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Development of latent fingerprints contaminated with ethanol on paper surfaces

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Abstract Fingerprints may be contaminated with ethanol solutions. In order to solve the case, the law enforcement agency may need to visualize the fingerprint from these samples, but the development method has not been studied. The paper with latent fingerprint was contaminated with ethanol solution and then the blurring of ridge detail was observed. As a result, when the copy paper was contaminated with ethanol solutions of less than 75 % (v/v), the amino acid components of latent fingerprint residue blurred but lipid components of latent fingerprint residue didn't blurred. On the other hand, when the paper was contaminated with ethanol solution of more than 80 % (v/v), the amino acid components of latent fingerprint didn't blurred but the lipid components of latent fingerprint blurred. Therefore, it is found that the paper contaminated with ethanol solutions of less than 75 % (v/v) should be treated by oil red O (ORO) enhancing lipid components, and the paper contaminated with ethanol solutions of 80 % (v/v) or more should be treated by 1,2-indandione/zinc (1,2-IND/Zn) enhancing amino acid components. The blurring of ridge detail was not observed when the fingerprints were deposited with fingers contaminated with ethanol solution. This fingerprints were treated with 1,2-IND/Zn or ORO to compare the latent fingerprint development ability, and using 1,2-IND/Zn was able to visualize the latent fingerprint more clearly than using ORO.

Key words: ethanol, contaminated fingerprint, paper, 1,2-indandione/zinc (1,2-IND/Zn), oil red O (ORO), blurring

1. Introduction

Fingerprints play a crucial role in solving crimes.[1] However, most fingerprints left at a crime scene are latent fingerprints that are not visible to the naked eye without a fingerprint developing process.[2] Thus, latent fingerprints must be appropriately developed to be visible to the naked eye in order to use them to identify a victim or suspect, or to compare with other fingerprints.[1] For this reason, developing latent fingerprints is a critical process in forensic science, and numerous forensic scientists have researched optical,[3,4] physical,[5,6] and chemical[7,8] methods for developing latent fingerprints. As a result, it has been found that different methods of development must be used depending on the components of the fingerprint

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residue and the surface upon which the fingerprint is deposited.[9]

Considering fingerprints residue components on a porous surface such as paper, moisture evaporates over time, leaving amino acids, lipids, salts, and urea. Depending on the state of the item (e.g., wet, burned) and fingerprint residue components, amino acid sensitive reagents and lipid sensitive reagents must be used for selective treatment.[10] Latent fingerprints on a porous surface that has never been wet can be developed using ninhydrin,[7,11] which reacts with amino acids, or its analogue 1,2-indandione/zinc (1,2-IND/Zn)[12-14] or 1,8-diazafluoren-9-one (DFO).[15,16,17] However, if a item with fingerprints is wet with water, the fingerprint cannot be developed with amino acid sensitive reagents because the amino acid components of the fingerprint are dissolved in water.[9,18,19] In such cases, the latent fingerprint can be developed using a lipid sensitive reagent, because lipids do not dissolve in water.[15] Common reagents for this purpose include oil red O (ORO)[8,20,21] and Nile red.[19,22]

Items upon which latent fingerprints have been deposited can be contaminated by various liquids encountered in daily life (e.g., alcoholic drinks, juice, milk, carbonated drinks).[23] Among them, ethanol-contaminated fingerprints are likely to be found at crime scenes because ethanol is included in a variety of products, such as alcohol, cleansers, and sanitizers. Contamination of objects with fingerprints by ethanol solution or touching of an object with ethanol-contaminated hands are such cases. In a study on developing fingerprints deposited on an object and contaminated with ethanol, Cohen *et al.* (2012), after touching a face and hair, deposited fingerprints on the surface of a polyvinyl chloride (PVC) window shutter and a white powder-coated aluminum window frame. Then, they contaminated the fingerprints with three types of cleaning agents with ethanol content < 5 % (v/v), and treated them with black magnetic powder. They found that fingerprints from the PVC window shutter and aluminum window frame were not developed, depending on the type of cleaning agent used.[23] After touching a face, then depositing a fingerprint on the surface of aluminum foil, contaminating it with beer and wine, and treating it with black magnetic powder or small particle reagent (SPR), Maslanka (2016) reported that a fingerprint treated with black magnetic powder was similarly or more clearly developed than a fingerprint treated with SPR.[24] In a study on developing fingerprints deposited by a hand contaminated with ethanol solution, Chadwick *et al.* (2017) applied an alcohol-based hand sanitizer on the hands, dried it for 20–30 seconds, deposited fingerprints on copy paper, and developed the fingerprints using 1,2-IND/Zn, ninhydrin, and physical developer (PD). The results showed that fingerprints were most clearly developed with 1,2-IND/Zn.[25] However, there has been no report on whether targeting amino acid or lipid components would better develop fingerprints when paper with fingerprints is contaminated with ethanol or is touched with an ethanol-contaminated hand.

Because ethanol consists of both polar and nonpolar functional groups, it can dissolve water-soluble substances such as amino acids[26] as well as insoluble substances such as lipids.[27] Fingerprints can be contaminated by alcoholic drinks, mouthwash, and hand sanitizers, as opposed to pure ethanol solution, and in such cases, the properties of dissolving amino acids or lipids included in the fingerprint residue components would vary due to the water content in the ethanol-containing product. Thus, fingerprints residue components would be washed away differently, and different methods need to be used to develop the fingerprints. However, to the best of our knowledge, there has been no relevant study.

2. Materials and Methods

2.1. Materials

ORO powder from Alfa Aesar (USA), 1,2-IND powder from 1,2-IND Sirchie (USA), and zinc chloride from Merck (Germany) were used. Cass beer (Oriental Brewery, Korea), Chamisul Fresh soju (Hite Jinro, Korea), Garglin Original mouthwash (Donga Pharmaceuticals, Korea), and Dettol Original hand sanitizer (Dettol, Thailand) were used.

The LS301 scale from Libra (Korea) and SSP-2308 digital steam press from Sienna (USA) were used. A 505-nm light source (Polilight Flare Plus 2 from Rofin, Australia) and orange filter from Rofin (Australia) were used. A D3400 camera from Nikon (Japan) was used with a 60 mm f/2.8 2X Ultra Macro lens from Laowa (China).

2.2. Fingerprint

Latent fingerprints were deposited by men and women in their 20s by pressing down their right thumbs for 5 seconds such that the needle of the scale pointed to 500 ± 100 g. Three types of latent fingerprints were prepared: eccrine gland secretion fingerprints, sebaceous gland secretion fingerprints, and natural fingerprints. The eccrine gland secretion fingerprints were prepared by having fingerprint donors wash hands with soap and water and wear plastic gloves for 30 minutes to secrete sweat before depositing a fingerprint with the right thumb. The sebaceous gland secretion fingerprints were prepared by having donors wash hands with soap and water and rub their noses with their right thumbs three times before depositing a fingerprint. The natural fingerprints were prepared by having donors deposit fingerprints after 30 minutes of free activity without washing hands.

2.3. Methods

Zinc chloride stock solution was prepared by dissolving 0.4 g of zinc chloride in 10 mL of ethanol and adding 1 mL of ethyl acetate and 190 mL of petroleum ether. The 1,2-IND/Zn solution was prepared by adding 80 mL of zinc chloride stock solution to a solution containing 0.8 g of completely dissolved 1,2-IND in 90 mL of ethyl acetate and 20 mL of acetic acid; then adding 820 mL of petroleum ether.[28] Fingerprints were developed by dipping them in the 1,2-IND/Zn solution for 5 seconds, completely drying them, and then applying heat for 10 seconds at 180 °C using a digital steam press.

The ORO solution was prepared by mixing a solution containing 9.2 g of sodium hydroxide dissolved in 230 mL of deionized water, with a solution containing 1.54 g of ORO powder dissolved in 770 mL of methanol, and then filtering the mixture. The washing buffer solution was prepared by dissolving 26.5 g of sodium carbonate in 2000 mL of deionized water, adding 18.3 mL of concentrated nitric acid, and then adding deionized water to the 2500 mL mark.[28] When staining with ORO, the fingerprint was dipped in the ORO solution for 5 minutes, taken out, and washed with the buffer solution. All experiments were performed in a laboratory with temperature and relative humidity maintained at 21 ± 10 °C and 50 ± 20%, respectively.

3. Results and Discussion

There are two ways by which paper at a crime scene could be contaminated with ethanol solution. The fingerprint could be contaminated with ethanol solution after being deposited, or the fingerprint could be deposited by a hand already contaminated with ethanol. Therefore, both cases were examined in this study.

3.1. Development of latent fingerprint contaminated with ethanol solution after deposition on paper

After depositing an eccrine gland secretion fingerprint or sebaceous gland secretion fingerprint on copy paper, it was contaminated with ethanol solution by submerging it in 0–100 % (v/v) ethanol solution for 5 seconds and then taken out and dired for 1 day. The eccrine gland secretion fingerprints were developed with 1,2-IND/Zn and sebaceous gland secretion fingerprints were developed with ORO. The results are shown in *Fig.* 1. The eccrine gland secretion fingerprint in *Fig.* 1 shows that the ridges are severely blurred when exposed to a low-concentration ethanol solution, but the ridge blurring decreased with exposure to more concentrated ethanol solutions. A fingerprint with good ridge detail is shown when it was exposed to a high-concentration of ethanol solution (≥ 80 % v/v). On the other hand, for the sebaceous gland secretion fingerprints, the ridges were not blurred and developed well when contaminated

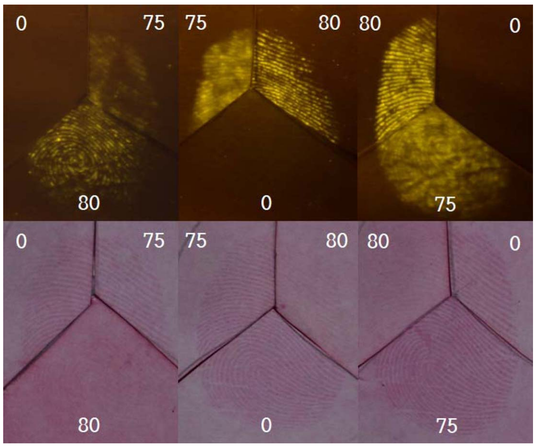


Fig. 1. The blurring of the eccrine and sebaceous gland secretion fingerprints contaminated with ethanol solutions (The numbers shown in the figure are the % (v/v) concentration of the ethanol solution that contaminated the fingerprint). Top: Eccrine gland secretion fingerprint treated with 1,2-IND/Zn. Bottom: Sebaceous gland secretion fingerprint treated with ORO.

with ethanol solution of ≤ 75 % (v/v), but the ridges blurred and fingerprints could not be developed when the sample was contaminated with an ethanol concentration of ≥ 80 % (v/v). These results seem to have resulted from the fact that, as the ethanol concentration decreases, the fraction of water content in the solution increases, thereby washing away more amino acid components and less lipid components, and vice versa.

These results show that ORO should be used when copy paper with fingerprints is contaminated with ethanol solution of ≤ 75 % (v/v) and 1,2-INDZn should be used when contaminated with ethanol solution of ≥ 80 % (v/v) in order to develop latent fingerprints with good ridge detail. To confirm this, natural fingerprints contaminated with ethanol solution with a concentration of 0–100 % (v/v) were split into two fragments. One fragment was treated with 1,2-IND/Zn while the other was treated with ORO. The results are shown in *Fig.* 2. As predicted, using ORO for latent fingerprints contaminated with ethanol solution with a concentration of ≤ 75 % (v/v) and using 1,2-IND/Zn for those contaminated with ethanol solution with a concentration of ≥ 80 % (v/v) best developed the fingerprints and provided good ridge detail.

The above results were obtained using pure ethanol solutions. However, ethanol-containing products on the market, such as beer, soju, mouthwash, and hand sanitizers, are not pure ethanol solutions. Therefore, actual items contaminated with such products should be tested in order for our results to be applied to real cases. *Fig.* 3 shows the results of contaminating natural fingerprints using products with varying ethanol concentrations (≤ 75 % v/v), including beer (4.5 % v/v), soju (17.2 % v/v), mouthwash (8 % v/v), and hand sanitizer (60–75 % v/v). Each of these was split into two fragments, one of which was treated with 1,2-IND/Zn and the other with ORO. As predicted, natural

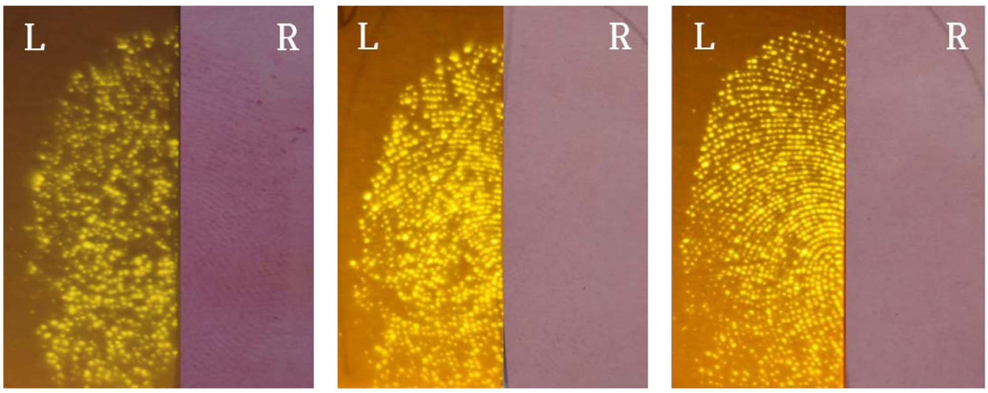


Fig. 2. The blurring of the natural fingerprints contaminated with ethanol solutions. Left: Fingerprint treated with 1,2-IND/Zn. Right: Fingerprint treated with ORO.

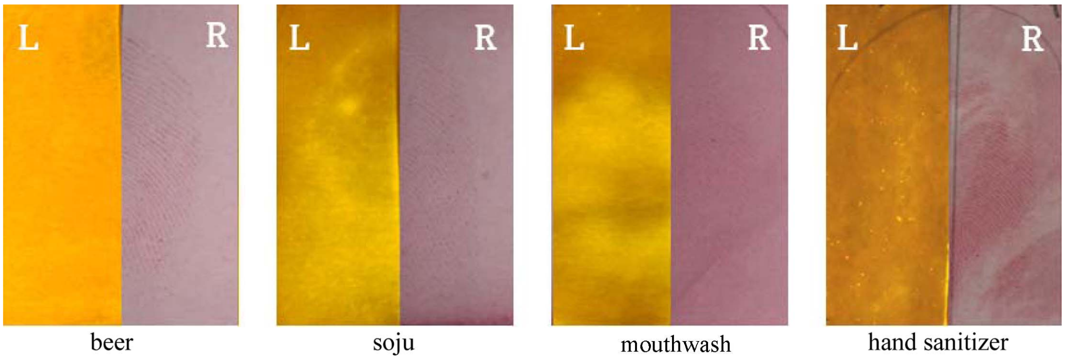


Fig. 3. The blurring of the natural fingerprints contaminated with beer, soju, mouthwash and hand sanitizer. Left: Fingerprint treated with 1,2-IND/Zn. Right: Fingerprint treated with ORO.

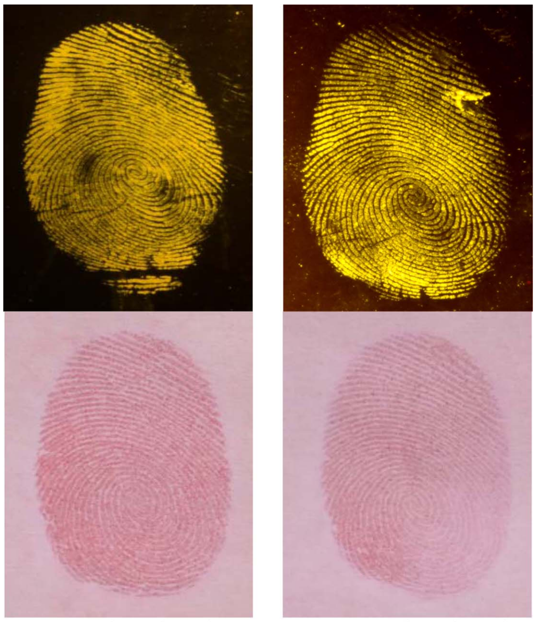
fingerprints contaminated with beer, soju, mouthwash, and hand sanitizer developed well without ridge blurring when treated with ORO, but the fingerprints were not developed well when treated with 1,2-IND/Zn. This shows that ORO can be used to develop fingerprints even when contaminated with solutions other than pure ethanol. Most market products with ethanol (e.g., alcoholic drinks, mouthwash, hand sanitizer) have ethanol content < 80 % (v/v). Therefore, when developing latent fingerprints exposed to market products with ethanol, reagents that enhance lipid components, such as ORO, should be used.

The 1,2-IND/Zn working solution consists of ethanol, ethyl acetate, petroleum ether, and acetic acid, whereas the ORO working solution consists of water and methanol. Water in the working solution can dissolve amino acids while organic solvents can dissolve lipid components. This means that it is impossible to re-treat with ORO after first treating with 1,2-IND/Zn or vice versa. Thus, when attempting to develop fingerprints from ethanol-contaminated paper, they need to choose between 1,2-IND/Zn and ORO. Investigators do not know whether the ethanol-contaminated item they are investigating has been exposed to an ethanol solution with a concentration of < 80 % (v/v) or ≥ 80 % (v/v). Nearly all ethanol solutions on the market have a concentration of < 80 % (v/v), and ethanol solutions with concentration of ≥ 80 % (v/v) are available only in special environments, such as chemical laboratories or chemical plants. Thus, ORO is recommended when treating fingerprints contaminated with ethanol at a general crime scene outside a chemical laboratory or chemical plant.

3.2. Development of latent fingerprints deposited on paper with finger contaminated with ethanol solution

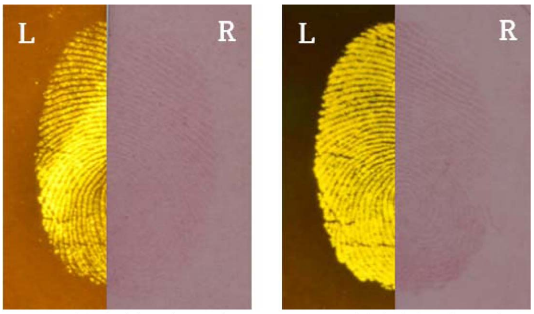
Immediately prior to depositing an eccrine gland secretion fingerprint or sebaceous gland secretion fingerprint, 1 mL of ethanol solution of varying concentrations (0–100 % v/v) was dripped onto the thumb, and the donors were asked to rub their thumb with their index and middle fingers to apply the ethanol solution evenly over the finger surfaces. Then the thumb was used to deposit a fingerprint on copy paper. Next, eccrine gland secretion fingerprints were treated with 1,2-IND/Zn, and sebaceous gland secretion fingerprints were treated with ORO. The results are shown in *Fig.* 4, in which good ridge details are achieved for both eccrine gland secretion fingerprints and sebaceous gland secretion fingerprints when the fingerprints were deposited by a finger contaminated with ethanol solution with a concentration of 0–100 % (v/v).

These results show that ethanol concentration does not affect fingerprint ridges when depositing fingerprints with ethanol-contaminated fingers. To confirm this, the thumb was contaminated with ethanol solution (0–100 % v/v) immediately prior to depositing a natural fingerprint on copy paper, and the deposited fingerprint was split into two fragments to treat one fragment with 1,2-IND/Zn and the other with ORO.



0 % (v/v) ethanol 100 % (v/v) ethanol

Fig. 4. Blurring of the fingerprints deposited with fingers contaminated with 0 % (v/v) and 100 % (v/v) ethanol. Top: Eccrine gland secretion fingerprint treated with 1,2-IND/Zn. Bottom: Sebaceous gland secretion fingerprint treated with ORO.



0 % (v/v) ethanol 100 % (v/v) ethanol

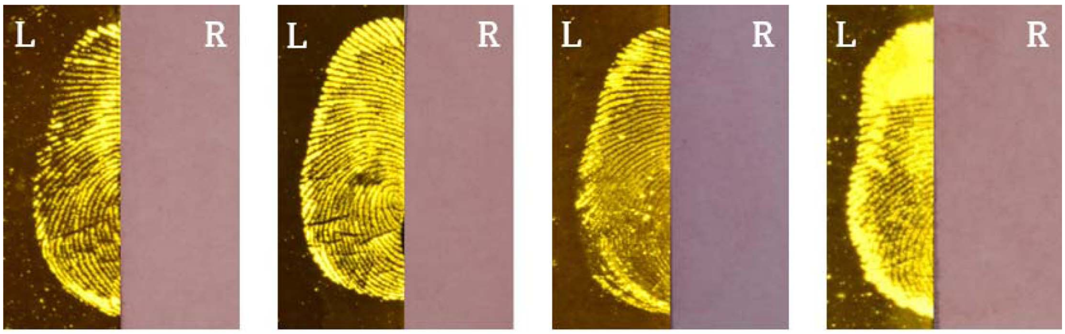
Fig. 5. Blurring of the fingerprints deposited with fingers contaminated with 0 % (v/v) and 100 % (v/v) ethanol. Left: Fingerprint treated with 1,2-IND/Zn. Right: Fingerprint treated with ORO.

As shown in *Fig.* 5, there was no ridge blurring in either case despite the fact that the fingerprints were deposited using fingers contaminated with ethanol solution of 0–100 % (v/v). Treatment with 1,2-IND/Zn led to more developed fingerprints than did treatment with ORO. These results seem to be due to the fact that sweat contains an abundance of amino acids,[29] and that 1,2-IND/Zn reacts with amino acids to generate strong fluorescence.[30]

These results were obtained by contaminating the finger with pure ethanol solution. However, ethanol-containing products on the market, such as beer, soju, mouthwash, and hand sanitizers, are not pure ethanol solutions, so actual items contaminated with such products should be tested in order for our results to be applied to actual crime cases. *Fig.* 6 shows the results of splitting natural fingerprints contaminated with varying ethanol concentrations (≤ 75 % v/v) using beer (4.5 % v/v), soju (17.2 % v/v), mouthwash (8 % v/v), and hand sanitizer (60–75 % v/v) into two fragments. One fragment of each pair was treated with 1,2-IND/Zn and the other with ORO. The figure shows that ridge blurring was not observed in any of the natural fingerprints deposited with fingers contaminated with beer, soju, mouthwash, and hand sanitizer. Moreover, 1,2-IND/Zn was more sensitive than ORO to develop latent fingerprints deposited with fingers contaminated with ethanol-containing solutions. Chadwick *et al.* (2017) reported that 1,2-IND/Zn can be used to develop clear fingerprints left with fingers after applying an alcohol-based hand sanitizer,[25] which is in line with our findings. Our results show that 1,2-IND/Zn should be used to develop latent fingerprints deposited with fingers contaminated with ethanol-containing solution.

4. Conclusions

In this study, the development of latent fingerprints on copy paper contaminated with 0–100 % (v/v) ethanol solution was attempted with 1,2-indandione/zinc (1,2-IND/Zn) or oil red O (ORO). The results showed that fingerprints were successfully developed using ORO for those contaminated with a concentration of of ≤ 75 % (v/v) ethanol and better developed using 1,2-IND/Zn for those contaminated with a concentration ≥ 80 % (v/v). Latent fingerprints deposited on copy paper that were contaminated with ethanol of ≤ 75 % (v/v) from commercial products such as beer, soju, mouthwash, and hand sanitizer were developed with better ridge detail when treated with ORO rather



beer soju mouthwash hand sanitizer

Fig. 6. The blurring of the natural fingerprints contaminated with beer, soju, mouthwash and hand sanitizer. Left: Fingerprint treated with 1,2-IND/Zn. Right: Fingerprint treated with ORO.

than 1,2-IND/Zn.

We also treated fingerprints deposited on copy paper by fingers contaminated with 0–100 % (v/v) ethanol with 1,2-IND/Zn or ORO and found that these fingerprints should be developed with 1,2-IND/Zn. Latent fingerprints deposited on copy paper with fingers contaminated with beer, soju, mouthwash, or hand sanitizer were developed with better sensitivity when treated with 1,2-IND/Zn compared to ORO.

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