear is the most frequent with 43.24% and the round-shaped ear is the least frequent with 10.81%. Table 2 and figure 4. demonstrate the fre-
frequency distribution of all the auricle shapes. Figure 5. a to 5.d shows the different auricle shapes found on the present samples of monozygotic twins. Arch shaped ear lobule has the highest frequency of 45.94% among all the twin pairs and a triangular lobule has the lowest frequency of 8.10%. Table 3 and figure 4. b demonstrate the frequency of all the ear lobule shapes. The attached ear lobule is more frequent than the free lobule among the twin pairs. Table 4 and figure 4. c demonstrate the distribution of the attached and free lobule percentage among the twins. The calculated ‘R’ values between the length of right ears of twin pairs and breadth of right ears of twin pairs were 0.99 and 0.95 respectively. The calculated ‘R’ values between the length of left ears of twin pairs and breadth of left ears of twin pairs were 0.98 and 0.95 respectively. The calculated ‘R’ value between the length of the right and left ears of an individual was 0.99. The calculated ‘R’ value between the breadth of the right and left ears of an individual was 0.97. A positive Euclidean distance was found between the same ears of every twin pair under the study. Table 5 shows all the Euclidean distances between the vector values of right and left ears in all the twin pairs. Figures 6.a and 6b show the euclidean distances between the right ears and left ears of twin pair 2 respectively. The lowest and highest Euclidean distances between the vector values of the left ear among all the twin pairs are 0.1 and 0.36056 respectively. The average Euclidean distances between the vector values of the right ears and vector values of left ears among all the twin pairs are 0.19674 and 0.22868 respectively.

DISCUSSION

The obtained results of the present study show that morphological characteristics of the external ear are identical between the individuals of a twin pair. The appropriate size of each ear is marginally different to every individual of a twin pair which is proof of the uniqueness. Several previous studies indicated the differences between structure and morphological characteristics of the ear between individuals for forensic purposes. 21-24

The present study shows that 43.24% of twin pairs have an oval-shaped auricle. The oval shape is found to be the most frequent among all. Similar results were properly obtained in the comprehensive studies by Krishan et al. (36%—40% in males and 39—46% in females) 10, 11, Iannarelli (40-46%) 25 and Singh and Purkait (47-52%). 26 Van der Lugt 26 found 68.75 and 65% oval shape in Dutch males and American males. Yadav et al. 27 equally determined a similar frequency of oval shapes (61.33%) in a North Indian population. Round shaped ears found in 10.81% of twin pairs in the present study. Krishan et al. 10 found 18 - 20% and 15 – 18.4% round-shaped ears in males and females of Himachal Pradesh, India respectively. Singh and Purkait 24 found a 23-59% round ear in the central Indian population, and Van der Lugt 26 found a round-shaped ear in 3% Dutch males and 2% American males. Yadav et al. 27 observed 14.66% round ear in a North Indian population. The rectangular auricle is present in 24.32% of twins in the present study. Krishan et al. 10 observed a dissimilar frequency of rectangular auricle (2– 8.9% in males and 7– 9.2% in females) in his similar study to the study on Dutch males 26 (9.1%). On the contrary, only 3% of Americans invariably showed rectangular auricle shape 26. Yadav et al. 27 observed a 12.66% rectangular ear in his study. 21.62% among all the twin pairs have a triangular auricle. Krishan et al. 10 found less percentage of the triangular auricle in their study (6 – 8.9% in males and 10 – 12.9% in females). Only 8.33% of triangular ears were observed in the study of Yadav et al. 27. Arch shaped lobule is the most frequent with 45.94% and a triangular lobule is the least frequent with 8.10% in the present study. Krishan et al. 10 also found arched shaped lobule as the most frequent with 61-74.4% in males and 59-72.4% in females. The frequency of triangular shape shows a similar percentage in the study of Krishan et al. 10 with 5-8.9% in males and 5-10.4% in females. In the study of Yadav et al. 27 round-shaped lobules were most frequent (43%) and a triangular lobule was least frequent (4.33%). Lobule attachment is categorized as attached and free. The attached lobule is more frequent (56.75%) than the detached lobule (43.25%) among twin pairs. Krishan et al. 10 classified lobule attachment in three categories i.e., attached, partially attached and free. They found 45-53.3% attached and 9-41.1% free lobule in males and 49-56.3% attached and 8-33.3% free lobule in females. 19 Singh and Purkait 24 found only 19-24% attached and 53.71-62% free ear lobule in the Central Indian population, which is similar to the present study. Farkas 28 observed only 2-3% attached ear lobule in the American Population. Gable 29 found a relatively similar percentage of attached earlobe (25-40%) in American Whites and Dunkers in comparison to the present study. Bhoomik 30 found 77-78% free lobule in Brahmin and Muslim males. Table 6 summarizes the frequency of morphological characters of previous studies and the present study. Yadav et al. observed free ear lobe (65.66%) more frequent than the attached ones (34.33%). The correlation between the length of the same ear and breadth of the same ear in twin pairs and length of the opposite ear in every individual from all the twin pairs were calculated to find out the interrelation between the ear morphometries of monozygotic twins. The results indicated an exceptionally positive correlation between all the selected parameters (0.99-0.97). Taura et al. 31 found a moderate positive correlation between the right ear length and left ear length (0.89) and right ear width and left ear width (0.72). In the present study, Euclidean distances between the two-dimensional vectors of the same ear in two individuals of a twin pair were used to find out any possible quantitative variability between them. The positive Euclidean distances between the same ears of every twin pair constitute empirical proof of the difference between them. The vectors were
generated from the values of length and breadth. Purkait and Singh performed a similar analytical procedure in their study based on Euclidean distances between multiple vectors generated from the distances between different landmarks on the external ear.

CONCLUSION

The present study represents an attempt to analyze the morphology of the external ear of identical twin pairs and find out the differences between them. The study satisfactorily concludes that both the individuals of an identical twin pair share the consistent morphological feature on the external ear, but the size of each ear has a minor difference. The frequency distribution of different features shows similarity with the results of a few previous studies on different Indian and world populations. The oval-shaped auricle is the most frequent and the round-shaped is the least frequent among all the twin pairs under the present study. The study also revealed the highest frequency of arched type ear lobe and lowest frequency of triangular ear lobe among all twin pairs. The attached ear lobe is more common than the free ear lobe in all the twin pairs. The specific Statistical results showed that the length of the same ear in a twin pair is more correlated than their breadths. The correlation between the length and breadth of the right and left ear of each individual in a twin pair is also highly correlated. The difference of size between the same ears of two individuals in a twin pair was established by Euclidean distance. A certain distance was noted between the two-dimensional vectors of the same ear in both individuals of every twin pair. This study will help to distinguish between monozygotic twins based on their morphometric differences. The present study is a preliminary experimental approach towards the comparison of monozygotic twins’ ears that consists of limited morphological and morphometric features. Further expansion of the study is under progress in the laboratory of our institute and the results of the experiments will be communicated soon.

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Conflict of Interest

The authors declare no conflict of interest.

Authors Contribution

Yash Baroniya: Conceptualization, performed experiments and wrote the draft of the manuscript.

Taurus Das: Analyzed the data and wrote the draft of the manuscript.

Abhimanyu Harshney: wrote the draft of the manuscript.

Dr. Ankit Srivastava: Conceptualization, edited the draft manuscript.

REFERENCES

1. Burbridge D, Galton F. Twins heredity and social class. Bri J Heal Sci. 2001; 34: 323-40.
2. Hall JG, Twinning. The Lancet. 2003; 362: 735-743.
3. Jodalli P, Panchmal GS, Sonde L and Somaraj V. Village of Twins: A Mystery. JOADMS 2016; 2: 3-6.
4. Mayo O. Early Research on Human Genetics Using the Twin Method: Who Invented the Method? Twin Res Hum Genet. 2009; 12: 237-45.
5. Wang LF, Yang Y, Zhang NX, Quan XL and Wu YM. The tri-allelic pattern of short tandem repeats identifies the murderer among monozygotic twins and suggests an embryonic mutation-al origin. Forensic Sci. Int. Genet. 2015; 16: 239-45.
6. Weber-Lehman J, Schilling E, Gradi G, Richter DC, Wiehler J and Rolf B. Finding the needle in the haystack: Differentiating “identical” twins in paternity testing and forensics by ultra-deep next-generation sequencing. Forensic Sci. Int. Genet. 2014; 9: 42-46.
7. Krawczak M, Budowle B, Weber Lehmann J and Rolf B. Distinguishing genetically between the germlines of male monozygotic twins. PLOS Genetics. 2018; 14: 1-9
8. Purkait R and Singh P. A test of the individuality of human external ear pattern: Its application in the field of personal identification. Forensic Sci. Int. 2008; 178: 112-18.
9. Jain AK, Ross A and Prabhakar S. An introduction to biometric recognition. IEEETransCircuits Syst Video Technol. 2004; 14: 4-20.
10. Krishan K, Kanchan T and Thakur S. A study of morphological variations of the human ear for its applications in personal identification. Egypt. J Forensic Sci. 2019; 9: 1-11.
11. Krishan K, Kanchan T. Identification: Prints - Ear. J. Forensic Leg. Med. 2016; 3: 74-80.
12. Kumar A, Wu C. Automated human identification using ear imaging. Pattern Recognit. 2011; 45: 956-68.
13. Annapurna K, Sadiq MAK and Malathy C. Fusion of the shape of the ear and tragus - A unique feature extraction method for the ear authentication system. Expert Syst. Appl. 2015; 42: 649-656.
14. Chattopadhyay PK and Bhaitia S. Morphological examination of the ear: A study of an Indian population. Leg. Med. 2009; 11: 190-93.
15. Rubio O, Galera V and Alonso MC. Morphological variability of the earlobe in a Spanish population sample. Homo. 2017; 68: 222-235.
16. Purkait R. External ear: an analysis of its uniqueness. Egypt J Forensic Sci. 2016; 6: 99-107.
17. Verma P, Sandhu HK, Verma KG, Goyal S, Sudan M, and Ladgstra A. Morphological variations, and biometrics of ear: an aid to personal identification. J Con Drug Res. 2016; 10: 138-42.
18. Alexander KS, Stott DJ, Sivakumar B and Kang N. A morphometric study of the human ear. Plast Reconstr Aesthe. Surg. 2011; 64: 41-47.
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19. Kearney B. Variations of the external ear in an Australian population for identification. *A thesis submitted to the University of Adelaide, in partial fulfilment for the award of Bachelor of Science (Honors)* 2003. http://www.eleceng.adelaide.edu.au/personal/dabbott/tamanshud/kearney_oct2003.pdf.

20. Twins Lynn Meijerman, Andrew Thean, et al. Individualization of Earprints Variation in Prints of Monozygotic. *Forensic Sci Med Pathol.* 2006; 2: 39-49.

21. Cameriere R., DeAngelis D. and Ferrante L. Ear identification: a pilot study. *J. Forensic Sci.* 2011; 56: 1010-1014.

22. Guyomarc’h P. and Stephan CN. The validity of ear prediction guidelines used in facial approximation. *J Forensic Sci.* 2012; 57: 1427-1441.

23. Swift B., Rutty GN. The human ear: its role in forensic practice. *J. Forensic Sci.* 2003; 48: 153-160.

24. Singh P., Purkait R. Observations of external ear—an Indian study. *Homo* 2009; 60: 461-72.

25. Iannarelli AV. Ear identification, Forensic identification series. Paramount Publishing Company, Fremont; 1989.

26. Van der Lught C. Ear Identification. *Elsevier, Bedrijfsinformatie’s Gravenhage, Amsterdam;* 2001.

27. Yadav MM, Nigam K., Srivastava A and Yadav VK. A Preliminary Study on Frequency Distribution & Inheritance Pattern of Different Characteristics of Ear among Population of Moth Region of Jhansi District. *Int J Res Ass Engg Tech.* 2017; 5: 236-41.

28. Farkas LG. Anthropometry of normal and anomalous ears. *Clin Plast Surg.* 1978; 5: 401-412.

29. Gable NE. A racial study of the Fijians. In: Anthropological records. *University of California Press, Berkeley and Los Angeles;* 1958.

30. Bhowmik DC. Ear lobe attachment in Uttar Pradesh. *Man India* 1971; 51: 157-161.

31. Taura MG, Adamu LH and Modibbo MH. External ear anthropometry among Hausas of Nigeria: the search of sexual dimorphism and correlations. *World J Med Sci.* 2013; 1: 91-95.

Table 1: Description of different auricle shapes.

| Shape       | Description                                      |
|-------------|--------------------------------------------------|
| Oval        | The width at the tragus level is less than half of the auricle. |
| Round       | The width at the tragus level is more than half of the length of the auricle |
| Triangular  | Helix is wider than the lobule                   |
| Rectangular | The width of the helix and lobule are approximately the same |

Table 2: Distribution of different ear shapes based on auricle.

| Different auricle Shapes | Twin Pair | Percentage (%) |
|--------------------------|-----------|----------------|
| ROUND                    | 4         | 10.81          |
| OVAL                     | 16        | 43.24          |
| RECTANGULAR              | 9         | 24.32          |
| TRIANGULAR               | 8         | 21.62          |

Table 3: Distribution of different ear shapes based on lobule.

| Different Lobule Shapes | Twin Pair | Percentage (%) |
|-------------------------|-----------|----------------|
| ROUND                   | 12        | 32.43          |
| ARCHED                  | 17        | 45.94          |
| RECTANGULAR             | 5         | 13.51          |
| TRIANGULAR              | 3         | 8.1            |

Table 4: Distribution of ear types based on the attachment of lobule.

| Lobule Attachment | Twin pair | Percentage (%) |
|-------------------|-----------|----------------|
| ATTACHED          | 21        | 56.75          |
| FREE              | 16        | 43.25          |

Table 5: The euclidian distances between the two-dimensional vectors of right and left ears of twin pairs.

| S. No. of Twin pairs | DRtp     | DLtp     |
|----------------------|----------|----------|
| 1                    | 0.2      | 0.223608 |
| 2                    | 0.31623  | 0.1414214|
| 3                    | 0.1414214| 0.2236068|
| 4                    | 0.1      | 0.1414214|
| 5                    | 0.2      | 0.3162278|
Table 5: (Continued)

| Study | Population          | Auricle Shape | Lobule Shape | Lobule Attachment |
|-------|---------------------|---------------|--------------|-------------------|
| Yash et al. (2019) | Himachal Pradesh, India | Oval (40-46.09%) | Rectangular (2.2-9.2%) | Attached (50-58.6%) |

N.B: DRtp: Euclidian distance between the vector of right ears of a twin pair.
DLtp: Euclidian distance between the vector of left ears of a twin pair.

Table 6: Summarized table showing the comparative frequency of morphological characters between previous studies and the present study.

| Study | Population          | Auricle Shape | Lobule Shape | Lobule Attachment |
|-------|---------------------|---------------|--------------|-------------------|
| Krishan et al. (2019) | Himachal Pradesh, India | Oval (40-46.09%) | Rectangular (2.2-9.2%) | Attached (50-58.6%) |
Table 6: (Continued)

| Study                        | Population         | Auricle Shape | Lobule Shape | Lobule Attachment |
|------------------------------|--------------------|---------------|--------------|------------------|
| Singh and Pukait (2009)      | Central India      | Oval (47.17-51.72%) | Round (6.57-17.14%) | Free (53.71-62%) Partially free (16-17.44%) |
| Verma et al. (2016)          | Northeast and North-west India | Oval (40%) | Round (5%) | Attached (65%) Free (35%) |
| Chatto-padhyay and Bhatia (2009) | Lucknow, U.P, India | Medium (46.49%) | Short and Broad (26.31) | Free (80.70) Absent (1.75) |
| Van der Lugt (2001)          | Dutch and American | Oval (68.7-65%) | Round (2-3%) | - |
| Yadav et al. (2017)          | Central India      | Oval (61.33%) | Polygonal (2.66%) | Detached (65.66%) Attached (34.33%) |
| Present Study                | Central India      | Oval (43.24%) | Round (10.81%) | Triangular (8.1%) Attached (56.75%) Detached (43.25%) |

Figure 1: Different morphological features of the external ear.

Figure 2a: Measurement of a. length and breadth of external ear.

Figure 2b: Measurement of external ear by vernier caliper

Figure 3: a and b: Right ears of two individuals of a twin pair.
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Figure 4a: Distribution of auricle shapes among the ear samples of monozygotic twins in the present study.

Figure 4b: Distribution of lobule shapes among the ear samples of monozygotic twins in the present study.

Figure 4c: Distribution of lobule attachments among the ear samples of monozygotic twins in the present study.

Figure 5: Different auricle shapes found in twins; a. oval b. round c. rectangular d. triangular.

Figure 6a: Euclidean distances between the right ears of a twin pair.

Figure 6b: Euclidean distances between the left ears of a twin pair.