

# Footwear and Foot Impressions: Foot Impressions and Linking Foot to Shoe

The forensic application of barefoot morphology involves the study of the physical features of feet and the impressions they make. This type of examination is used in cases when either an impression has been made at the scene of a crime or when the wearer of a shoe needs to be determined. However rare the application, in instances where it is needed to answer a question in a criminal case, barefoot impression evidence can become extremely important.

## Barefoot Impressions as Physical Evidence

Barefoot impressions are a type of impression evidence that may be found at the scene of a crime. For example, if an individual involved in a homicide steps into a pool of blood with bare feet, they may track impression detail of the skin of the feet (friction skin and creases) that may be compared and identified in the same manner as fingerprints [1] (*see Friction Ridge Skin: Comparison and Identification*).

The shape and size features of the foot, defined as the morphology of the foot, may be examined and compared in barefoot impression evidence cases where the detail is insufficient to make a friction skin identification [2]. This type of examination is relevant when impressions have been made by a sock-clad foot, or when detail of the impression is limited due to a variety of deposition manner or surface type factors. It is also applied to the examination of the impressions found on the inner surfaces of footwear.

Barefoot impressions found on the insoles of footwear are analyzed to determine possible association or lack of association between a suspect and a particular shoe or boot. Scenarios in which this may provide important investigative information include cases in which discarded footwear has been associated to an impression from a crime scene, or in which footwear is found at a scene and may belong to either a suspect or a victim [3].

Accepted techniques for the comparison of footwear impression evidence include a side-by-side visual comparison, and the creation of an overlay tracing of the known item to be placed over the item in question to determine correspondence of features [4] (*see Footwear and Foot Impressions: Comparison and Identification*). The same techniques, side-by-side visual examination and overlay, are employed in the examination of barefoot impression evidence [5].

## The Structure of the Foot and the Foot Inside a Shoe

A normal foot has 26 bones. Five metatarsal bones, which reach from the arch area to the metatarsal head area, are distinctly separated from one another. Phalanx bones are anterior of the metatarsal bones, forming five separate toes [6]. When a foot is placed inside a shoe, the forefoot and toes are most commonly constricted inward.

Barefoot impressions on the insoles of shoes are the result of pressure, heat, and sweat that occurs during the wearing of a shoe [3]. These impressions characteristically do not include friction ridge skin or crease detail, as socks are normally worn and the impressions result from repeated wearing of the shoe, with the foot constantly rubbing, rather than from a single touch of the foot inside the shoe. These impressions are often a clear recording of toes and the forefoot leading edge of the ball portion of the foot, referred to as the *metatarsal ridge* [2, 3, 5, 7]. In some footwear, impressions of the ball, arch, and heel areas may also be present (Figure 1).

In a barefoot comparison of shoe insole impression evidence, the recording of the features of the foot visible on the inner surface of the shoe are compared with the known exemplars taken from a person in question to include or exclude them as a source of the impressions inside the shoe. Comparisons also take place between the inside uppers of the shoes and the wear patterns as associated to the three-dimensional features of the foot which come into contact with the upper inside surface of shoes, such as toe nails, protruding toes, or toe joints [5].

As can be seen in Figure 2, an inked barefoot impression taken of a foot outside a shoe is wider in the forefoot and toe areas than is the impression of the same foot inside a shoe. A significant constriction

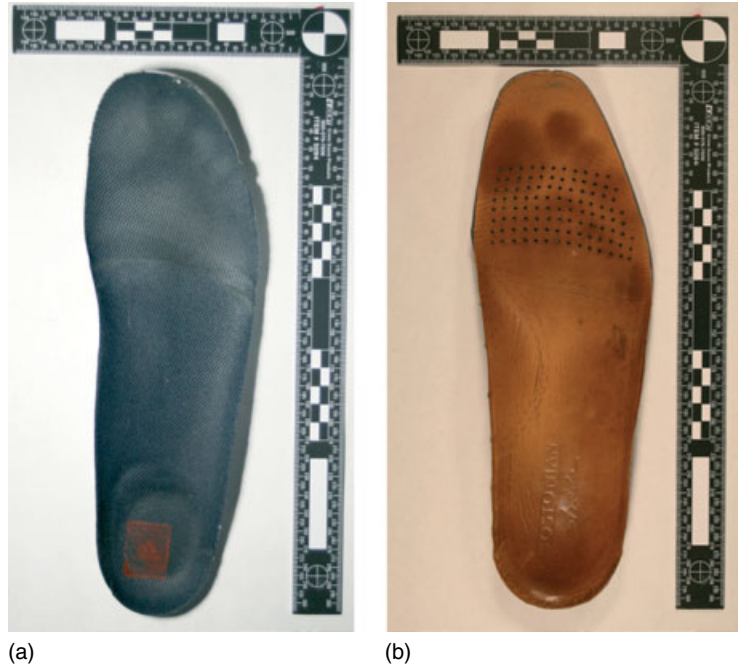


Figure 1 Foot impressions on shoe insoles

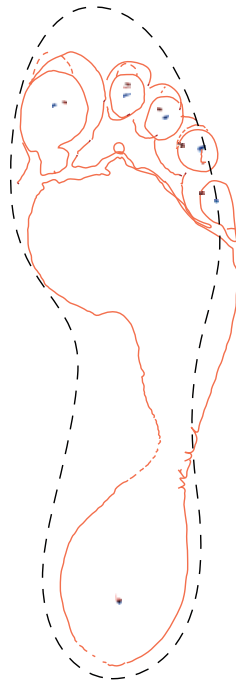


Figure 2 Tracing of a barefoot impression overlaid onto a tracing of the impression of the same foot inside a shoe

of the toes and metatarsal area is often observed when comparing a barefoot impression inside a shoe to one taken outside of a shoe. It is extremely important to take this constriction into consideration during an analysis of a barefoot impression inside a shoe.

### Known Exemplars Used in Barefoot Comparison Cases

For the comparison of barefoot impression evidence, inked impressions are taken both walking and standing, both of naked and socked feet (Figure 3) [7]. Walking impressions involve the inking of the person's feet, and then having the person walk a length of paper approximately 15-feet long, down one side and back the other. This provides a series of naturally walking impressions for use in the comparison process. These successive impressions have been observed to "exhibit little or no change" from one another as they are made along the paper [8].

Known shoes of the person in question may also be seized for comparison to barefoot impressions found inside the shoes in question involved with a crime [8]. However, in practice, occasionally, only



**Figure 3** Three barefoot impressions of the same right foot

inked impressions are available for comparison to the impressions of feet inside of shoes [9]. Thus, although it is generally recommended in forensic examinations to compare “like to like” exemplars, such as a shoe insole impression to another shoe insole impression, occasionally it is necessary to compare an inked bare foot impression to an impression inside a shoe.

### Databases and Studies of Barefoot Impression

Some of the research in the area of foot morphology and forensic application has taken the form of

the collection of large numbers of barefoot impressions from individuals and categorization of them to determine how variable the feet are.

The 1980 study of this type conducted in India collected footprints from 725 individuals. From the measurements taken, a series of indices were calculated to represent variation among the feet. These indices were combined to calculate probabilities. This appears to be one of the first applied databases using foot measurements and calculated statistics to estimate the variability of barefoot morphology in the human population [10]. Previous and subsequent similar studies have derived similar indices to one another, providing support for both the method employed and statistics demonstrating the high level of individuality of feet [11]. The five foot impressions in Figure 4 show the variability in shape of the features of the feet and toe positions between different individuals.

In 1986 and 1987, the FBI collected barefoot impressions from 500 individuals. Measurements, as described previously, were entered into a computer database and intercompared. It was noted that the size and shape features varied considerably and concluded that no left or right foot of any individual in the sample set was found to be identical. Further, results showed that only a few combined size and shape characteristics were required to discriminate a foot from this population [3].

The Royal Canadian Mounted Police (RCMP) has collected approximately 12 000 barefoot impressions for the study [12]. Two statistical analyses have been carried out on portions of these samples that have been entered into a database. The population used in the first preliminary study was 960, and for the second study it was increased to 5755 [13, 14].



**Figure 4** Impressions of right feet from five different individuals

These studies concluded that measurements taken of the feet show a great degree of variability between the barefoot impressions of individuals, and a great degree of similarity between multiple impressions of feet taken of the same individual. The second study reports the statistical odds of a chance match of barefoot impressions, based solely on the positions and measurements of the characteristics of the feet recorded, with no ridges or creases considered, to be one in 1.27 billion. This number is not used in criminal cases, it is applied as an indication of the high degree of variability of barefoot morphological features for background and research purposes.

Both the footwear industry and military researchers have studied the population of human feet for the purpose of achieving comfort in footwear. Although not the goal of the studies, the results include comments which reflect upon the wide variety and differences in the structure of feet [3, 15, 16]. Although these are not to be considered forensic validation studies, they do support the concept of high degree of individuality of the morphology of the foot.

In addition to the construction and statistical analysis of databases, forensic texts that include sections on the examination and comparison of barefoot impression evidence, as well as articles specific to this discipline, have been published [2, 3, 17–19]. Through discussion, practice, peer review, and study, the development of forensic barefoot morphology impression comparison has been shaped over the last few decades. It is this process that has led to the current procedures and methodologies for the examination of this type of evidence. Both empirical and statistical studies validate the identifying nature of specific physical features of the foot, and that these features may be used to exclude an individual as the source of a barefoot impression, include them as a possible source of the impression or may lead to an inconclusive conclusion.

### DNA Analysis Applied to the Insides of Shoes

It should be noted that DNA technology may be applied on samples taken from inside the shoes (*see DNA: Sources of*). This analysis could assist to assess if a contact occurred between an individual's feet and the shoes. However, in many circumstances, the chance of obtaining a profile may be small.

Additionally, the DNA from more than one person is often found on the insides of shoes, not necessarily including the owner of the shoes [20].

### Case Examples in the Comparison of Feet to Shoes

There have been many interesting cases in the past decade involving the examination and comparison of the insoles of shoes in determination of the wearer of the shoe, examples are mentioned later.

In 1948 in Canada, a shoe to foot comparison was conducted between a pair of shoes and two brothers who were suspects in a series of break and enters. One brother, Donald Kett, was convicted. The other brother, William Kett, claimed he was innocent and that all the shoes that were matched to the crime scene belonged to Donald. However, through comparison of the impressions inside the shoes, it was determined that William had worn the shoes, and he was also convicted [21].

In 1955, a burglar left his shoes at the scene of a crime in Surrey, England. Shoes were obtained from a suspect, and casts of the insides of the shoes were made and compared against one another. The shoes were found to have been worn by the same individual. This evidence was presented in court and a conviction was the result [22].

William Bodziak, a retired FBI Special Agent, describes a case in which a fleeing suspect lost his right shoe at the scene of a homicide. By comparing the sweat stains and depressions of the wearer's foot on the insole of the crime scene shoe to those found in the right shoe the suspect was wearing when apprehended, it was determined that there was a high probability that both the shoes were worn by the same person [3].

Robert Kennedy, a retired RCMP Officer, has conducted many cases involving the comparison of shoe insoles. One of his cases involved the homicide of a prostitute in Israel. A young man was the suspect, and when shoes were seized from his house, it was determined that his brothers and father also wore the same style of shoe. All the shoes were examined, and the victim's blood was found on the outside of one of the pairs of shoes. After the insole impressions of the shoes were examined, it was determined that the impression in one shoe did correspond to the suspect, but the impression in the other shoe did not. After

further examination of the insoles, it was determined that the insole that was different from the suspect's foot was not the original insole. Through a physical match of the glue residues on the bottoms of the insoles of all the shoes, the original insole was found in one of the other shoes. The impression on this insole was also found to correspond to the suspect, which linked the suspect to the pair of shoes on which the victim's blood had been found [23].

Another example of the use of barefoot morphology to link a suspect to a shoe associated with a crime in a series of break and enters in 1999 and 2000 that occurred in Manitoba, Canada. Similar shoe impressions were found at three crime scenes. When a suspect was located, and discarded shoes were found corresponding to the shoe impressions from the crime scenes, he denied ownership of the shoes. After examination and comparison it was determined that the suspect was likely the wearer of the shoes, and he was charged with the three offenses [24].

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