Naif Arab University for Security Sciences
Arab Journal of Forensic Sciences and Forensic Medicine
المجلة العربية لعلوم الأدلة الجنائية والطب الشرعي
https://journals.nauss.edu.sa/index.php/AJFSFM

A Study of External Ear Morphological Variation in Central Indian Population for Genealogical Purposes

دراسة التباين في شكل الأذن الخارجية لسكان وسط الهند لأغراض التعرف على الأنساب

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Received 25 Nov. 2022; Accepted 25 Jun. 2023; Available Online 30 Jun. 2023

Abstract

The study aims to determine the inheritance pattern of different morphological features of the external ear in three generations from five states of India to assess the similarities between P1, F1, and F2 generations. The research involved 62 families, each with 124 grandparents P1 (62 males and 62 females), 124 parents F1 (62 males and 62 females), and 82 F2 generations (53 males and 29 females), a total of 330 samples, ranging in age from 1 to 75 years. All the samples were collected from five different states of India: Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar and Maharashtra. The external ear is distinct in terms of shape, size, and orientation. Its morphological variation aids in the determination of genetic inheritance. Fisher exact test was performed to assess the inter-generation association of morphological characteristics of the ear. Similar to other body characteristics, it is established that the auricle shape, lobule shape, and ear lobule attachment are also inherited. The associations of ear traits in three generations were studied, and the results might be used in forensic identification.

Keywords: Forensic science, external ear, morphological variation, morphological features, genetic inheritance, paternity and maternity.

المستخلص

تهدف الدراسة إلى تحديد نمط وراثة السمات الشكلية المختلفة للأذن الخارجية في ثلاثة أجيال من خمس ولايات في الهند لتقييم أوجه التشابه بين الأجيال P1 و F1 و F2. وشمل البحث 62 عائلة، لكل منها 124 جداً (62) P1 ذكرًا و(62) أنثى، و 124 أبًا من الجيل الأول (F1 (62) ذكرًا و (62) أنثى، و 82 جيلًا من الجيل الثاني (53) F2 ذكرًا و 29 أنثى)، أي ما مجموعه 330 عينة، تراوحت في العمر من 1 إلى 75 سنة. تم جمع جميع العينات من خمس ولايات مختلفة في الهند: أوتار براديش وماديا براديش وراجستان وبيهار ومهاراشترا. والأذن الخارجية متميزة من حيث الشكل والحجم والاتجاه. يساعد تباينها من حيث الشكل في تحديد الوراثة الجينية. وقد تم إجراء اختبار فيشر الدقيق لتقييم الارتباط بين الأجيال في خصائص شكل الأذن الخارجية. على غرار خصائص الجسم الأخرى، وثبت أن شكل الأذن وشكل الفصيص ومرفق فصيص الأذن موروث أيضًا. وتمت دراسة ارتباطات سمات الأذن في ثلاثة أجيال، ويمكن استخدام النتائج لأغراض جنائية مثل تحديد الهوية.

الكلمات المفتاحية: علوم الأدلة الجنائية، الأذن الخارجية، التباين المورفولوجي، السمات الشكلية، الوراثة الجينية، الأبوة والأمومة.

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doi: 10.26735/KEXU1412

1. Introduction

Biometrics, voice recognition, shoe prints, face detection and DNA are some of the traits used in a forensic investigation for criminal identification [1]. The human ear provides hearing as its main function, but in forensic science, its shape and measurements are taken into account for biometric analysis and identification. The study of the ear is called earology (otomorphology) [11]. Earology was first defined by Johan Casper Lavater. Furthermore, Haken Jorgensen developed a scheme for documenting the morphological characteristics of the external ear in Denmark around the turn of the century, employing ear parameters as well as perpetrator ear castings [2, 10].Alphonse Bertillon has been using the external ear as an anthropometric tool for measuring and identifying people since the late 1800s [6]. Personal identification from the external ear is a relatively new and unique field. External ears can be used to identify both living and deceased persons [12]. Several genetic variables indeed affect different aspects of the external ear, and it is expected that these traits will behave similarly in people who are genetically related to one another. Therefore, it was thought crucial to assess the level of similarity between generations. Using a comparative analysis of the human ear's anatomy, ear biometrics can positively identify a person [13]. Using a comparative analysis of the human ear's anatomy, ear biometrics can positively identify a person [2]. The human ear is an excellent trait for personal identification because of its consistency and individuality in individuals from birth to old age [14]. At the time of conception, every gene is contributed by one parent. The information needed for the cell to put together proteins, which result in specific physical features, is stored in these original genes (allele) [17]. In humans, the auricle appears for the first time at six weeks of gestation. While it is generally reported that in humans, the hillocks of His form at the junction of the first and second pharyngeal arches [19].

The external ear architecture is connected to the crucial neck tissues, it is significant from a clinical and surgical standpoint. These results imply that this research will be useful for identifying dysmorphic traits in various chromosomal abnormalities, which will be useful in plastic and reconstructive surgery. The auricle has been used by medical professionals to discriminate against people of colour. Psychologists and criminologists have also used it as a sign of underlying disease [16]. The main purpose of using ear morphology and the variances that its physical structure produces is to identify offenders. Regarding criminal conduct, the external ear's physical structure is used to help identify living individuals. Several cases show this kind of evidence, and several have resulted in convictions based on the examination of the feature [2]. It is known that different aspects of the external ear are influenced by several genetic factors and are predicted to behave similarly in genetically related individuals. Even genetically related individuals have highly diverse ear characteristics, making them a potential 'Soft Biometric' characteristic for personal identification research [13]. The form, size, and unique traits of his ears may help identify the deceased, along with other identifying features of the human body, in some circumstances where the dead body is retrieved in a dismembered or mutilated condition [1]. For automated human identification and verification systems, ear biometrics is a good option. The primary use of this technology is in criminal investigations. Forensic sciences have long relied on ear characteristics for identification [18].

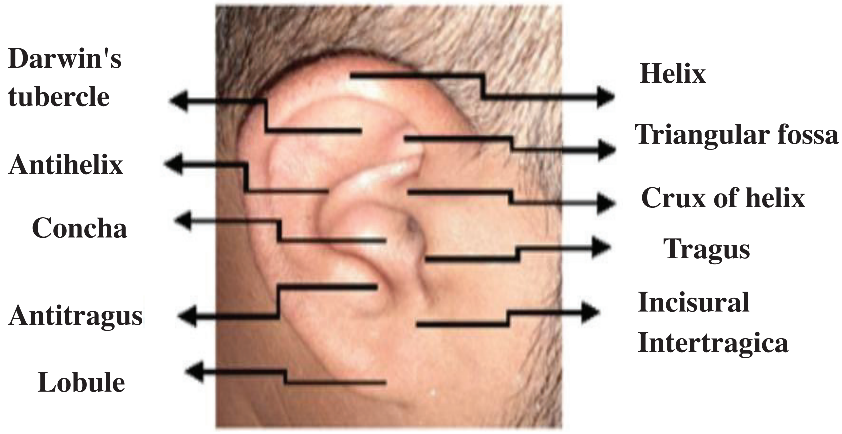

Figure 1 - *shows the structure of human external ear morphology.*

2. External Ear Morphology

Fig. 1 shows the structure of human external ear morphology. The auricle is the exterior component of the human external ear, whose lateral surface is irregularly concave, faces forward slightly, and has multiple eminences and depressions [3]. The ear is among the most significant characteristics of the face, usually projecting from the skull. The auricle is a network of yellow elastic fibrocartilage covered by a very thin skin layer firmly attached to the perichondrium [15].

Auricle shape: Auricles are classified based on their general shapes and fundamental dimensions which are visible in Fig. 2 [4, 5]. The width of the impression at the tragus level is less than half the length of the oval-shaped ear auricle. At the tragus level, the width of the impression surpasses 1/2 of its length, and both side borders of the auricle are rounded to a similar degree as the round auricle. The impression has a triangular shape, with a greater region in the top helix and a narrowing towards the lobule. The impression is shaped like a rhomb, with the upper helix's and lobule's widths roughly equal.

Lobule Shape: Fig. 3 shows different types of lobules. A lobule is a soft, fleshy portion of the ear that hangs from the lower edge. Only the lobule of the external ear is not supported by the cartilage [6]. Lobules are classified into four types based on their shape: rounded, arched, triangular, and Rectangular.

Lobule attachment: The condition of the lobule attachment to the cheek has been classified into two categories [7]. The lobule attached to the cheek is the attached ear lobule attachment. The lobule that hangs freely from the cheek without being attached is the detached ear lobule attachment, Fig. 4.

Inheritance is the process of transferring biological qualities from parents to kids via genes. A morphogenetic trait is one in which an organism's genetic makeup shows phenotypically as an observable attribute, such as ear lobule attachment. Geneticists can forecast the likelihood of offspring receiving specific features from their parents by studying inheritance patterns [8, 9].

The purpose of this study is to observe the pattern of inheritance for various morphological characteristics of the external ear, such as the shape

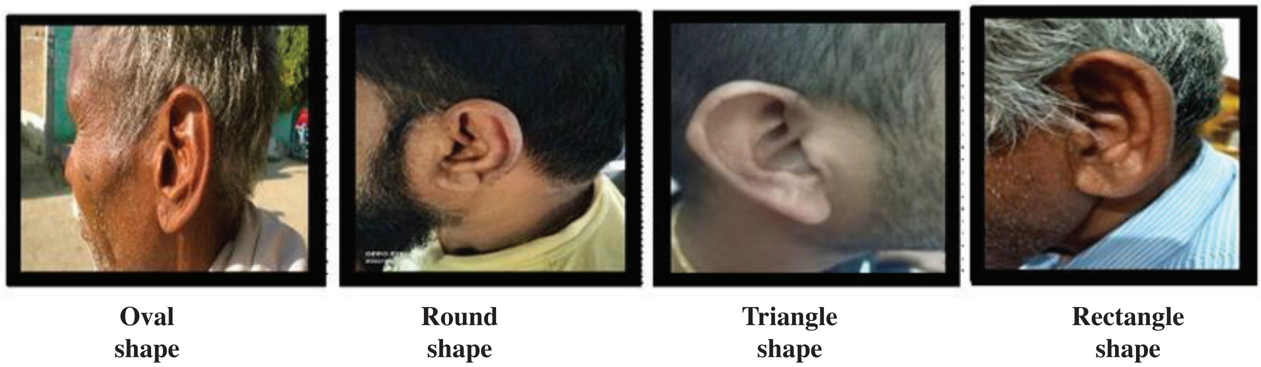

Figure 2- *Shows the different auricle shapes based on their fundamental dimensions.*

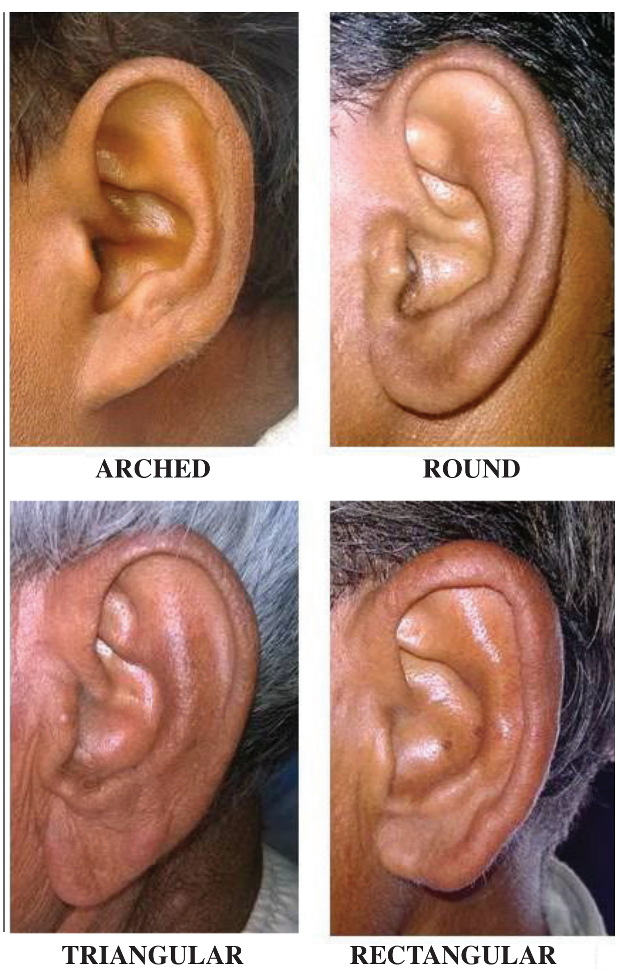

Figure 3- *Shows different types of lobules.*

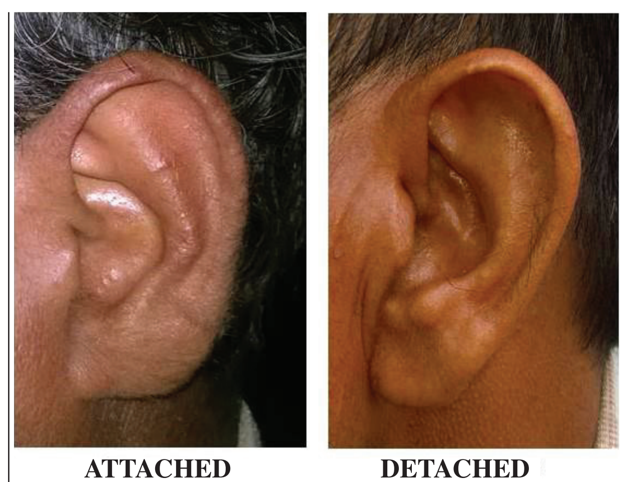

Figure 4- *Earlobe attachment*

of the auricle, the shape of the lobule, and the attachment of the ear lobule, and to compare the P1, F1, and F2 generations from the above-mentioned structures (Figure 5).

3. Material

This study was carried out on 330 Indians belonging to central India. These 330 Indians were from 62 families, each with 124 grandparents P1 (62 males and 62 females), 124 parents F1 (62 males and 62 females), and 82 F2 generations (53 males and 29 females). All the selected participants were normal and healthy and their families were not ge-

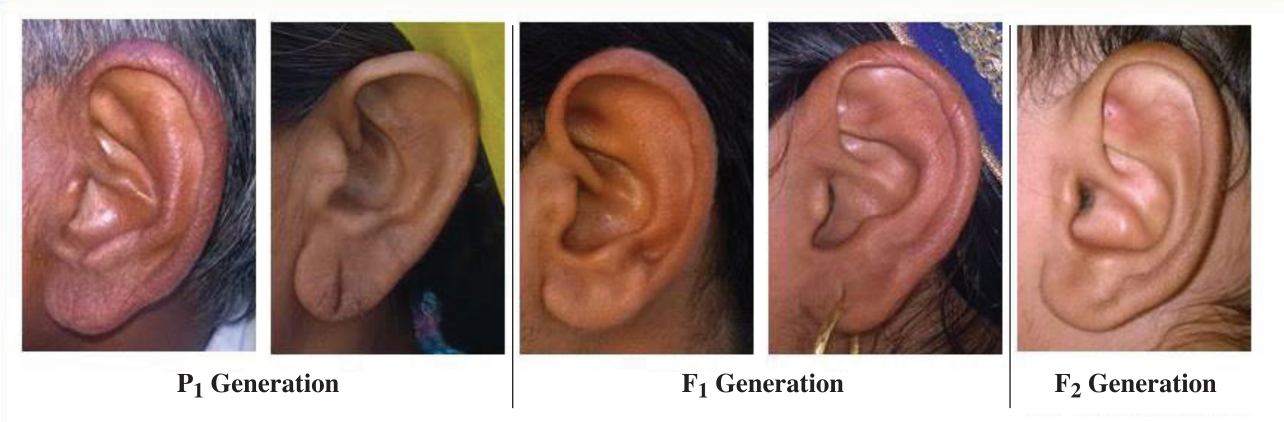

Figure 5- *Parental combination of auricle in three generations i.e. P1, F1 and F2.*

netically interconnected. Participants were informed of the nature of the study, and their written consent was acquired. According to the code of Ethics, the research was conducted.

4. Methodology

Simple random sampling was used to acquire the data. Before starting sample collection, the subjects were instructed to sit straight on a chair. The methodology consists of following steps:

Image Capture: The smartphone directly captured the ear image in JPEG format. All of the photographs were taken with extreme caution. In the situation of poor vision, additional lighting was utilized. Those with torn ear lobules, fire-burned or gunshot ear lobules, or ear lobules creases were not taken. The saree, scarf, cap, and hair were removed to achieve a clear and complete ear image.

Image analysis: After capturing the ear image, they were transferred to a laptop and classified into families and arranged according to generation starting with the grandfather, grandmother, father, mother, and children. The ratio of auricle height to width was used to categorise them and the shape of the lobule and ear lobule attachment was used to categorise them. A transparent graph sheet was placed on the laptop screen, and the height and width ratio of the ear were observed manually without any visual alterations.

Feature extraction: After categorizing the image, the features of interest were retrieved from the external ear. Auricle shape, lobule shape, and lobule condition data were recorded in a sample format in a sequence of the grandparents (P1), parents (F1) and grandchildren (F2) generations.

Statistical Analysis: The data were analyzed using R-Studio 2022.12.0 Build 353 (Posit Software, PBC) In order to determine the association between P1 to F1, F1 to F2, and P1 to F2 generations, inferential statistics, the Fisher exact test was performed to the data of the aforementioned morphological parameters of the external ear.

5. Results

The Fisher exact test was used to assess the relationship between morphological characteristics of external ear in three generations. We stated null hypothesis as there is no association of morphological features of ear in two generations while alternate hypothesis stated that there is an association of morphological features of the ear in two generations.

The Fisher exact test comparing variables of different auricle shape combinations in P1 generations to different auricle shapes in their offspring F1 generations revealed a p-value of 0.0001347 with a level of significance of 0.05. The test indicates the nonrandom association of auricle shapes between P1 and F1 generations (Table 1).

The p-value of 0.000155 with a significance level of 0.05 revealed the nonrandom association between different auricle shapes of F1 and F2 generations (Table 2). Similar results were seen in Table 3, where a nonrandom relationship of auricle shapes combination between P1 and F2 generations was observed with a p-value of 0.00327 and a significance level of 0.05. It is evident from p-value of 0.0001347 with a significance level of 0.05 that different lobule combinations in P1 generations and lobule shapes in F1 generations are non-randomly associated (Table 4). The Fisher test indicates the nonrandom association between lobule shape among F1 and F2 generations by the p-value of 0.000155 with a significance level 0.05 (Table 5). The p-value of 0.00327 with a significance level of 0.05 was revealed by Fisher's exact test comparing the variables lobule shape combinations in P1 generations and lobule shapes in F2 generations. It indicates the nonrandom relationship between these two variables (Table 6). Table 7 shows the ear lobule attachment combination in P1 generation and F1 generations. The Fisher exact test revealed the p-value of $9.365^{\wedge-06}$ with a significance level of 0.05. It indicates the nonrandom association between these two variables. Table 8 shows the ear lobule attachment combinations in F1 and F2 generations. Fisher exact test revealed a p-value of $7.246^{\wedge-05}$ with a significance level of 0.05. It indicates the nonrandom association between ear lobule attachment of F1 and F2 generations. Fisher exact test reveals a p-value of 0.0005118 with a significance level of 0.05 for the data of ear lobule attachment among P1 and F2 generations. It denotes a nonrandom relationship of ear lobule attachment between P1 and F2 generations; Table 9.

6. Discussion

The study has been conducted to determine the inheritance pattern of various external ear features such as auricle shape, lobule shape, and ear lobule attachment in three generations: grandparents P1, parents F1, and grandchildren F2. The Fisher exact test is performed to determine any nonrandom relation between P1 to F1, F1 to F2 and P1 to F2 generations of aforesaid features of the ear. It is evident from observations of the study that auricle shape, lobule shape and lobule attachment condition in all three generations are associated with each other.

Ordu et al. studied the inheritance pattern of ear lobule attachment between parents and their offspring [8]. They used the chi-square test to calculate the level of significance and results for the parental combination of mother attached & father detached and both detached were significant in his study. Very similar results were also observed for the same combinations in a study conducted by Yadav et al. in 2017 [7]. Results for a parental combination of both attached ear lobules were not significant in both previous studies. Moreover, Yadav et al. reported no significant results for the parental combination of mother detached and father attached, and their offspring for ear lobule attachment.

The findings of the current study for ear lobule attachment indicate a strong association between

Table 1- *Grandparent P1 auricle shape combination and auricle shapes in their offspring F1 generation.*

Grandparent auricle shape combination P1	No. of families	No. of offspring F1				Total
		Oval	Round	Triangle	Rectangle	
Oval-oval	38	37	0	1	0	38
Oval-round	2	1	1	0	0	2
Oval-rectangle	2	2	0	0	0	2
Oval-triangle	3	3	0	0	0	3
Round-oval	6	6	0	0	0	6
Round-round	1	0	1	0	0	1
Round-triangle	1	0	1	0	0	1
Rectangle- oval	2	2	0	0	0	2
rectangle-triangle	2	0	0	1	1	2
Triangle-oval	4	4	0	0	0	4
Triangle-triangle	1	0	0	1	0	1
Total	**62**	**55**	**3**	**3**	**1**	**62**

Table 2- *F1 generation auricle shape combination and auricle shapes of their offspring F2 generation.*

Parent auricle shape combination F1	No. of families	No. of offspring F2				Total
		Oval	Round	Rectangle	Triangle	
Oval-oval	46	51	12	0	0	63
Oval-round	3	2	1	0	0	3
Oval-rectangle	1	0	0	1	0	1
Oval-triangle	2	3	0	0	0	3
Round-oval	3	2	3	0	0	5
Round-round	1	0	1	0	0	1
Rectangle-triangle	1	0	0	0	1	1
Triangle-oval	3	3	0	0	0	3
Triangle-round	1	0	1	0	0	1
Triangle-triangle	1	0	0	0	1	1
Total	**62**	**61**	**18**	**1**	**2**	**82**

Table 3- *Grandparent P1 auricle shape combination and their F2 generation grandchildren's auricle shapes*

Grandparent auricle shape combination P1	No. of families	No. of grandchildren F2				Total
		Oval	Round	Triangle	Rectangle	
Oval-oval	38	42	11	0	0	53
Oval-round	2	1	1	0	0	2
Oval-rectangle	2	3	0	0	0	3
Oval-triangle	3	4	0	0	0	4
Round-oval	6	2	4	0	1	7
Round-round	1	0	1	0	0	1
Round-triangle	1	1	1	0	0	2
Rectangle- oval	2	3	0	0	0	3
Rectangle-triangle	2	1	0	1	0	2
Triangle-oval	4	4	0	0	0	4
Triangle-triangle	1	0	0	1	0	1
Triangle-triangle	1	0	0	0	1	1
Total	**62**	**61**	**18**	**2**	**1**	**82**

Table 4- *F1 generation grandparent lobule shape combination and lobule shapes in F2 offspring.*

Parent lobule shape combination F1	No. of families	No. of offspring F2				Total
		Arched	Round	Rectangle	Triangle	
Arched-arched	46	51	12	0	0	63
Arched-round	3	2	1	0	0	3
Arched-rectangle	1	0	0	1	0	1
Arched-triangle	2	3	0	0	0	3
Round-arched	3	2	3	0	0	5
Round-round	1	0	1	0	0	1
Rectangle-triangle	1	0	0	0	1	1
Triangle-arched	3	3	0	0	0	3
Triangle-round	1	0	1	0	0	1
Triangle-triangle	1	0	0	0	1	1
Total	**62**	**61**	**18**	**1**	**2**	**82**

Table 5- *P1 generation grandparent lobule shape combination and lobule shapes in F1 offspring.*

Grandparent Lobule shape combination P1	No. of families	No. of offspring F1				Total
		Arched	Round	Triangle	Rectangle	
Oval-oval	38	37	0	1	0	38
Oval-round	2	1	1	0	0	2
Oval-rectangle	2	2	0	0	0	2
Oval-triangle	3	3	0	0	0	3
Round-oval	6	6	0	0	0	6
Round-round	1	0	1	0	0	1
Round-triangle	1	0	1	0	0	1
Rectangle- oval	2	2	0	0	0	2
Rectangle-triangle	2	0	0	1	1	2
Triangle-oval	4	4	0	0	0	4
Triangle-triangle	1	0	0	1	0	1
Total	**62**	**55**	**3**	**3**	**1**	**62**

Table 6- *P1 grandparent lobule shape combination and lobule shapes in their grandchildren F2 generation*

Grandparent Lobule shape combination P1	No. of families	No. of offspring F2				Total
		Arched	Round	Triangle	Rectangle	
Arched-arched	38	42	11	0	0	53
Arched-round	2	1	1	0	0	2
Arched-rectangle	2	3	0	0	0	3
Arched-triangle	3	4	0	0	0	4
Round-arched	6	2	4	0	1	7
Round-round	1	0	1	0	0	1
Round-triangle	1	1	1	0	0	2
Rectangle- arched	2	3	0	0	0	3
Rectangle-triangle	2	1	0	1	0	2
Triangle-arched	4	4	0	0	0	4
Triangle-triangle	1	0	0	1	0	1
Total	**62**	**61**	**18**	**2**	**1**	**82**

Table 7- *P1 grandparent ear lobe attachment combination and their F1 offspring*

Grandparent ear lobe attachment combination P1	No. of families	No. of offspring F1		Total
		Attached	Detached	
Attached-detached	14	7	7	14
Detached-attached	8	7	1	8
Both attached	8	7	1	8
Both Detached	32	5	27	32
Total	**62**	**26**	**36**	**62**

Table 8- *F1 parent ear lobe attachment combination and their offspring F2*

Parental ear lobe attachment Combination F1	No. of families	No. of offspring F2		Total
		Attached	Detached	
Attached-detached	12	5	12	17
Detached-attached	9	5	5	10
Both attached	14	17	2	19
Both detached	27	30	6	36
Total	**62**	**57**	**25**	**82**

Table 9- *P1 grandparent ear lobe attachment combination and their F2 grandchildren*

Grandparent ear lobe attachment combination P1	No. of families	No. of grandchildren F2		Total
		Attached	Detached	
Attached-detached	14	7	12	19
Detached-attached	8	5	8	13
Both attached	8	8	0	8
Both detached	32	10	32	42
Total	**62**	**30**	**52**	**82**

three generations. These observations support the findings of previously conducted studies to a large extent. Previous studies were limited to trace inheritance of one auricular feature i.e. ear lobule attachment in two generations while the current study is expanded to three auricular features in three generations and results were impressive. Results strongly suggested the association between the three generations.

7. Conclusion

The outer ear has been the most unique feature of the face. The basic morphological features of the external ear such as auricle shape, lobule shape and ear lobule attachment were taken into account in the current study. It can be concluded that there were non-random associations based on the auricle shape, lobule shape and ear lobule attachment combination in three generations from P1 to F1, F1 to F2 and P1 to F2. Like other body characteristics, auricle shape, lobule shape, and ear lobule attachment of the ear are inherited. This kind of research data will be useful for genetic analysis and predicting the traits of offspring. It can connect a child to his or her grandparents and parents in some cases, such as newborn baby identification, paternity and maternity disputes, prisoner identification, excluding the falsely accused, intentional mutilation and dismemberment, identification from side-angle photos and CCTV footage, explosions or other mass disasters, and other disputed cases.

Conflicts of interest

The authors declare no conflicts of interest.

Source of funding

The authors received no financial support for the research, authorship or publication of this paper.

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