Comparison of Concealment Methods on the Visibility of Accidental Marks on Shoe Soles

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Edited by: Adamaris Rosas

Abstract: Forensic Science is a continuously expanding field that incorporates the analysis of a multitude of variables in shoeprint and impression analysis. Footwear evidence is currently considered in crime scene investigations conducted by forensic experts. The research explores the difference in the characteristic points on the sole of a shoe with the addition of concealment materials in the creation of impressions and shoeprints. In the experiment, results of three treatments involving the addition of a plastic bag, an elastic shoe cover comprised of nylon, and duct tape are considered. The impressions and footprints were documented in photographic results that are compared to a control group without any added materials. The data was analyzed through the observation of changes in the visibility in ten minutiae points of characteristics chosen before the commencement of the research. The nylon shoe cover produced the smallest number of visible minutiae that correlates to being the technique of concealment of shoe impressions and prints that produces the most observable change in their visibility.

Keywords: *impression, shoeprint, randomly acquired marks, concealment, forensic science*

Forensic science applies a multitude of techniques from various branches of natural science to examine and document evidence for use in law implications in civil and criminal cases (Katz and Halámek 2016). Among the new fields of study being further developed is the broadening scope of shoe impression and print analysis. Within the specialty of forensic impression analysis, many class characteristics can be concluded, such as length, size, style, make, model, and randomly acquired marks (Bodziak 2013).

The ability to determine indicators of specific makes and models of shoes in a crime scene has been impeded due to a lack of complete shoe prints or impressions, but recent research continued developing

approaches to make conclusions from partial prints and impressions through new technology or methods to reduce the probability of producing inaccurate results when quantifying data (Chiu et al. 2019). Regression analyses created through several sets of data made from the two furthest visible points on partial shoeprints have reduced the average error related the visibility of partial shoeprints (Zhang et al. 2020). This allows the concept of receiving accurate information from obscured shoeprints or impressions to be considered during criminal investigations when the probability of error could possibly declare the evidence as inadmissible. The Electrostatic Dust Print Lifter is an example of technology used to develop impressions while reducing dust residue on surfaces. This technology is able to document higher quality prints for further review than the Electrostatic detection Apparatus that produced less accurate shoeprints as it continues to be used (Craig et al. 2006). 3D scanners have become an available option for documenting both impressions and prints that does not result in the degradation of evidence from the production of an impression cast or the documentation of a shoe print (Liao et al. 2020). Learning algorithms that compare the edge pixels of footwear evidence photos can be adapted to determine if a shoeprint matches the characteristics shown on a 2-dimensional image of a shoe sole (Park and Carriquiry 2021). By classifying descriptors of shoe impressions, multilabel computer neural networks can utilize greyscale to classify and medically image footwear impressions (Budka et al. 2021). These instances of improvements in the technology available to be used in footwear analysis displays the ability to accurately document impressions and prints while reducing the chance of only recording partial evidence, yet these resources were tested on impressions and prints that were made unimpeded by other variables.

The positive identifications made between two shoes is based off the ability to detect random individual characteristics that are visible on each shoe to result in a match of the physical shoe soles (Bodziak 2013). Randomly acquired marks or accidental marks are markings made that affect the measure the rarity of a comparison between an impression found at a crime scene and an impression retrieved from a suspect. These characteristics can produce a probability on the rarity of finding the same combination of randomly acquired marks in the general population (Damary et al. 2018).

The probability of matching characteristics decreases when only partial prints and impressions are being considered. However, the materials that can affect the production of these impressions and prints could be a resource used to aid forensic examiners in identifying other areas of footwear evidence to link an individual to a crime scene. Wear or the addition of other materials specific to the evidence can reduce the number of shoes

in the general population capable of making the shoe print being investigated. The evaluation of these characteristics in coordination allows forensic experts to match a suspect as a person at a scene when a positive match was not viable before.

Materials and Methods

Treatment One. The experiment procedure conducted three treatments: documentation of the original shoe sole, the effect of concealment methods on shoe impressions in sand, and the effect of concealment methods in shoeprints created with acrylic paint. Concealment methods are for the purpose of this experiment defined as any materials that can possibly alter the visibility of a shoe impression or print when added to a shoe sole. The three concealment methods that was obtained for the experiment was a self-sealing plastic bag (Gallon Food Storage Bags, Ziploc, San Diego, CA), an elastic shoe cover comprised of nylon (Model MD-002, MagicDesign, Changsha, Hunan, China) and duct tape (Model 394475, Shurtape Technologies, Hickory, NC). The first treatment photographically documented the sole of the shoe (Kamryn Black, Universal Threads, Fairfield, CT) to be used in all further treatments. 10 minutiae points were selected at this time for comparison to photographic evidence in further treatments.

Treatment Two. The second treatment documents the changes in the visibility of a shoe impression in a medium of sand (Premium Play Sand, Quikrete, Atlanta, GA) as each concealment method is applied. The sand was held in an aluminum tray (Model 2106E-4, Three Roaster/Baker Pans, Handi-foil, Wheeling, IL) at an approximate depth of two inches to cast an impression in the sand without reaching the bottom and disrupting the image. While utilization of hairspray in holding play sand impressions before casting produces more identifiable characteristics, the use of a fixative was not needed to capture only photographic results (Battiest et al. 2017). The sand substrate was formed of grains that were fine rather than coarse. Soil substrates formed of sand are able to produce an adequate amount of randomly acquired marks in impressions made in a medium of sand to produce an identification with another impression (Snyder 2015). The sand was compressed with an undisturbed surface before the next steps of the experiment were performed. A new tray was used for each method of concealment that was tested. Each impression made by the same shoe was photographically documented after completion.

Treatment Three. In the final treatment, 8 ounces of black acrylic paint (Apple Barrel, Columbus, NE) was poured into an aluminum tray to evenly coat the bottom of the shoe. This produced a series of black

and white shoeprints that specific minutiae points of characteristics could later be determined following the curvature of the shoe (Wei et al. 2014). A control group was created first through creating a print with no additional materials covering the sole of the shoe. The shoe prints in this treatment were created by placing the sole of the shoe on white printer paper (20#, Up & Up, Minneapolis, MN) to create prints using the acrylic paint. The same three groups of concealment methods used in the first treatment were repeated in the treatment of producing altered shoeprints. Each group created three copies of shoeprints that were labeled in the upper right corner and left to dry for 24 hours. The shoeprints were photographically documented in the same manner as the impressions and control groups. The photographic data was then reviewed and analyzed after the completion of the experiment.

Results

The experiment produced results both qualitative and quantitative in nature. The first treatment photographically documented ten minutiae points to match in further impressions and prints later in the experiment (Fig. 2 and 3).

Fig. 1 Impression of shoe sole with no concealment methods.

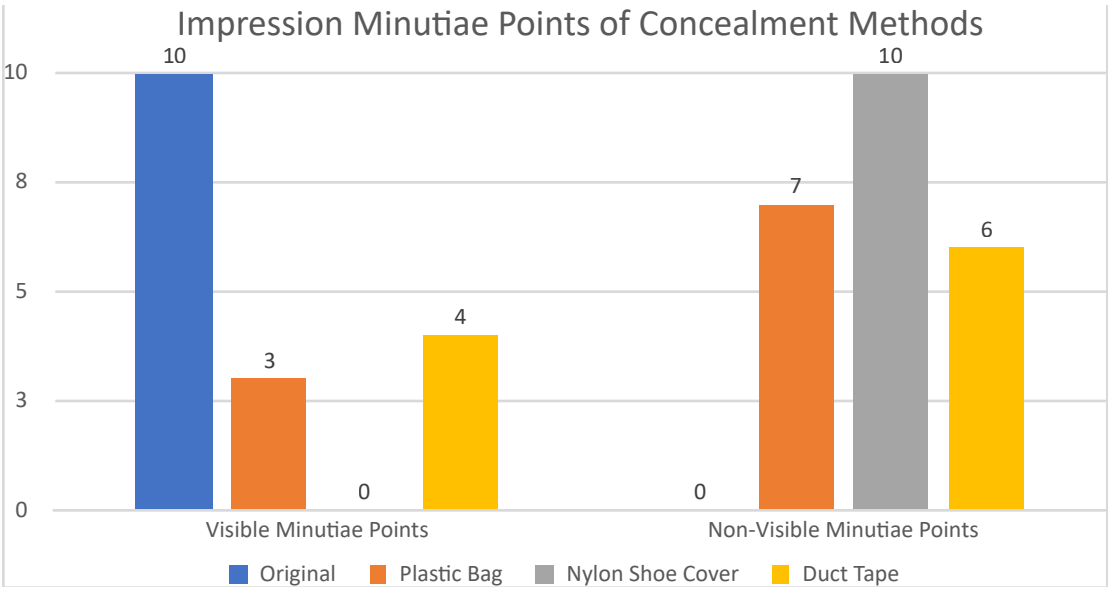
The number of visible points of minutiae, also known as randomly acquired marks, differentiates with the addition of concealment method materials made during

Fig. 2 The original shoe sole with ten chosen points of minutiae.

treatment two (Graph 1). The group with the nylon shoe cover added onto the sole of the shoe displayed the highest number of non-visible areas (Fig. 3 and 4).

Table 1 Categorized Minutiae Points of Impressions in Differing Concealment Methods

	Original	Plastic Bag	Nylon Shoe Cover	Duct Tape
Visible Minutiae Points	**10**	**3**	**0**	**4**
Non-Visible Minutiae Points	**0**	**7**	**10**	**6**
Total Minutiae Points	**10**	**10**	**10**	**10**



Graph 1 Impression Minutiae Points of Concealment Methods

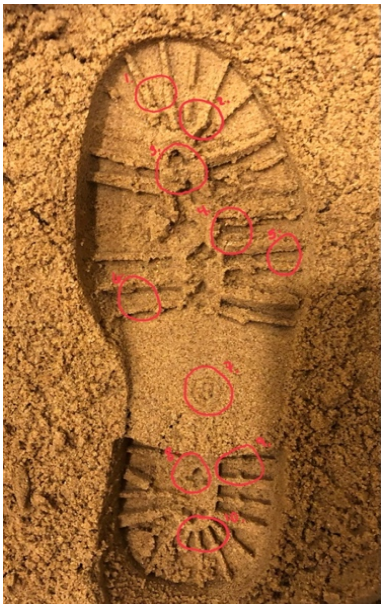


Fig. 3 Impression with no added materials in the second treatment control.

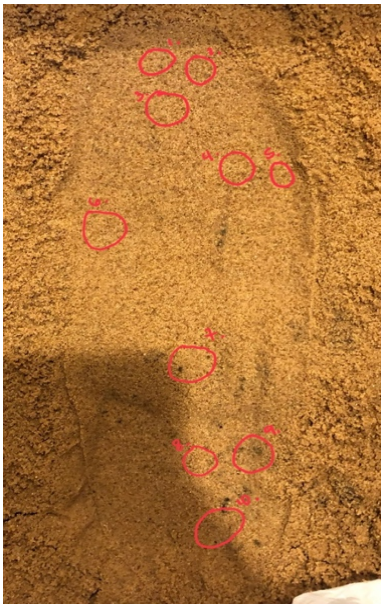


Fig. 4 Impression with nylon shoe covering added in treatment two.

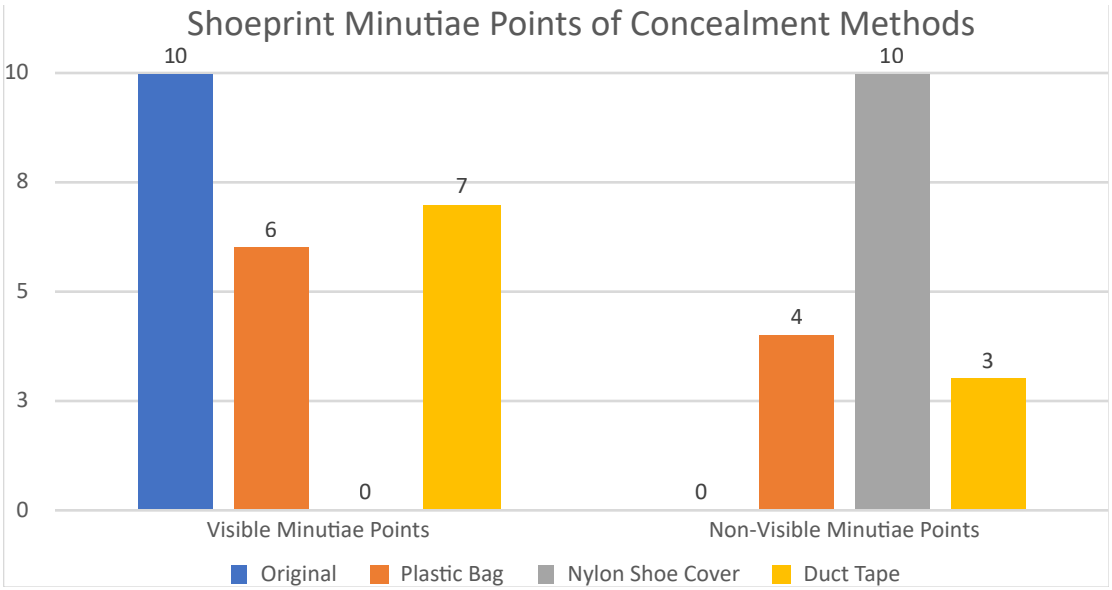
Fig. 5 Impression with plastic bag added in treatment two.

Fig. 6 Impression with duct tape added in treatment two.

The concealment method using a nylon shoe cover had the lowest number of visible marks of minutiae that were modeled in the control group (Fig. 4). The number of randomly acquired marks present in shoeprints display, similarly to the trials involving shoe impressions, the nylon shoe cover as producing the largest number of non-visible areas in shoeprints. The comparison between the control group, shoeprint, and the shoeprint made with the concealment methods is compared using photographic results (Graph 2).

Table 2 Categorized Minutiae Points of Shoeprints with Differing Concealment Methods

	Original	Plastic Bag	Nylon Shoe Cover	Duct Tape
Visible Minutiae Points	**10**	**6**	**0**	**7**
Non-Visible Minutiae Points	**0**	**4**	**10**	**3**
Total Minutiae Points	**10**	**10**	**10**	**10**



Graph 2 Shoeprint Minutiae Points of Concealment Methods

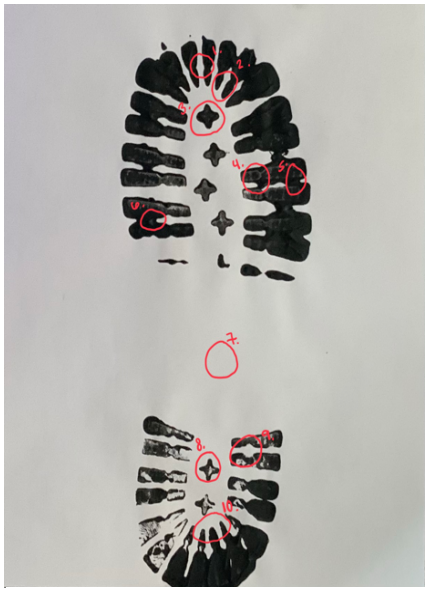


Fig. 7 Original shoeprint with no concealment method added in third treatment control.

Fig. 8 Shoeprint with nylon shoe cover used as the concealment method added in treatment three.

Fig. 9 Shoeprint with a plastic bag used as the

Fig. 10 Shoeprint with duct tape used as the concealment

differe isible accidental marks in comparison to the control group had the largest effect on casting shoeprints and

The concealment method using a nylon shoe cover produced similar results to the second trial by having the lowest number of visible marks of minutiae. There were no displayed visual similarities between the original shoeprint (Fig. 7) and the shoeprint impeded by a nylon shoe cover (Fig. 8). The plastic bag concealed more randomly acquired marks than the addition of duct tape to the shoe sole (Fig. 9 and 10).

Discussion

The results of the experiment show the shoe impressions and prints made with a nylon shoe cover as having the lowest number of visible minute characteristics specific to the tread of the shoe (Graph 1 and 2). The type of shoe concealment method with the largest impressions. Observing different shoeprints and impressions produced similar results in the number and pattern of visible points of characteristics. In both areas of the study the nylon shoe cover produced the least amount of visible randomly acquired marks that could be used to identify a match with the control group impression and shoeprint. Both treatments then display that the addition of a plastic bag and then duct tape is the order in which the visible accidental marks increase to identify footwear evidence. The shoe impressions and prints created with the use of duct tape produced the clearest footprints with the largest

number of identifiable points in both treatments, while the use of the nylon shoe cover created an obscured shoe impression and print (Fig. 4 and 8).

The comparison of randomly acquired marks allow the pattern of two shoe prints or impressions to be compared and reduce the prospects of having this category of forensic evidence be declared inadmissible (Petraco et al. 2010). With the use of a statistical algorithm, such as the Statistical Evaluation of Shoeprint Accidentals (SESA), randomly acquired marks can be compared to other accidental marks in a database to produce a score of rarity that can assist in the conclusion and credibility of forensic footwear comparison and identification (Wiesner et al. 2020). The use of synthetic data creates depth predictors to store with 3-dimensional images of shoe treads in an online database that can be compared to photographic evidence of shoe soles, impressions, and prints (Shafique 2022). The ability to declare a match between multiple pieces of footwear evidence is based on the assessment of numerous variables, such as the quantity of randomly acquired marks and the intricacy of the pattern of these marks, that creates the probability of another piece of footwear matching in the general population (Stone 2015).

When examining partial prints and impressions in footwear analysis, the scores and probabilities forensic experts consider to accurately declare findings decreases with the number of visible randomly acquired marks and the complexity of the configuration of these marks decreases as well. The identification of materials or resources used to conceal footwear can be used in combination with the statistical probability of declaring a match to produce results that are still considered admissible within the legal system. The ability to quantify the effect of elements that obscure shoeprints and impressions can be factored into regressions that can calculate information based on partial evidence to increase the reliability and statistical accuracy of results produced by forensic examiners.

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