Ear Prints in Forensic Science: An Introduction

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Abstract

Earmarks or ear prints are considered an additional tool for the personal identification of suspects. Due to its characteristic morphology, it can be easily differentiated from other prints like lip prints, palm prints, fingerprints, footprints, etc. Every person has a different ear morphology. Therefore, ear prints discovered at a crime scene can help identify the offender and narrow the pool of suspects. Ear prints can be observed at the crime scenes like burglary, theft, HBT, etc. Anthropometric measurements and biometric tools are widely applied to ear print classification and identification. The present chapter incorporates the classification system, feature of the ear, ear print collection methods and forensic significance of ear prints. The forensic investigator can use ear prints in conjunction with other evidence to positively identify the offender. However, additional research is necessary for partial ear print analysis.

Keywords

Ear Print Identification · Ear Print Classifications · Ear Morphology · Biometric Identification · Latent Prints

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11.1 Introduction

The human face has many characteristic features like eyes, eyebrows, nose, lips, chin, cheeks, and ears. Biometric systems have been employed to identify the eye by extracting the characteristic features of the iris (Czajka 2021; Marra et al. 2018). Lip prints have also been used for personal identification (Agarwal and Raman 2022; Ahmed et al. 2018; Doroz et al. 2022; Karim and Gupta 2014; Wrobel et al. 2018). Physiognomy helps in facial reconstruction (Davy-Jow 2013; Aulsebrook et al. 1995; Tedeschi-Oliveira et al. 2016), which may serve in a personal identification of the suspect and identification of dead bodies in the cases of mass disaster, arson, and burns.

Human skin, including the facial skin, secrets sweat. Furthermore, whenever skin comes in contact with any surface, it tends to exchange its mark/print on that surface. Similarly, the external human ear forms a print whenever it comes in contact with a surface. The human ear has a typical morphology; however, the structure is highly variable from person to person and thus can be used to identify the suspect. Ear print can be observed on surfaces like doors, windows, glass, or walls in theft and burglary cases. They are also found in sexual assaults, sexual abuse, or physical assault cases. Usually, these prints are latent, i.e. not visible through the naked eye and therefore overlooked by the culprit while leaving the crime scene. However, in some situations, when a person is physically injured, we may also find bloody ear prints. Ear prints may not be as unique as fingerprints but are also not common. Human ears do have morphological features which can help in personal identification. Unknown ear prints can be compared with the sample ear print collected from the suspect as well as ear prints can also be advantageous in identifying the suspect with the CCTV footage. Ear identification can be made using surveillance camera images (Hoogstrate et al. 2001). Ear examination also aids in the personal identification of deceased individuals whose dead body has been mutilated (Krishan et al. 2019; Verma et al. 2014). The uniqueness of the ear was studied in the central Indian population with 1404 adult male and 1257 female subjects, confirming that every ear has a unique morphology and can be used for personal identification (Purkait 2016).

"Earology" is also known as "otomorphology", which means the study of the external ear. "Earology" was first reported by Johann Casper Lavater. Later, Haken Jorgensen developed a method to record the morphology of ears using measurements of ear and ear moulds collected from criminals in Denmark. Alphonse Bertillon devised a system to record different parts of the human body and described this system as "*Portrait Parle*", meaning "speaking picture". Bertillon considered the ear as the most specific part of the body. In the 1940s, Alfred Iannarelli devised a classification system for ears. Van der Lugt also attempted to classify the ears based on the different ear measurements and morphological features (Verma et al. 2014).

11.2 Application of Ear/Ear Print Examination in Forensic Science

The ear's general structures were examined in various populations (Alexander et al. 2011; Bozkır et al. 2006; Chattopadhyay and Bhatia 2009; Singh and Purkait 2009; Rubio et al. 2015). The ear lobe is used for personal identification and shows characteristic differences in identical twins (Feenstra and Van der Lugt 2000). Sex identification based on the ear dimension is also possible (Ahmed and Omer 2015; Kaushal and Kaushal 2011; Murgod et al. 2013; Sforza et al. 2009). Earmark and ear print recognition and comparison were demonstrated by researchers (Dhanda et al. 2011; Junod et al. 2012).

Ear biometrics: Biometric identification serves as a non-invasive method for identification. Dinkar and Sambyal (2012) demonstrated a method for identification using the biometric method. The external ear was studied and classified based on the weighted scoring system and pattern recognition with neural networks. Using the biometric system, ten features of the external ear could further be divided into 37 sub-features. In the study, they included 400 Indian Goans people as subjects. The photographs of both right and left ears were taken. Out of the total of 800 ear photographs, only 80 showed visual similarities, and by analysing these visually similar ears with the biometric tools, it was found that none of the individuals had identical weighted scores in different individuals as well as in the left and right ear of the same individual (Dinkar and Sambyal 2012). Mussi et al. (2021) developed an image processing algorithm to identify the auricular elements of the ears with its application in identifying and recognizing the suspects. This method was based on two parts: image contrast enhancement and identification of four anatomical regions, namely, helix, anti-helix, concha region, and tragus region (Mussi et al. 2021). Canny edge detection method has also been used for personal identification (Kavipriya et al. 2021). 2D ear imaging is used for automated human identification (Kumar and Wu 2012). Kumar and Chan (2013) have demonstrated the application of Radon transform and local curvature encoding system. Fusion of tragus with ear was also used for identification (Annapurani et al. 2015). Abaza and Bourlai (2013) demonstrated real-time human identification based on ear morphology. This method had the advantage that it could be utilized during the day as well as night time. The complete system was based upon two steps: the first step was to collect the thermal imprints of the human skin using the high-definition mid-wave IR camera, and in the second step, a fully automated ear recognition system was developed (Abaza and Bourlai 2013).

11.3 Ear Morphology

In order to compare ear prints/marks or examine the ear through photographs or videos, the examiner needs to understand various parts of the ear clearly. The ear has different parts; the external ear is called the pinna or auricle. The external ear comprises skin, cartilage, connective tissues, and ligaments (Krishan and Kanchan 2015) (Fig. 11.1).

Various parts of the ear are discussed below (Tables 11.1 and 11.2):

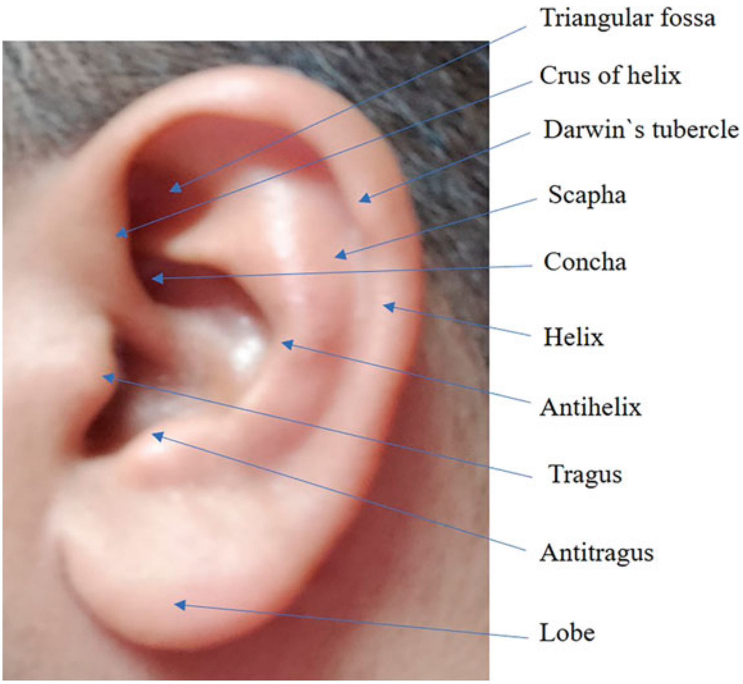

Fig. 11.1 General anatomy of the external ear

Table 11.1 Various parts of the external ear with their description (https://elementsofmorphology.nih.gov/anatomy-ear.shtml)

Sr. No.	Name of part of the ear	Description
1.	Helix	The outer rim of the ear forms the "helix". Helix can be divided into three parts: (1) ascending helix, (2) superior helix, and (3) descending helix
2.	Crus of Helix	The anteroinferior ascending helix's continuation, which protrudes posteriorly into the concha cavity over the external auditory meatus
3.	Scapha	The channel running through the helix and anti-helix
4.	Tragus	A posterior, slightly inferior, protrusion on the inner side of the external ear of skin-covered cartilage, anterior to the auditory meatus
5.	Concha	The fossa bounded by the tragus, incisura, antitragus, anti-helix, inferior crus of the anti-helix, and root of the helix, into which opens the external auditory canal
6.	Antitragus	The cartilaginous protrusion between the incisura and the anti-helix's origin that protrudes anterosuperiorly
7.	Anti-helix	The separation of the concha, triangular fossa, and scapha from the antitragus results in the creation of a curving cartilaginous ridge in the Y-shape is the anti-helix
8.	Triangular fossa	The concavity enclosed by the ascending part of the helix and the superior and inferior crura of the anti-helix
9.	Lobe/lobule of auricle	Lobe is present at the bottom of the external ear. It is the soft, fleshy structure lacking firmness as compared to the rest of the auricle

Table 11.2 Somatoscopic characteristics describing the form of the external ear (Purkait 2015)

Sr. No.	Features	Characteristics	Classification
1.	External ear	Shape	Triangular
			Round
			Oval
			Rectangular
2.	Darwin's tubercle	Shape	Absent
			Nodosity
			Enlargement
			Projection
			Tubercle
3.	Helical fold	Form	Flat
			Curved
			Normally rolled
			Wide covering scapha
		Shape of upper helix	Upper directed angle
			Obtuse medial angle
			Obtuse lateral angle
			Obtuse acute angle
			Double right angle
			Obtuse angle
			Circular
4.	Tragus	Shape	Long
			Round
			Knob shaped
5.	Antitragus	Shape	Prominent
			Medium
			Flat
6.	Lobule	Shape	Tongue
			Triangular
			Rectangular
			Arched
			Round
		Attachment to cheek	Attached
			Partially attached
			Free
7.	Concha	Shape	Narrow
			Proportionate
			Broad
8.	Anti-helix concha border	Shape	Straight
			Curved
			Round
			Laterally protruding

11.4 Classification of Ear Based on the Shape of the Auricle

The shape of the auricle can be oval, round, rectangular, or triangular.

1. Oval ear: The length of the ear is more than its width. Furthermore, the width is observed to be maximum at the centre.
2. Round ear: The ear's length and width are nearly the same, with a rounded top and bottom.
3. Rectangular ear: The length of the ear is more as compared to the width, but it shows a rectangular top and bottom, i.e. the width of the ear is uniform throughout the top, middle, and bottom.
4. Triangular ear: The length of the ear is more than its width, and the width is maximum at the rounded top (Kaushal and Kaushal 2011).

Measurement of the ear: Length—The length of the ear is measured as a distance between the uppermost point of the helix and lowermost point of the ear lobe parallel to the ear base (the base attached to the head); Width—The width of the ear is measured as a distance between the base of the ear and the outermost part of helix, which is perpendicular to the ear base (Kaushal and Kaushal 2011).

11.5 Iannarelli System of Ear Classification

Alfred Iannarelli is considered a pioneer in using ear measurements for personal identification. In 1949, he developed a forensic method for personal identification based upon the ear examination. He collected a large number of ear images and then divided each image into 12 different parts and developed a database which included more than 10,000 ear images. However, Iannarelli's method could only be applied to a population of less than 16.7 million (4^{12}).

The Iannarelli system is based upon 12 measurements of the ear (Bhanu and Chen 2008). Iannarelli used photographs to classify ears based on these measurements. To take the measurements of the ear, a transparent compass with eight spokes, each separated by 45° angles, is placed over the image of the ear. The compass is placed so that the first reference line should touch the crux of helix at the top and the innermost point of the tragus at the bottom. In the next step, the second reference line is focused on meeting the concha from top to bottom. Once both reference lines are placed, the ear measurements are noted.

11.6 Polish Otoscopic Identification System

Otoscopy involves classifying and examining ear auricle print for human identification. Habil and Kasprzak (2005) have briefly described the Polish otoscopic identification system in three levels.

Level I: Type of Ear Auricle	Level II: General Identification Characteristics	Level III: Detailed Identification Characteristics
1. Oval type 2. Round type 3. Triangular type 4. Rhomboidal type 5. Polygonal type	These characteristics are observed and compared with a catalogue which consists of 1- 24 fields.	1. Scars 2. Marks of ear piercing 3. Elongated pierced hole due to heavy jewellery 4. Traces of worn jewellery 5. Creases

This method is very effective and has been included in Poland's forensic expert training curriculum (Habil and Kasprzak 2005). The Polish methodology described six steps for ear print examination.

Step 1: Assessment of the print recovered from the crime scene and the print collected from the suspect to check the suitability of the prints for identification.
Step 2: Elimination of false suspects. The suspect prints are eliminated based on the ear auricle type and the ear print's measurement.
Step 3: Coding of characteristics. If the comparative prints collected from the suspects have not been excluded in steps 1 and 2, then the general characteristics of the prints are examined on the evidential and comparative prints. To make this step user-friendly, a catalogue has different fields from 1 to 24. Any characteristic feature present in the evidential print but absent in the comparative prints can be excluded.
Step 4: Contour technique. In this step, a clean, transparent sheet is placed on the evidential print, and the contour of the print is traced with dotted lines. Then this transparent sheet is placed over the print under comparison, and the dotted lines are matched.
Step 5: Determination of common identification characteristics. In this step, the photographs of the evidential and comparative prints are compared using the 24 fields. Similar characteristics observed in different areas of both prints are highlighted in photographs. 10–15 details are usually marked.
Step 6: The final step includes the analysis of results with a record of course examination and statistical evaluations. Furthermore, a conclusion is formulated based on the results, and an expert report is written.

11.7 Development and Collection of Latent Ear Prints from Crime Scene

The following methods can be used to develop ear prints:

1. Powder method
   Latent ear prints can be found on surfaces like door knobs, tables, screens of mobile phones, etc. Such prints can be developed using fingerprint powder. If the

surface is light-coloured, then the examiner shall use a dark-coloured powder, whereas when the suspected prints are likely to be present on the darker or multi-coloured surface, they must use white powder/light-coloured powder. Excess powder is removed with the help of an ostrich feather brush and fixed with cellophane tape. When the whole article bearing the print cannot be collected, the print is lifted using cellophane tape.

2. Ninhydrin method
   It is a chemical method that involves the application of a chemical reagent over the surface to develop the latent print. To prepare the reagent, 1 g of ninhydrin is dissolved in 100 ml acetone, and 1 ml of acetic acid is added to this solution. This reagent can be sprayed or applied using a brush over the surface. The article bearing the print may be heated in an oven at 60 °C for 10 min to increase the reaction rate and develop the prints faster. Purple-coloured prints are observed. This method is more suitable for porous surfaces.
3. Iodine fuming method
   The article bearing the ear prints is placed in the fuming iodine chamber for 4–5 min to develop the latent prints. However, the prints developed by iodine fuming are temporary and shall be fixed using cellophane tape.

With these methods, the ear prints can be developed and compared with the ear print samples collected from the suspects. The procedure to collect the ear print from suspects is given below:

1. Take a photograph of the ear.
2. Take a thermographic picture of the ear with the help of a thermal camera.
3. The earmark/ear print is collected by pressing the ear against a flat glass surface. Several prints shall be collected at varying pressure. The prints are then developed with fingerprint powder and fixed by cellophane tape (Dhanda et al. 2011).

The prints are then examined for the presence of various morphological characteristics of ear. These features can be used for comparison. Only clear and readable prints are considered for positive identification; else, it is deemed inconclusive (Fig. 11.2).

11.8 Forensic Significance of Ear Print

The human external ear has many characteristic features. All individuals, including the monozygotic twins, show variation in ear morphology. Even the left and right ears of the same person are not identical; thus, ear prints are unique and can be used for personal identification. Ear prints are formed due to the deposition of sweat present on the skin; thus, they are typically not visible by the naked eye and have a high probability of being overlooked by the perpetrator while leaving the crime scene. Developed latent prints help in the exclusion of a large number of suspects. The presence of an ear print of a suspect at the crime scene links the suspect to the

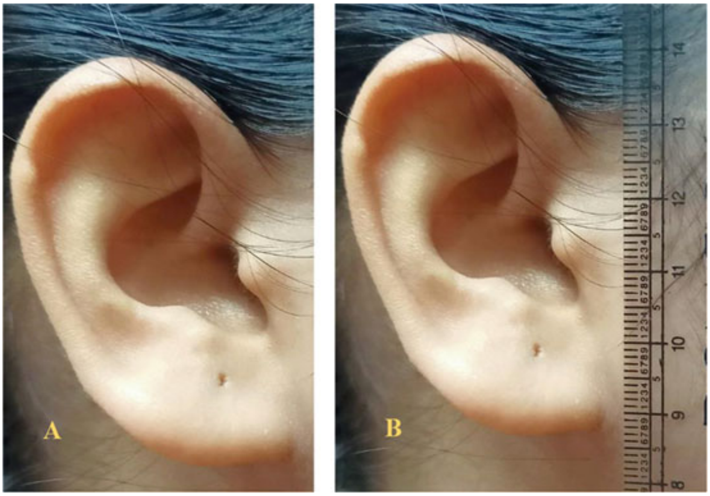

Fig. 11.2 Photograph of ear without scale (**a**) and with scale (**b**)

crime scene; thus, such print should be carefully handled and preserved. Ear prints can be compared with the available database to identify the suspect when there is no suspect. The ear is used to identify people in cases like mass disasters, arson, drowning, etc. A mutilated body can also be identified with the help of an ear examination. Studies conducted on the Indian population reveal that the ears of the male are considerably more significant than the females. The women also wear artefacts like earrings, tops, danglers, loops, etc. These features can also be used for sex identification. Biometric systems have wide applications in the ear, earmark, and ear print examination. Various biometric systems record the ear's image, which can be used to compare the evidential ear print. Recent advancement in research also facilitates real-time image analysis from CCTV. Thermal image analysis helps analyse and compare the prints with real samples.

11.9 Conclusion

In conclusion, the chapter has provided a brief overview of the application of ear/ear print examination in forensic science. The discussion explored various aspects, including the significance of ear prints as forensic evidence, the morphological characteristics of ears, and the classification systems used to categorize ears based on auricle shape. The Iannarelli and Polish Otoscopic Identification systems were examined as prominent classification methodologies. Additionally, the chapter addressed the development and collection of latent ear prints from crime scenes, emphasizing the forensic value of such evidence. This chapter sheds light on the diverse aspects surrounding the application of ear prints in forensic investigations.

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