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Research Paper

Personal Identification Based on Morphological Features of Ears Among the Uttarakhand Region of India

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Abstract

The external ear, particularly the pinna, is a crucial physical trait that may aid in personal identification in criminal investigations. Oil on the ear can deposit its impression on surfaces mobile phone screens, glass windows. The ear morphology can be affected by geographical regions. The current study aims to look into variations in ear morphology and analyse ear impressions to have better understanding of their significance in personal identification. The study involved 100 participants, aged between 15 - 30 years from Ramnagar area, Nainital district, Uttarakhand state, northern India. The morphological features such as shape of the ear, size, earlobe shape, concha size, attachment of the earlobe was studied. The ear prints were recorded using ink method and Photographs. Further, the ear impressions were analysed using Image J software to measure data such as ear length, ear breadth, earlobe length, earlobe breadth, concha length, concha breadth. The findings showed that oval shaped ears are common among males and round shaped ears in females with other shapes like rectangle and triangle also present. Similarly, the most common ear lobe shape was square in males and tongue shaped in females. Females had slightly larger averages of ear length and width than males. Significant differences were found between males and females right ear length (p-value =0.05) and right concha length(p-value=0.01). The study contributed to existing research by highlighting the variability in ear morphology among Uttarakhand Region of India. It further emphasizes the need of understanding and analysing these differences in personal identification.

Keywords: Ear morphology, ear prints, personal identification, forensic science, North Indian population, ear variations.

1. Introduction

The external ear is an important instrument in personal identification since it has numerous morphological traits that aid in forensic investigations. Personal identification is the process of determining the identities of people involved in criminal cases based on physiological traits [1]. The ear prints appear as a useful tool, providing a 2-D replica of the human external ear upon contact with surfaces [2]. The distinct morphological characteristics of ear prints serve as key indicators, tying suspects to criminal crimes [3]. This involves examining ear prints found at crime scenes, such as on doors and windows, which can be taken and developed as a tool for identification

[4]. The external ear consists of the outer and inner ears. The pinna is a skin-covered flap in the outer ear region, typically positioned on the side of the head. Oil on the external ear aids in accurately detecting the ear. If the suspect is unknown in such circumstances, the latent prints can be matched to a database including prints retrieved from the crime scene [2]. The study of ear structure, known as otoscopy or earology, has drawn interest not just from forensic scientists but also from anthropologists, plastic surgeons, and physicians due to its importance in a wide range of professions [5]. Hirschi was the first to demonstrate the significance of ear prints for personal identification in the field of forensics [2]. Some pioneering studies by researchers, such as Iannarelli's first study, selected ten thousand human ears at random in California and measured twelve distances from certain locations on the ears, demonstrating the uniqueness of the anatomical features of the human external ear [6]. If we trace the history of ears and ear prints, we will come across Darwin's findings, which captured the scientific world's attention, leading to the ear [7]. Darwin studied primates, focusing on the ear. He noticed a shrinking primitive ear corner, referred to as the 'tubercle of Darwin' [1].

The morphological characteristics of the external ear play a crucial role in Disaster Victim Identification (DVI).

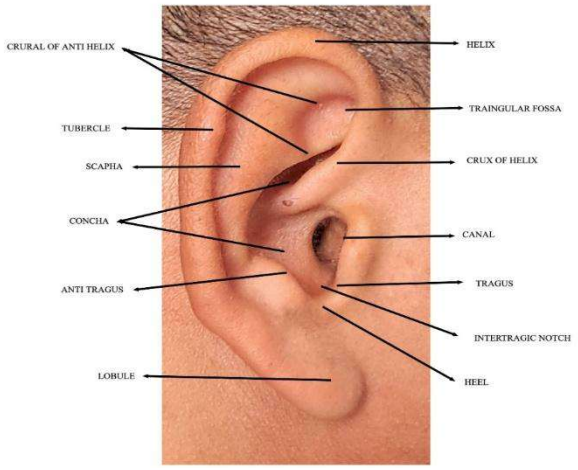

Fig.1: Shows the morphology and different parts of the ear.

Veerappan, a notorious sandalwood smuggler, was identified by the Special Task Force in India in 2004, through an examination of his ear morphology [3]. The external ear develops significantly, with evident features appearing as early as the 38th day of fetal development. On the 56th day, the ear takes on its defined position, and on the 70th day, the external ear shape is recognized [8]. The predominance of human pinna size after development emphasizes its usefulness in forensic scenarios [9]. Piercings and other changes to the earlobe, however feasible, have no major impact on the diagnostic traits required for identification [7]. The anatomical features of the human external ear vary among different individuals [10]. The external ear has significant variations in form, size, contour, and depression, making it a distinguishing trait for identification [11]. The human ear is well-known for its peculiarity and is among the most noticeable facial features [3]. The key morphological features to be researched are size, shape, moles, earlobe, tragus, anti-tragus, helix, and antihelix [12]. Taking photographs helps in making exact measurements of ear dimensions possible, increasing their utility in forensic investigations [12]. Despite potential variations caused by deliberate modifications or disease, the physical features of the human external ear are typically stable, facilitating personal identification [4]. However, some traits can be changed purposefully through piercings or alterations, while others may be caused by disease, but these changes have little effect on the diagnostic features of the human external ear [2]. Climate can have an impact on the physical properties of human ears. However, environmental factors such as migration and the period since the print was left to when it is lifted may have an indirect effect on ear identification. Human ears form throughout fetal development and are relatively stable throughout life unless subjected to severe trauma or pathological circumstances [12]. Variations in the genetic histories of different populations can impact the ear's structure, size, and characteristics. Geographically unique ear characteristics may originate from genetic variability among populations. The climate, which includes

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factors like humidity and temperature influences ear shape, with colder climates having ears that are larger and more shaped like those in warmer climates. Environmental adaptations and cultural customs also impact ear shape over time.[10]. The current research aims to look into variations in ear morphology and analyse ear impressions to have a better understanding of their significance in personal identification.

2. Materials and Method:

100 participants, aged 15 - 30 years from the Ramnagar area in Nainital district, Uttarakhand state, northern India were selected. Individuals with physical abnormalities of the ear were excluded from the study. Random sampling was used to ensure a representative distribution among the stated age and gender groups. Local community centres, educational institutions, and public areas were approached to recruit individuals. Individuals were provided with information about the research study's aims and methods. Before participation, each volunteer was provided written informed consent. Instruments that were used for data collection included a ruler, vernier calliper, fingerprint ink (ivory black), glass slab, and roller. Two techniques were used to record ear prints: (1) Ink and (2) Photographs. Ensured that the ear and the surrounding area were cleaned and dried to facilitate the transfer of ink and obtain accurate prints. Fingerprint ink was applied evenly onto a clean glass slab using a roller. This ensures uniform coverage of ink on the slab's surface. The ear was placed against the inked surface of the glass slab. The pressure was applied evenly to ensure that the ink transfers uniformly onto the ear's surface. As the pressure was applied, ink was transferred from the glass slab onto the ear, creating a clear impression of the ear's morphology. For getting the print, the inked ear was carefully lifted from the slab and placed onto an A4 sheet or another suitable surface. Ensured that the inked ear made full contact with the paper to transfer the print accurately. Once the print was obtained, the characteristics presented in the ear print were studied as mentioned in Fig.2. For taking photographs, the subject was positioned in a shadow-free area to obtain clear image of the ear. The mobile camera was set up at an appropriate distance, approximately 1 meter away from the individual, to get a detailed image of the ear. Ensured that the subject's ear was visible and positioned properly within the mobile camera's frame. Once the photographs were captured, they were transferred to a computer or any digital device for further analysis using ImageJ software. This information was stored digitally for further analysis as given in Fig.3. Digital images can be of great importance when the physical prints cannot be recorded. The ear impressions were analysed using ImageJTM software for measurements of data. This software is used for image processing and analysis, which makes it easier to examine the morphological features of the ear for personal identification and investigating variations in these features. This software measures area, min and max of selection or entire image. Measures lengths and angles.

Fig. 2: Shows the ear impression taken by the ink method.

The following morphological characteristics were examined in the Ear impressions:

(1) Ear length: The distance between the base of the earlobe to the top of the helix.

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(2) Ear breadth: This is the width of the ear, commonly measured from the outside edge of the helix on one side to the outer edge of the helix on the opposite side, at the widest point of the pinna.

(3) Earlobe length: The earlobe's length, measured from the attachment site to the ear's lowest point.

(4) Earlobe breadth: The width of the earlobe, usually measured at its broadest point.

(5) Concha length: The distance measured along the concha, the ear's bowl-shaped cavity that is adjacent to the ear canal.

(6) Concha breadth: The concha's width, usually measured at its broadest point.

(7) Ear shape: The overall structure of the ear, which might include round, oval, triangular, or rectangular features.

(8) Earlobe form: The earlobe's shape, which might include square, triangular, arched, or tongue-shaped features.

(9) Earlobe attachment: This refers to whether the earlobe is fixed to the side of the head or, in the case of a free-hanging earlobe, if it is detached from the head [3, 10]. Fig. 4, 5, and 6 demonstrate the morphological characteristics of the ear.

Fig.3 shows the ear sample taken by the photographic method.

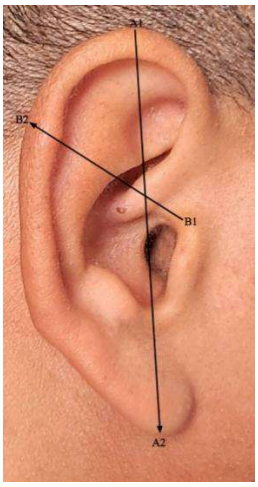

Fig.4 Ear length and breadth.

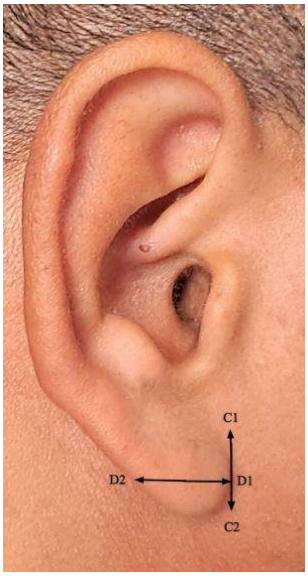

Fig. 5 Earlobe length and breadth.

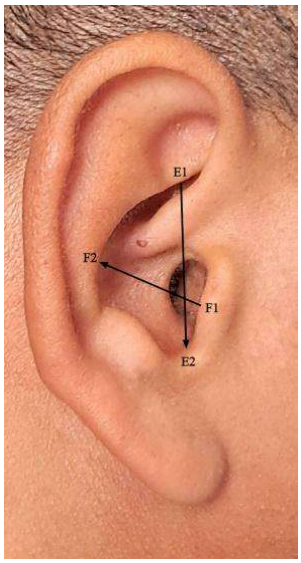

Fig.6 Concha length and breadth.

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3. Results:

The results show an average ear length of 5.27 cm, while the average width of the ear was 2.813 cm. A previous study by Verma [3] shows the average ear length was approximately 6.42 cm, and the average ear width was approximately 3.53 cm. Similarly, the average ear lobe length was 0.646 cm, and the average ear lobe width was approximately 1.464 cm. And the average concha length was approximately 2.139 cm, while the average concha width was approximately 1.296 cm.

The distribution of ear shapes for both the ears among the male individuals was observed and result shows total of 65 oval shapes, followed by 20 round, 11 rectangle, 4 triangle Fig. 7. Oval-shape of the ear was observed to be most common with 65%, Round shape of the ear was 20%, Rectangle was 11%, Triangle shape of the ear was least common with 4%. Previous study Krishan [10] shows the oval shape more commonly seen with 40 % in the left ear and 40 % in right ear, so the average of both ear shapes was approximately 40% in both ears with oval shape.

The distribution of ear lobe shapes for both the ears among the male individuals was observed and result shows total of 25 arched shapes ears were observed, followed by 38 squares, 35 tongue, 2 triangles Fig. 9. Arched shapes of the ear were observed to be 25%, Square shape of the ear was more common with 38%, Tongue shape was 35%, Triangle shape of the ear was least common with 2%. Previous study Krishan [10] shows that the arched shapes were commonly seen with 67.8% in the left and 74.4% in the right ear, so the average of both ear lobe shapes was approximately 71.1%.

The distribution of ear lobe attachment for both ears among male individuals was observed, and result shows a total of 37 free ear lobe attachments, 41 partially attached, and 22 attached ears Fig. 11. Free ear lobe attachment was observed to be 37%, partially attached was 41%, and attached was least common with 22%. Previous study Krishan [10] shows the attached ear lobe attachment to be commonly seen with 50% in left ear and 53.3% in the right ear, so the average of both the ear lobe attachment was approximately 51.65%.

The average ear length was 5.612 cm, and average width was 2.982 cm in female samples, and the average ear lobe length was approximately 0.662 cm, while the average ear lobe width was approximately 1.556 cm. And the concha length was approximately 2.256 cm, while the average concha width was approximately 1.439 cm.

The distribution of ear shapes for both the ears of females was observed, and result shows total of 34 oval shapes ears were observed, followed by 47 round, 16 rectangle, 3 triangle Fig. 13. Oval-shape of the ear was observed to be 34%, Round shape of the ear was most common with 47%, Rectangle was 16%, Triangle shape of the ear was least common with 3%. Previous study Krishan [10] shows the oval shape more commonly seen with 44.8 % in the left ear and 46 % in the right ear, so the average of both ear shapes was approximately 45.4% in both ears with oval shape.

The distribution of ear lobe shapes for both the ears of females was observed, and result shows a total of 26 arched shapes ears were observed, followed by 35 squares, and 39 tongues. No triangle shape was observed in females Fig. 14. Arched shapes of the ear were 26%, Square shapes of the ear were 35%, Tongue shape was 39%. Previous study Krishan [10] shows the arched shapes were commonly seen with 67.8% in the left ear and 72.4% in the right ear, so the average of both ear lobe shapes was approximately 70.1%.

The distribution of ear lobe attachment for both the ears of females was observed, and result shows a total of 48 free ear lobe attachments, 20 partially attached, and 32 attached ears were observed Fig. 15.

Free ear lobe attachment was observed to be more common, with 48%, partially attached was the least common, with 20%, and attached was 32%. Previous study Krishan [10] shows the attached ear lobe

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attachment to be commonly seen with 56.3% in left ear and 56.8% in right ear, so the average of both the ear lobe attachment was approximately 51.55%.

Findings also indicated the significant differences between males' and females' ear characteristics, such as right ear length with a significant difference showing p-value of 0.05 and right concha length with a significant difference showing p-value of 0.01 Table 1.

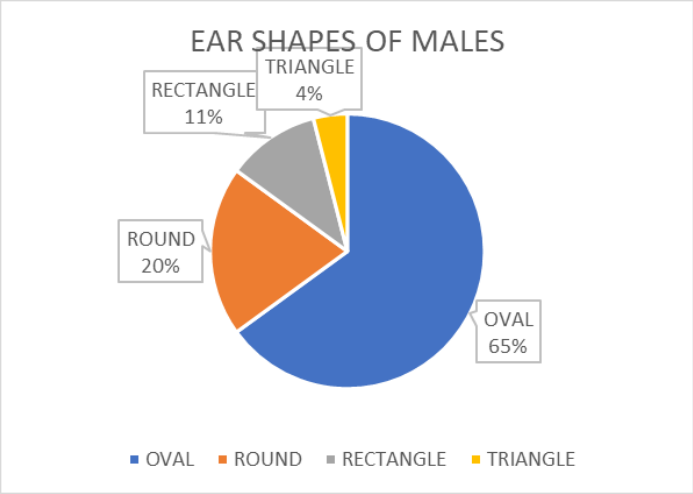

Fig. 7. The pie chart shows the distribution of ear shapes in male samples.

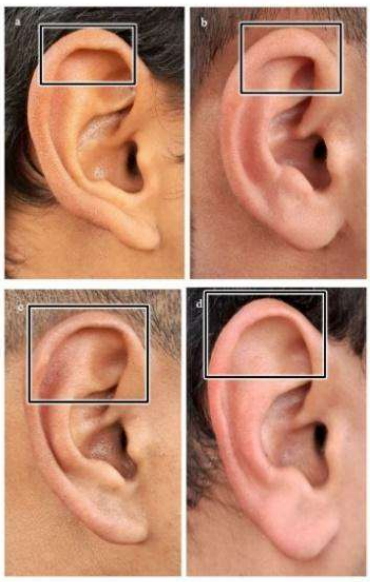

Fig. 8. Photograph showing different ear shapes: (a) rectangle, (b) triangle, (c) round, (d) oval.

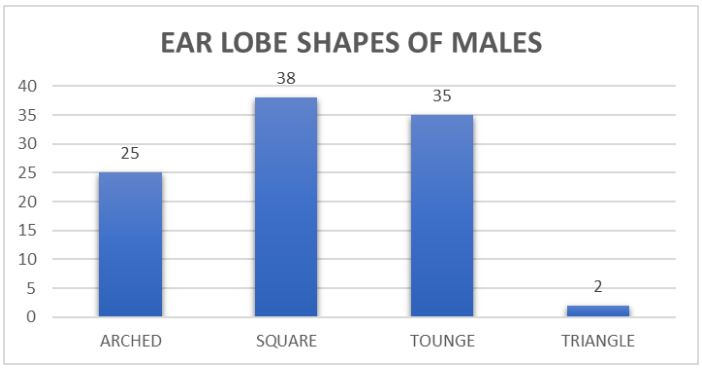

Fig. 9: Shows the distribution of earlobe shapes in male samples.

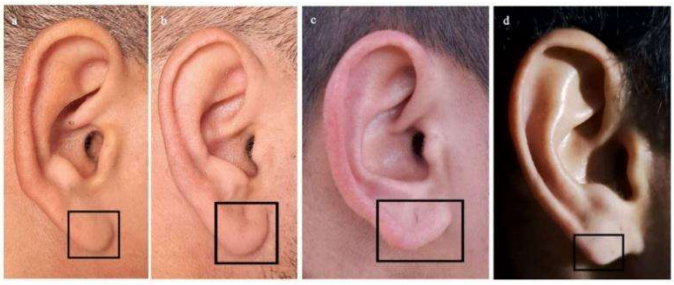

Fig. 10. Photograph showing different earlobe shapes: (a) arched, (b) tongue, (c) square, (d) triangle.

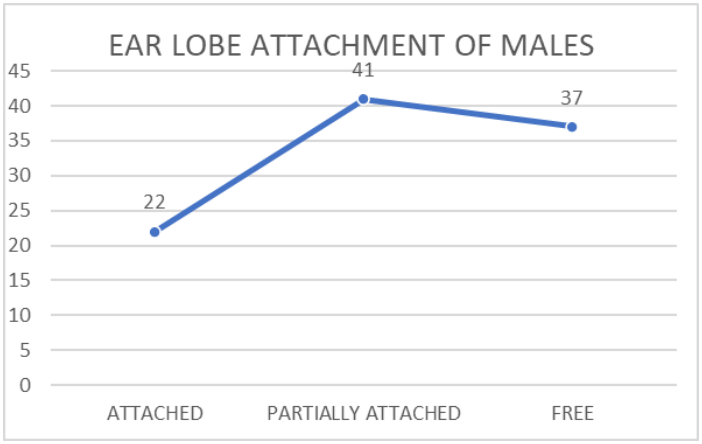

Fig. 11: Shows the distribution of earlobe attachment in male samples.

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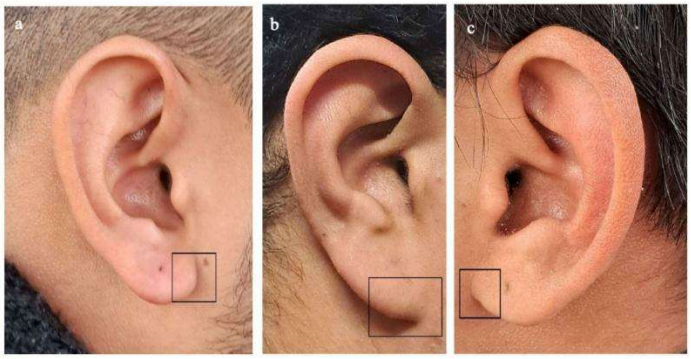

Fig. 12. Photograph showing different earlobe attachment: (a) free, (b) attached, (c) partially attached.

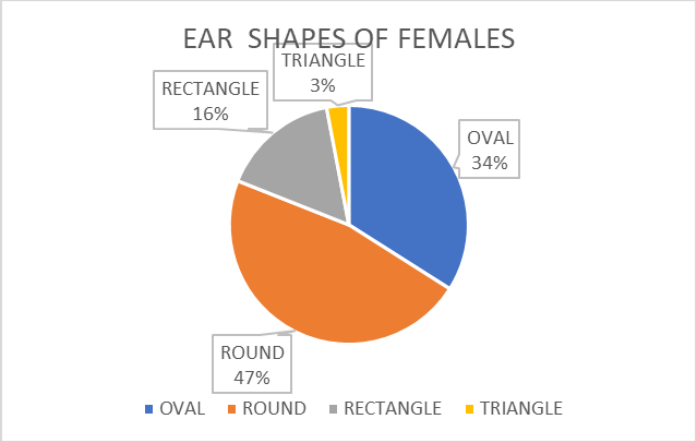

Fig. 13: Shows the distribution of ear shapes in female samples.

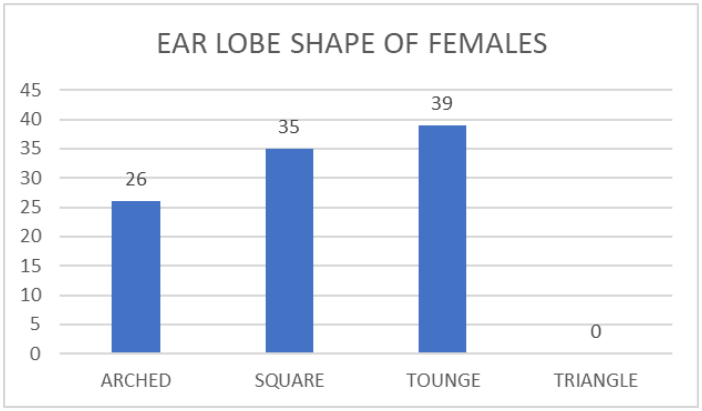

Fig. 14: Shows the distribution of earlobe shapes in female samples.

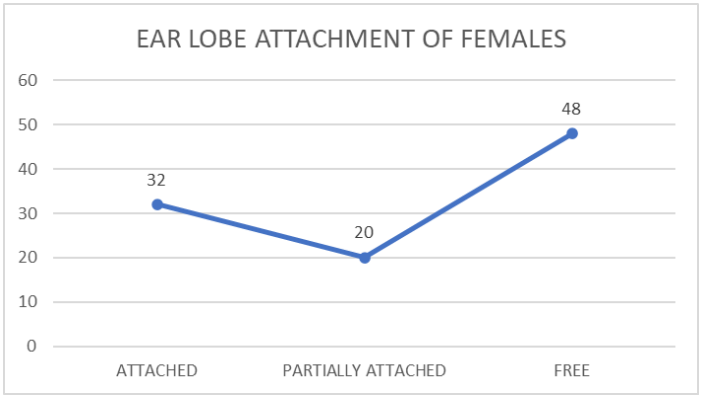

Fig. 15: Shows the distribution of earlobe attachment in female samples.

Table 1: Findings of previous studies.

SL NO	Author & year	No of samples	Ear characteristics	Selected population	Findings	Reference
1	Verma, et al. 2013	100 samples	Ear length, Ear length above tragus, ear length below tragus, Tragus length, Ear breadth, concha length, concha breadth, lobule height, lobule width.	Greater Noida- Uttar Pradesh.	Significant differences in lobule height, width, length, were seen especially in males. The location of the ears on the head also differed significantly, with 39.78% of ears placed in the posterior region and 60.21% in the centre. Subjects' ear types differed.	[1]

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2	Angelakopoulos, et al. 2023	Females- 633, Males - 778.	Helix, Antihelix, Concha, Lobe.	Brazil, India, Japan, Russia, South Africa, Turkey.	Cameriere's ear identification approach is highly distinctive, according to a multi-ethnic study, with a low possibility of matching numerical codes across six countries	[2]
3	Rani, et al.2022	Females- 264, Males-233.	33 Morphological Characteristics.	Solan-Himachal Pradesh	Studied 1056 morphological traits, and found significant correlation in 5 factors, Substantial correlation with 15 factors in external ear shape.	[6]
4	Krishan, et al. 2019.	Females- 87, Males- 90.	Overall shape, Size, Shape of tragus, Ear lobe, Shape of helix, Darwin tubercle.	Upper regions of Himachal Pradesh.	The study found that 40% of males and 44.8% of females have an oval-shaped ear, while other types like oblique, rectangular, round, and triangular are also present.	[13]
5	Rani, et al. 2021	Females- 69, Males- 71.	Ear length, Ear breadth, Ear length from tragus, Distance from tragus to helix, Distance from tragus to anti helix, Lobule height, Lobule breadth.	Sirmaur district-Himachal Pradesh	Study found six differences in males, and developed discriminant function model for sex identification.	[3]
6	Chattopadhyay, et al. 2009.	79 samples	Ear length, Ear breadth, Position of the ear, Ear lobe types.	Lucknow	Study found that the difference in the indices is within ten percent, Ear is mostly found at the posterior 1/3 of the head, Oblique ear and free lobe is most frequent in samples.	[14]
7	Fakorede, et al. 2021.	Females- 176, Males- 131.	Shape of ear, Form of helix,	Hausa, Igbo, Yoruba.	Study found that ear shapes varied with round and triangle shapes more common in Hausa	[15]

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			Shape and attachment of ear lobe, Shape of ear tragus, Darwin's tubercle.		males in oval shapes in Igbo females.	
8	Nedunuri, et al. 2018.	Females- 16, Males- 20	Ear length, Ear breadth, Ear length above tragus, Ear length below tragus, Tragus length, Concha breadth, Lobule height, Lobule width.	Asian and African population	Study found that the parameters Ear length below tragus, Lobule height, and Lobule width of both the sides show a significant difference ($p < 0.05$) between both the population groups.	[16]

Table- 2 Shows the descriptive statistics for different ear morphological features studied. (Measurements in cm)

FEATURES	MEAN		STANDARD DEVIATION		MINIMUM		MAXIMUM		*P-VALUE*
	MALES	FEMALES	MALES	FEMALES	MALES	FEMALES	MALES	FEMALES	
RIGHT EAR LENGTH	5.203	5.546	0.721	1.021	3.834	3.183	7.285	7.6	0.05*
LEFT EAR LENGTH	5.387	5.560	0.860	0.956	3.919	3.154	8.078	7.755	0.34
RIGHT EAR WIDTH	2.854	3.015	0.399	0.567	2.186	1.436	3.621	4.258	0.10
LEFT EAR WIDTH	2.853	2.961	0.497	0.590	1.858	0.658	3.939	4.147	0.32
RIGHT EAR LOBE LENGTH	0.714	0.648	0.222	0.201	0.295	0.187	1.468	1.087	0.12
LEFT EAR LOBE LENGTH	0.719	0.654	0.225	0.190	0.306	0.142	1.536	1.137	0.12
RIGHT EAR LOBE WIDTH	1.548	1.687	0.306	0.531	0.853	0.195	2.106	3.302	0.11

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LEFT EAR LOBE WIDTH	1.522	1.626	0.401	0.501	0.398	0.4	2.349	2.827	0.25
RIGHT CONCHA LENGTH	2.068	2.304	0.403	0.566	0.022	0.656	2.859	3.26	0.01*
LEFT CONCHA LENGTH	2.172	2.329	0.314	0.595	1.613	0.533	3.185	3.544	0.10
RIGHT CONCHA WIDTH	1.347	1.360	0.239	0.359	0.946	0.455	1.869	2.403	0.82
LEFT CONCHA WIDTH	1.348	1.379	0.327	0.374	0.68	0.317	2.444	2.267	0.66

***Significant Differences**

4. Discussion:

The findings of this study underscore the remarkable uniqueness and diversity of ear morphology among individuals in the Uttarakhand region, reinforcing the ear's value as a reliable biometric marker in forensic identification. The differences observed in ear shapes-oval predominating in males and round in females-reflect the natural variation shaped by genetic and environmental factors that characterize this population. These variations are consistent with earlier studies from nearby regions, validating the patterns of ear morphology while also highlighting distinctive regional traits.

The study revealed that the average ear length among participants was 5.27 cm and the average ear width was 2.813 cm, which is smaller compared to the findings by Verma who reported an average ear length of 6.42 cm and width of 3.53 cm [3]. The average ear lobe measurements and concha dimensions in this study were consistent with expected regional morphological variations.

Among males, oval-shaped ears were predominant (65%), followed by round (20%), rectangle (11%), and triangle shapes (4%). This contrasts with Krishan, where about 40% of ears were oval-shaped, indicating regional differences in ear shape distribution [10]. The commonest male ear lobe shape was square (38%), with tongue-shaped lobes closely following (35%), and arched lobes observed at 25%, a lower percentage than Krishan's [10] reported 71.1% arched lobes, again reflecting regional variability.

In terms of ear lobe attachment in males, partially attached lobes were most common (41%), followed by free (37%) and attached (22%). This differs from Krishan, who found attached lobes to be the most frequent (~51.65%) in their sample, suggesting population-specific genetic influences on this trait.[10]

Female participants had slightly larger average ear dimensions than males, with ear length of 5.612 cm and width of 2.982 cm. round ear shapes were most prevalent in females (47%), followed by oval (34%). Female ear lobe shapes showed a balance between tongue (39%) and square shapes (35%), with arched lobes at 26%. No triangular lobes were observed in females, aligning with patterns observed in previous studies.

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Regarding ear lobe attachment in females, free lobes were dominant (48%), followed by attached (32%) and partially attached (20%). This pattern again diverges from Krishan's findings, with attached lobes being less frequent here [10].

Statistical analysis indicated significant gender differences, particularly in right ear length ($p = 0.05$) and right concha length ($p = 0.01$), confirming sexual dimorphism in ear morphology. These differences can be crucial for forensic differentiation in personal identification.

Overall, variations seen in this study highlight the importance of population-specific biometric data in ear morphology for forensic use. Differences between findings here and previous studies underscore the genetic and regional diversity affecting external ear features.

5. Conclusion

This study investigated the morphological features of ears among the Uttarakhand Region of India. The ear features, including length, width, earlobe characteristics, concha measurements, and overall ear shape, were examined from ear prints and photographs. The results were studied using descriptive statistical analysis. Males had an average ear length and width of 5.27 cm and 2.813 cm, with an earlobe length of 0.646 cm and a width of 1.464 cm. The concha, or inner ear, measured 2.139 cm in length and 1.296 cm in width. Oval-shaped ears were the most common, followed by round, rectangle, and triangle shapes. Females had slightly larger averages of 5.612 cm and 2.982 cm, with an earlobe attachment of free attachment, arched and square-shaped earlobes, and partial attachment. The results showed the significant differences between males and females ear characteristics, such as right ear length with a p-value of 0.05 and right concha length with a p-value of 0.01. The findings highlight the diversity and similarity of ear morphology in the geographical region. The distinct features of ear morphology may offer significant clues for identifying people in criminal cases. In future studies, other geographical regions may be explored to study the variations in morphology of ear.

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Ethical Statement:

This research was conducted in the Ramnagar area, Nainital district, Uttarakhand state, northern India, following strict ethical guidelines to ensure the dignity, rights, and welfare of all participants. Prior to data collection, the study methodology and objectives were thoroughly explained to all potential participants in their local language to ensure a complete understanding of the research purpose, procedures, and their role in the study.

Informed Consent Process: Each of the 100 participants (aged 15-30 years) was provided with detailed written informed consent documents that clearly outlined the study's aims, methods, potential benefits, and their right to withdraw from the study at any time without consequence. The consent forms were available in English to ensure a comprehensive understanding. Participants were given adequate time

to consider their participation and ask questions before providing their voluntary consent.

Participant Recruitment and Protection: Participants were from local community centers, educational institutions, and public areas using random sampling methods to ensure representative distribution across age and gender groups. Special care was taken to exclude individuals with physical abnormalities of the ear to maintain the scientific integrity of the study while ensuring no discrimination based on physical characteristics.

Privacy and Confidentiality: All ear print samples and photographic data were collected with utmost respect for participant privacy. Personal identifying information was kept strictly confidential and separated from the morphological data to maintain anonymity. The digital storage of photographs and measurement data followed secure data management protocols to protect participant identity.

Voluntary Participation: Participation in this study was entirely voluntary, and participants were informed of their right to discontinue participation at any stage without providing reasons and without any negative consequences. No monetary or material incentives were provided to ensure that participation was genuinely voluntary and not influenced by external factors.

This study was conducted in accordance with the ethical principles and received approval from the institutional review board at Chandigarh University, Gharuan, Punjab, India.

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