JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, January 2011, Vol. 56, No. S1
doi: 10.1111/j.1556-4029.2010.01617.x
Available online at: onlinelibrary.wiley.com

PAPER

CRIMINALISTICS

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A Comparative Research of Two Lifting Methods: Electrostatic Lifter and Gelatin Lifter*

ABSTRACT: Two-dimensional dust shoeprints are often of very high resolution and contain unique features. Lifting these prints in the most effective method may contribute much to preserving these fine details. A research was conducted by experts from Israel and Switzerland to compare gelatin lifters and electrostatic lifters for lifting shoeprints. Several substrates were chosen, and on each material a set of dry dust shoeprints was made. A set of wet prints was made on paper as well. The shoeprints were approximately of the same quality, and the only variable was the nature of the material. On substrates indifferent to the method used, the preferable sequence was tested. Gelatin lifter was superior on most substrates and for wet prints. The superior sequence for using both methods is electrostatic lifting followed by gelatin lifter.

KEYWORDS: forensic science, shoeprints, footwear impression, electrostatic dust print lifter, gelatin lifter, pneumatic press, dust print

Two-dimensional dust shoeprints found at crime scenes are often of very high resolution and contain unique features. Thus, it is most desirable to lift these prints in the most effective method. Several methods are known and practiced by crime scene officers. Professional literature dealing with the documentation of shoeprints describes several methods to lift those traces. These methods include electrostatic lifting (1), lifting by means of adhesive lifter (2), and lifting with gelatin lifters (3). The electrostatic lifter (ESL) method was developed in Japan in 1970 (4). In the mid-1980s, it was introduced in the U.S.A. (5), and since has become popular and one of the common methods used for recovering dust shoeprints.

The method of lifting shoeprints with gelatin films has been known for many years. The first gelatin surfaces used were those present on photographic film (6). The gelatin coating on photographic film was too thin for practical use, and therfore the "Lift Print" was developed. The "Lift Print" was simply a black rubber backing with a supplied surface which, once used, could be cleaned and used again (7). Commercial gelatin lifters were developed as an improvement to these methods, and their use is more efficient and convinient.

Electrostatic lifting and gelatin lifters are complementary methods. When trying to recover a shoeprint from any substrate, the examiner should decide which method should be applied for lifting. Bodziak (1) recommends using gelatin lifters mainly in the absence of an ESL device or if the ESL method will not be successful because of the nature of the impression. The questions arise: Why prefer the ESL and not the gelatin lifter? Is one method superior to the other, in general? Perhaps on certain substrates or under certain circumstances (wet/dry)? If no one method shows an advantage over the other, is there a sequence of the two that yields better results than just one of them alone?

A decade ago, a presentation was made by Carlsson (8). The conclusions presented were that on many substrates, the ESL is better than or equal to the gelatin lifter, except in the case of wet shoeprints where the gelatin gave superior results. Since then, some innovations were introduced concerning the method of using gelatin lifters (9,10), and they challenge the conclusions presented by Carlsson. In this paper, research was conducted by experts from Israel and Switzerland, and the two methods were compared again on several substrates using the new methods and techniques existing today.

Adhesion Forces—Scientific Background

In the adhesion process, the dust particles are captured between the substrate and the adhesive media. The particles will transfer to the adhesive media if the sum of all the forces applied on them, chemical and physical, is greater than the forces applied by the hosting substrate.

The efficiency of lifting dust shoeprints is derived directly from the adhesion of the dust to the lifting substrate. Adhesion can occur through several mechanisms: physical adsorption, chemical bonding, diffusion, electrostatic forces, and mechanical interlocking. The type of surface involved in a particular adhesion situation determines the implicated mechanisms in the adhesion process (11).

Electrostatic lifting and gelatin lifting have different mechanisms for lifting the dust shoeprints. With the ESL method, a metal sheet coated with an insulating layer is electrically charged, and the static electricity attracts to the surface with the dust shoeprint on it. The metal sheet reserved a weak electric charge that keeps the dust particles intact. This method is effective only on surfaces resistant to electric flow and charged positively. As a result of the surface charge imbalance, the metallic sheet is attracted to the surface. The presence of surface charge imbalance means the metallic sheet and

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*Presented at the 6th SPTM Meeting, May 29–June 1, 2007, in Copenhagen, Denmark.

Received 15 Nov. 2009; accepted 23 Jan. 2010.

the surface will exhibit attractive forces. The attraction force is dependent on the nature of the surface; if the surface is rough, less contact is made between the surfaces, the distance between the particles on the surface and the metal foil is greater; hence, the attractive forces are smaller as expressed by Coulomb's law

$$\vec{F} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} \quad (1)$$

while (r) is the distance between the surface and the metal foil. Substrates charged positively to a greater extent will be more attracted to the metallic sheet.

The gelatin lifting method works in a totally different way than ESL. The gelatin lifter is made of a thick black gel layer on a woven surface. The gel is sticky and porous. The lifter is pressed against the surface with the dust shoeprint, the gelatin penetrates into the pores of the substrate and the dust particles stick to it. Peeling the gelatin lifter removes the dust particles as well, and they remain in their original arrangement. The forces between the dust particles and the gelatin lifter are adhesion forces. Good adhesion is created when the adhesive and the adherent have similar solubility parameters. The surface of the adherent is usually rough and porous, hence increasing the area of physical contact. Pore penetration by adhesives is dependent on the radius of the pore and the adherent size. One of the criteria for obtaining a good adhesive bond is that the surfaces of the materials spontaneously "wet" each other.

In the thermodynamics theory, the equilibrium equation of minimal Helmholtz free energy, between area surface (dA') and a particle (i) is:

$$dA' = \sum_i \mu_i (dn_i) \quad (2)$$

where (dA') is the free energy of a surface area, μi the chemical potential of component i, dn_i is the number of atoms that cross between the particle surfaces for each component i.

The change in the Helmholtz free energy per interface unit area (dA) is dependent on the surface tension and the surface energy as described in the next equation:

$$dA' = \gamma\, dA \text{(When the temperature and the volume are constant)} \quad (3)$$

γ is a constant that describes the surface tension calculated from the number of chemical bonds broken per unit area, multiplied by energy per bond.

In other words, the surface tension (γ) is the work required to create a unit area for a new surface. This factor plays a major role in the boundary's shape created between the two surfaces.

The boundary interaction between two materials A and B is determined by the difference between their surface tensions. Figure 1*a* shows two boundaries between the two phases of A and B on the left side of the figure ($\gamma_{\alpha\beta}$) and the boundary surface phase of A on the right side of the figure ($\gamma_{\alpha\alpha}$). δ is the dihedral angle between the two phases. This angle is determined by the differences between this two γ factors. It is influenced by the surface tension force balance between surface and particle.

There are two extreme states: "no wetting" and "complete wetting".

- When $\gamma_\alpha >> \gamma_\beta$, δ = 180, hence there is no wetting (see Fig. 1*b*, like Mercury on glass).
- When $\gamma_\alpha \leq 0.5\ \gamma_\beta$, δ = 0, hence there is complete wetting (see Fig. 1*d*, like oil on glass).
- The intermediate state is when $\gamma_\alpha = \gamma_\beta$, δ = 120 (see Fig. 1*c*, like water on glass).

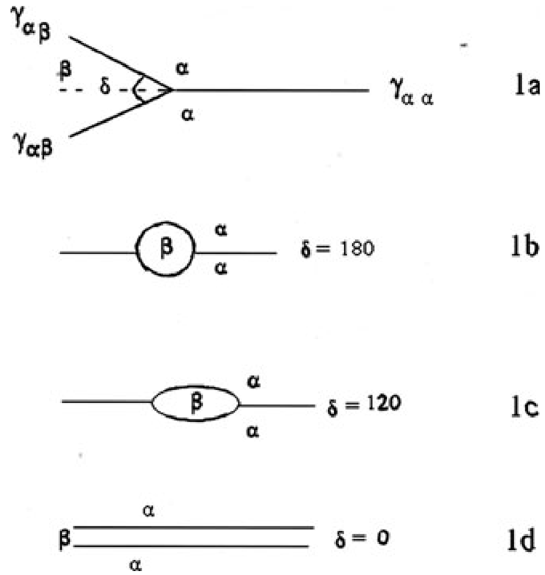

FIG. 1—*Schematic presentation of the relation between surface and particle for two different dihedral angles. (a) Two boundaries between two phases (a and b). (b) No wetting, δ = 180. (c) The intermediate state between complete wetting and no wetting, δ = 120. (d) Complete wetting, δ = 0.*

For all adhesion methods, the cohesive energy density (CED) determines whether the molecules, in our case the dust, will be separated from the surface (12).

$$\text{CED} = \frac{E_{\text{coh}}}{V}$$

E_{coh} is the amount of energy necessary to separate molecules to an infinite distance. V is the molar volume. This equation explains why very dust shoeprints, with higher molar volumes, are lifted more easily than prints with very little dust.

Methods

Several dust shoeprints were placed on various substrates. The materials were flannel cloth, "Masonite" (compressed cardboard), corrugated cardboard, plastic sheet, crumpled brown wrapping paper, white paper, linoleum, plaster board, and towel cloth. All the shoeprints were prepared using shoes with a controlled amount of dust. The person wearing the shoes stepped on adhesive lifters until they were clean then walked down the corridor for 50 m. After this process, two sets of shoeprints were left on each surface. One was lifted using the ESL method, and the other using gelatin lifters.

Moist prints were left on paper as well. After walking down the corridor, a slightly wet sponge was stepped on, and then the prints were placed on the papers. The prints were lifted after they were air-dried for several hours.

Whole shoeprints were lifted with each method instead of dividing them in half because as mentioned above, the amount of dust was controlled, and this way, fine details could be compared. A second set of experiments was performed on substrates on which no lifting method has proved superior, to determine the correct sequence using both methods.

A shoeprint was divided lengthwise in half. One-half was lifted using the ESL and then the whole shoeprint was lifted using a black gelatin lifter. The same process was repeated using the gelatin lifter first.

TABLE 1—*Results of both methods.*

Material	Clarity		Fine Details		Absence of Extraneous Materials Attaches to the Print		Print Without Substrate Texture	
	Gelatin Lifter	ESL	Gelatin Lifter	ESL	Gelatin Lifter	ESL	Gelatin Lifter	ESL
Corrugated cardboard*	++	+	++	+	+++	+	−	++
Flannel cloth*	++	+	+	−	++	+	+++	++
Towel*	++	−	+	−	++	+	+	+++
Brown paper	+++	++	++	+	+	++	++	++
Mazonite	++	−	++	−	+	+	+	+
Plastic sheet	+++	+++	+++	+++	+++	+++	+++	+++
White paper	+++	+++	+++	+++	+++	+++	+++	+++
PVC–linoleum	+++	+++	++	++	+++	+++	+++	+++
Plaster board*	+	++	+	+	−	+	++	++
Dusty floor	+	++	++	++	−	+	+	++
Wet prints	+++	−	+++	−	++	+	+++	+

*After cleaning with adhesive lifter.
ESL, electrostatic lifter.
+++ Very good; ++ good; + fair; − not adequate.

TABLE 2—*The comparison between the methods.*

GEL>>ESL	GEL = ESL	GEL << ESL
Corrugated cardboard	Plastic sheet	Plaster board
Flannel cloth	White paper	Dusty floor
Towel	PVC–linoleum	
Brown paper		
Mazonite		
Wet prints		
Nonflat porous surfaces		

ESL, electrostatic lifter.

The ESL was conducted using a big electrostatic dust print lifter (Lightning Powder Company, Jacksonville, FL).

The gelatin lifter method was applied using the Press method (9). Pressure was applied using an adjustable pneumatic press. When necessary, the cleaning procedure was applied on the gelatin lifters (10). Black 180×360 mm^2 size gelatin lifters (BVDA International, 2002 Ch Haarlem, Holland) were used for lifting the dusted imprints.

Each print was photographed prior to lifting, and the lifted print was photographed immediately after treatment as well.

The quality of each shoeprint was then evaluated according to several criteria: the clarity of the print, the presence of fine details, the amount of extraneous materials attached to the print, and the appearance of the substrate texture.

Results and Discussion

The results can be divided into three categories: substrates on which the ESL gave better results than the gelatin lifter, substrates on which the quality of the lifted prints was the same, and substrates on which the gelatin lifters were superior. These differences indicate that no one method is superior to the other on all substrates. The results are shown in Tables 1 and 2.

On most substrates, the gelatin lifter gave better results, for example on flannel cloth (Fig. 2*a–c*). The greater adhesive force of the sticky gelatin layer was more successful in collecting most of the dust forming the shoeprint, while the results obtained by the ESL were not as good because of the weaker electrical force applied.

Electrostatic lifting and gelatin lifting have different mechanisms for lifting the dust shoeprints. With the ESL method, a metal-

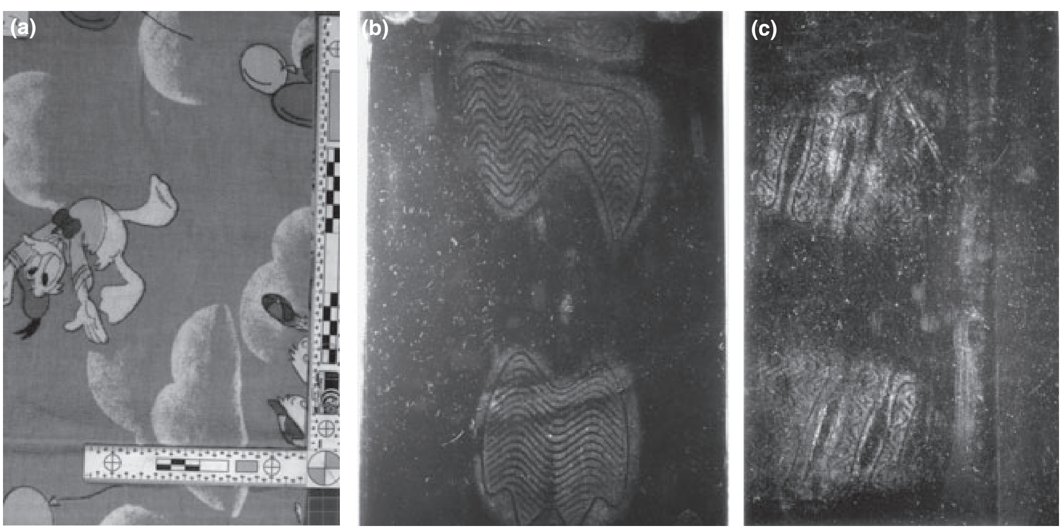

FIG. 2—*The results of the gelatin and the electrostatic lifter (ESL) on flannel cloth. (a) The flannel cloth with a faint shoeprint on it. (b) Gelatin lifter (after cleaning from loose fibers). (c) ESL lifter.*

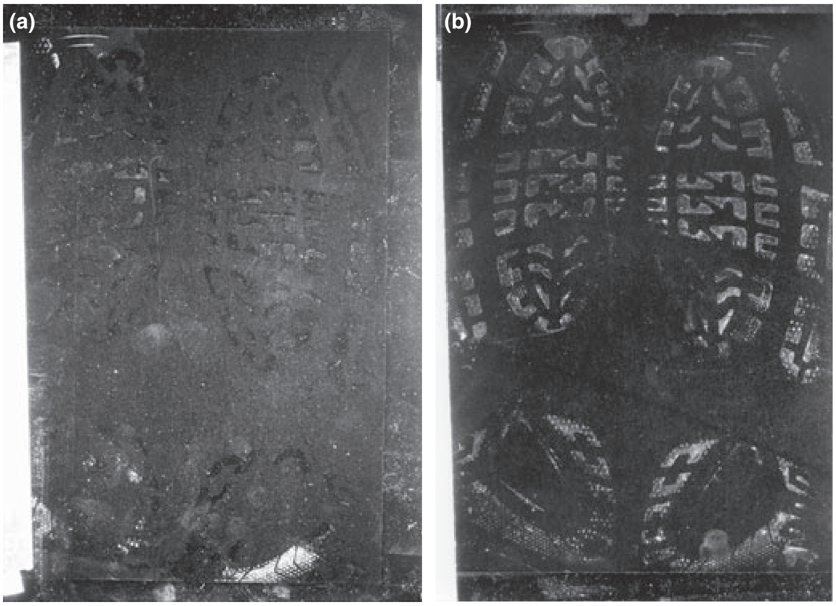

FIG. 3—*Shoeprints collected from wet paper. (a) Electrostatic lifter. (b) Gelatin lifter.*

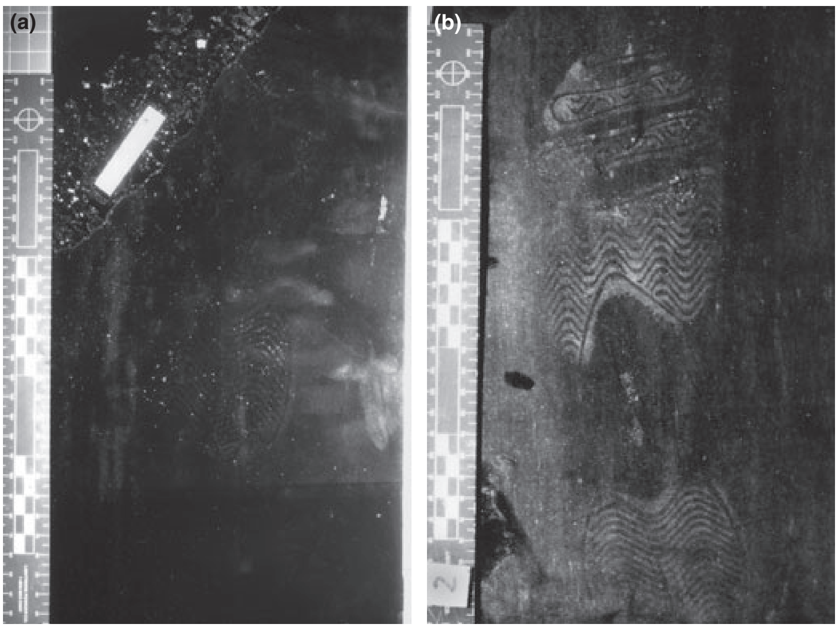

FIG. 4—*Shoeprints collected from plaster board. (a) Gelatin lifter. (b) Electrostatic lifter.*

coated sheet is electrically charged, and the static electricity attracts the surface with the shoeprint on it and the dust particles. The dust particles, in the ESL method, are charged with electrical (positive) charge, and they are transferred from the original surface to the charged sheet. Weak electric forces bind the dust to the metallic sheet used for the ESL method.

When applied to thick porous surfaces, the ESL's metallic sheet was not able to adhere properly to the surface by applying electrical current. This phenomenon occurred because the average microscopic distance between the surface and the metallic sheet is greater than on smooth and flat surfaces, as shown in the fundamental equation of electrostatics, Coulomb's law, thus reducing the adhesive force.

Coulomb's law, which describes the force between two point charges Q_1 and Q_2:

$$\text{Coulomb's law} : \vec{F} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} \quad (1)$$

The equation shows that the force $\vec{F}$ between the surfaces is dependent on the charge of the metallic sheet by the power source (Q_1) and the positive charge of the substrate with the shoeprint on it (Q_2). The force is also oppositely dependent on the distance between the surfaces (r). This distance is derived from the roughness of the material.

The gelatin lifter does not suffer from this problem because physical pressure is applied on the gelatin lifter and it adjusts to the topography of the surface. The roughness of the surface is an advantage to this method, because the forces between the dust particles and the gelatin lifter are adhesion forces. Good adhesion is created when the adhesive and the adherent have similar solubility parameters. The surface of adherent is usually rough and porous, hence increasing the area of physical contact.

On wet prints, the ESL gave poor results (Fig. 3*a*), and even the gelatin lifter needed more time and force to detach the dust particles from the substrate (Fig. 3*b*). The disadvantage of the ESL method on wet prints or on prints of wet origin is mentioned in the literature (1,8) and was demonstrated in our research as well.

This phenomenon might be due to the greater depth of penetration of the wet dust particles into the porous paper or because the wet particles create a stronger bond with the paper, a dipole bonding, instead of van der Waals bonds. The force and penetration depth needed for detaching the captured dust particles are greater than those for dry dust prints.

On plaster boards and dusty floors, the ESL gave better results than the gelatin lifter (Fig. 4*a*,*b*). This might be attributable to the large amount of various sized loose particles that are collected by the gel, hence masking the print, while the weaker force of the ESL lifts only the right amount of fine dust to show a good image of the shoeprint.

On the plastic sheet, white paper and the PVC or linoleum, both methods gave excellent results. On all of these substrates, effective adhesion built up with the ESL, and good contact was created with the adhesive layer of the gelatin lifter. The comparative method was then applied on these substrates, and on all of them the same phenomenon occurred. Even though the ESL lifted the first print half nicely, lifting the complete print with the gelatin lifter yielded excellent whole prints. On the other hand, when the gelatin lifter was applied first on half of the print, the ESL lifted only the print half that was not treated with the gelatin lifter first.

Conclusions

As can be seen from the results of these experiments, the optimal process is not the same for all shoeprints. The gelatin lifting methods seemed to be superior to the ESL methods on most of the substrates, especially on nonsmooth, porous, and fibrous substrates. It is important to mention that many times the superiority of the gel method was revealed only after the cleaning procedure was applied. On wet origin shoeprints, the advantages were even more dramatic.

On the other hand, on big surfaces, such as floors, and on dusty substrates with big concealing particles, like plaster board, the ESL gave better results. On smooth clean surfaces, both methods performed well. The authors' recommendation is that on these surfaces, and in any case of doubt, the ESL should be applied first and then the gelatin lifter. The ESL will not influence the quality of the print later recovered with the gelatin lifter, because the ESL removes only a small portion of the dust, and enough is left on the surface to be removed with the gelatin lifter.

Conflict of interest: The authors have no relevant conflicts of interest to declare.

Acknowledgment

The authors thank Eliot Springer, Scientific Deputy to the head of the DIFS, for his editorial assistance.

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