

Preliminary studies into the secondary transfer of undeveloped latent fingerprints between surfaces

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Journal of Forensic Identification 68 (3): 421-437.

Abstract

This study investigates the possibility and conditions for transfer of undeveloped fingerprints. The lack of research in this area has made it complicated for experts to provide a substantiated response when questioned on the transfer of latent fingerprints in Western Australian and overseas courts. Latent fingerprints were deposited on a glass surface, transferred to commercial printing paper and developed for visualisation and analysis. Good contrast and ridge definition was observed when fresh fingerprints were transferred by contact with the secondary surface for a minimum of 24 hours under a 5.00 kg pressure. The water soluble components of the fingerprint residue were readily transferred and developed using an indanedione-zinc treatment. The high degree of clarity and contrast of the developed transferred fingerprint made it difficult to differentiate as a secondary mark. Transferred marks can only be recognised due to a mirror image when compared to a mark directly deposited from an individual.

Introduction

The direct transfer of fingerprint residue from the ridges on the finger to a surface it makes contact with is a classic example of Locard's Exchange principle [1]. This principle also applies to secondary transfer of fingerprint residue from one surface onto another as they come into contact, replicating the original mark in mirror image, as has been shown in attempts to forge fingerprints [2, 3]. Since the early 20th century, cases have reported fingerprint forgery as evidence, however little research has explored the issue of secondary transfer of latent fingerprints [2, 3].

Fingerprint experts have been questioned regarding whether secondary transfer of latent fingerprints from a non-porous surface to a porous surface is possible. Beaudoin has previously reported research investigating the possibility of transferring treated and untreated latent fingerprints [4]. His study utilised ninhydrin as the development method to investigate whether a fingerprint could be deposited through transfer to a surface prior to and post treatment. The results demonstrated that secondary marks transferred using a lifter or by pressing a smooth surface were unlikely to be detected using ninhydrin [4].

Since Beaudoin's research, little has been reported in the open literature concerning the possibility of secondary transfer of latent fingerprints, despite the advancements in detection treatments. The development of indanedione-zinc treatment, which provides more sensitive detection of amino acids, delivers the opportunity to further investigate the possibility of detecting secondary transfer [5, 6]. Expanding from Beaudoin's research, the potential of using treatments which target the water insoluble components of fingerprint residue provides the ability to target sebaceous material. Aqueous Nile blue, Oil red O and Single Metal Deposition (SMD) II are methods capable of detecting fingerprints on wetted surfaces due to their ability to target the non-water soluble components of fingerprint residue. When prepared in an aqueous solution, Nile blue A spontaneously hydrolyses to form trace amounts of Nile red, which dissolves into the neutral lipids present in the fingerprint, providing a fluorescent fingerprint when excited at 505 nm and viewed through a 550 nm orange barrier filter [7]. Oil red O can also be used to detect the water insoluble components present in fingerprint residue by diffusing into the lipid-rich secretions of the fingerprint [8, 9]. By contrast, SMD II uses the deposition of gold nanoparticles onto the fingerprint ridges, the mechanism of which is yet to be fully established [10-11]. Using these complementary treatments to analyse secondary fingerprints will allow for their comparison with amino acid sensitive treatments and provide information regarding which components of the fingerprint residue may be transferred on contact.

The aim of the research reported here was to utilise the improvements in fingerprint detection techniques to investigate the possibility of secondary transfer of undeveloped latent fingerprints. Firstly, the possibility of secondary transfer was explored by considering the variable conditions which could affect secondary transfer and its detection, including comparison of multiple detection techniques. This was followed by investigations into whether the transferred latent fingerprints have sufficient clarity for identification or exclusion. Ultimately, it is hoped that this study will help provide fingerprint practitioners with the information needed to answer questions in court relating to secondary transfer of latent fingerprints.

Materials and methods

Chemicals

Reagents were sourced from the following suppliers: tetrachloroauric acid trihydrate; trisodium citrate dihydrate; sodium hydroxide; L-aspartic acid; Tween 20; citric acid monohydrate; and hydroxylamine hydrochloride (Sigma-Aldrich, USA); glacial acetic acid (CSR Chemicals, AUS, Rowe Scientific, AUS); absolute ethanol (CSR Chemicals, AUS, Rowe Scientific, AUS); 1,2-indanedione (Optimum Technology, AUS); ethyl acetate (Univar Analytical, AUS, Ajax Finechem, AUS); anhydrous zinc chloride (BDH, USA); Nile Blue A (dye content $\geq 75\%$; Sigma-Aldrich, USA); Oil red O (dye content $\geq 75\%$; Sigma-Aldrich, USA); propylene glycol ($\geq 99\%$; Sigma-Aldrich, USA); ninhydrin (Sigma Aldrich, USA) and carrier solvent HFE-7100 (3M, USA). Reagents were used as received and of analytical grade unless otherwise stated.

Solution Preparation

Aqueous Nile blue preparation was based on the method proposed by Cain and revised by Frick *et al.* [7, 12]. Nile blue A (5.0 mg) was added to deionised water (100 mL) with constant stirring. The solution was stored in a glass bottle away from light.

The indanedione-zinc solutions were prepared according to the method recommended by the National Centre for Forensic Science (NCFS) [13]. The 1,2-indanedione stock solution contained 1,2-indanedione (2.3 g) dissolved in ethyl acetate (480 mL) and glacial acetic acid (20 mL). The zinc chloride stock solution contained zinc chloride (8 g) dissolved in absolute ethanol (200 mL). The working solution was made by combining the 1,2-indanedione stock solution (65 mL) with the zinc chloride stock solution (2 mL) and HFE-7100 carrier solvent (435 mL). All solutions were made fresh and stored at room temperature in glass bottles wrapped in aluminium foil, to avoid exposure to light.

Following the method published by Moret and Bécue, five different stock solutions were prepared for the single metal deposition (SMD) II development procedure [14]. Their contents are described in Table 1.

Table 1: Stock Solutions prepared for the SMD II development procedure

Solution A	0.500 g tetrachloroauric acid trihydrate dissolved in 5 mL deionised water
Solution B	1.70 g trisodium citrate dihydrate dissolved in 85 mL deionised water
Solution C	0.120 g sodium hydroxide and 0.380 g L-aspartic acid dissolved in 25 mL deionised water
Solution D	31.5 g citric acid monohydrate dissolved in 150 mL deionised water
Solution E	1.00 g hydroxylamine hydrochloride dissolved in 50 mL deionised water

The SMD II gold nanoparticle stock solution was prepared by adding Solution A (1 mL) to deionised water (460 mL) and heating to boiling point under constant stirring. When the boiling point of the solution was reached, a solution containing solution B (42 mL) and solution C (420 μ L) was quickly added. The solution was heated under constant stirring until a colour change was observed to produce a deep red coloured solution. The solution was then cooled, diluted with deionised water to a final volume (2.5 L) and the surfactant, Tween 20 (2.5 mL) was added under stirring. The solution was stored in a polypropylene container in a refrigerator at 4°C.

Ninhydrin was prepared according to the method prescribed by the NCFS [13]. The ninhydrin stock solution comprised of ninhydrin (35 g) dissolved in ethanol (425 mL), followed by the addition of ethyl acetate (35 mL) and acetic acid (40 mL). The working solution was made by combining the ninhydrin stock solution (65 mL) with HFE-7100 carrier solvent (935 mL). All solutions were stored at room temperature in a dark bottle, to avoid exposure to light.

Oil red O was prepared following the method outlined by Frick *et al.* [15]. Oil red O (0.05 g) was dissolved in propylene glycol (100 mL) with constant stirring at 95°C. The solution was left to cool and undissolved Oil red O was removed using vacuum filtration. The Oil red O solution was stored at room temperature in an aluminum wrapped glass bottle, to avoid exposure to light.

Substrate

OfficeMax[®] 50% recycled high white 80 gsm A4 copy paper (made in Indonesia) was utilised as the porous substrate for the experiment. 10 cm by 10 cm glass squares (JP Glass, Mirrabooka) were used as the non-porous substrate.

Preparation of samples

During the preparation of all substrates, nitrile gloves were worn in order to prevent any unwanted fingerprint deposits. Using a permanent black marker and a ruler, a centre line was drawn on the glass pieces dividing them into two sections. Donors provided split fingerprint deposits by placing their index, middle and ring fingers on the substrate, with the middle finger over the centre line. Each donor provided natural uncharged fingerprint deposits, which allowed donors to carry out their usual activities prior to deposition, as recommended by Kent [16], Sears *et al.* [17] and Croxton *et al.* [18]. To investigate the best case scenario, each donor also provided charged (groomed) fingerprint deposits. To charge their fingerprints, donors rubbed their fingers on the rear of their neck or forehead areas; providing fingerprint deposits with an increased proportion of natural sebaceous secretions. Throughout preliminary testing one donor was used unless otherwise stated, best case scenario testing utilised three donors and four replicates.

OfficeMax[®] high white copy paper was prepared as a mirror image of the glass pieces, with lines drawn in pencil to separate deposition areas. Each section was marked with identifiers corresponding with the marked glass pieces. As soon as fingerprint deposits were obtained, the prepared paper samples were placed onto the glass pieces and a 5.00 kg weight (2x reams of unopened copy paper) was placed on top of the sample (see Figure 1).

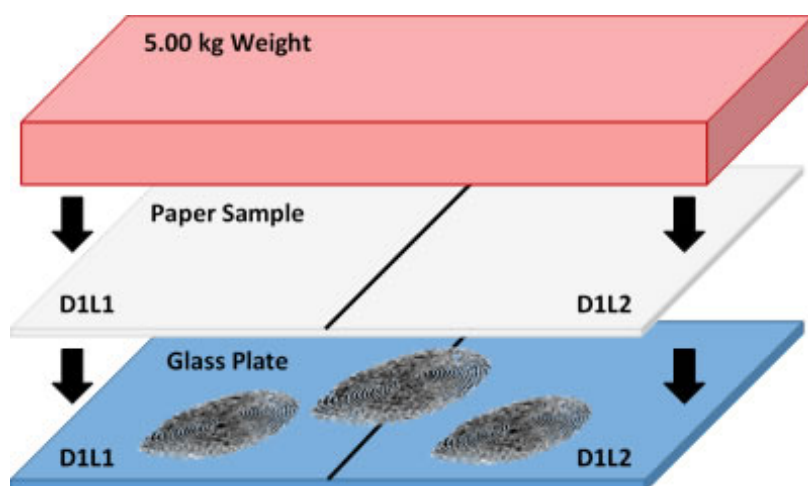


Figure 1: Diagrammatic representation of fingerprint deposition experimental set up

After 24 hours, the weight and paper samples were removed from the glass pieces. The paper samples were cut along the marked centre lines. This allowed the use of split fingerprint deposits on the paper samples which were then treated with the relevant chemical treatment.

Reagent application

Paper samples for treatment with aqueous Nile blue followed the method established by Frick *et al.*, with the samples submerged in the aqueous Nile blue solution for 20 minutes [7]. The samples were removed from the solution, rinsed with a small amount of deionised water and left to dry at room temperature.

Paper samples for treatment with indanedione-zinc and ninhydrin were submerged for approximately 20 seconds in trays containing the working solutions. The samples were then removed and air dried. Paper samples treated with indanedione-zinc were pressed in an Elna press set at 165 °C for 10 seconds. Ninhydrin treated samples were placed in a brown paper bag and left for 48 hours to develop as per local jurisdiction standard procedures.

Paper samples for treatment with SMD II followed the optimised procedure outlined by Newland *et al.* [10]. Fingerprint samples were first rinsed in deionised water for 3-5 minutes. The samples were then submerged in a solution comprising the gold nanoparticle stock solution (300 mL) which had been left to warm to room temperature, and solution D (9 mL). The samples remained in this solution for 20 minutes under constant orbital shaking on a PathTech Basic Orbital Mixer set to approximately 50 RPM. Samples were removed from the nanoparticle solution and rinsed in deionised water for 3-5 minutes. In a separate dish, the samples were submerged in a mixture of solution A (300 µL), solution E (300 µL) and deionised water (300 mL) for 20 minutes under constant orbital shaking at approximately 50 RPM. The samples were rinsed in deionised water for 3-5 minutes before being left to dry on paper towels at room temperature.

Paper samples treated with Oil red O were treated as per the method proposed by Frick *et al.* [15]. The samples were submerged in the Oil red O solution for 15 minutes, with agitation provided by manually swirling the tray for the first 30 seconds of treatment. Samples were then rinsed twice with deionised water and air-dried on paper towels at room temperature.

Photographic recording

The results were photographed using a digital Nikon D300 Single Lens Reflex (SLR) camera fitted with a 60 mm f2.8 Nikon Nikkor lens. The camera was set with the following settings: Auto White Balance, full automatic focus, centre metering and ISO setting of 200. The camera was mounted on a stand and placed directly overhead of the sample paper. A computer running the Nikon Camera Control Pro software (Version 2.0.0) was used to control the camera's shutter and capture all photographs in JPEG format.

Samples treated with indanedione-zinc and aqueous Nile blue were illuminated using a Rofin Polilight PL500 (Rofin, Australia) set with wavelength of 505 nm and results photographed with a KV550 barrier filter placed in front of the camera lens. The samples treated with ninhydrin were photographed under white light from a fluorescent lamp, with no filter attached to the camera lens.

Preliminary Testing Procedures

Several variables and techniques were tested through preliminary testing to identify the most likely scenario for secondary transfer to occur, this process is outlined in Table 2. All preliminary tests were conducted with charged fingermark deposits.

Table 2: Outline of Preliminary Testing Procedures

Preliminary Test No.	Detection Technique	Contact Pressure	Contact Time	Fingermark Deposit Age on Transfer	Lifted using adhesive lifter	Transferred Surface
1	Indanedione-Zinc / SMD II / Aqueous Nile Blue / Oil Red O	5.00 kg	24 hours	Less than 24 hours	No	Non-porous (glass) to porous (paper)
2	Indanedione-Zinc	0.30 kg / 0.55 kg / 2.50 kg	24 hours	Less than 24 hours	No	Non-porous (glass) to porous (paper)
3	Indanedione-Zinc	5.00 kg	2 minutes / 2 hours / 24 hours	Less than 24 hours	No	Non-porous (glass) to porous (paper)
4	Indanedione-Zinc	5.00 kg	24 hours	24 hours / 72 hours	No	Non-porous (glass) to porous (paper)
5	Indanedione-Zinc	2.50 kg	2 hours	Less than 24 hours	Yes	Non-porous (glass) to porous (paper)
6	Indanedione-Zinc	5.00 kg	24 hours	Less than 24 hours	No	Porous (paper) to porous (paper)

Results and Discussion

Fingermarks from three donors were deposited on glass substrates with paper samples placed immediately on top of the deposited fingermarks followed by 5.00 kg contact pressure that was applied for 24 hours, followed by the relevant development treatment. Figure 2 shows samples treated with indanedione-zinc, indicating adequate ridge detail and contrast for this treatment. Samples treated with SMD II, aqueous Nile blue or Oil red O provided little ridge definition or signs of fingermark transfer across three replicate trials. These results suggest that the water soluble component is more readily transferred and detectable on the paper surface than the non-water soluble sebaceous compounds. For this reason, indanedione-zinc was selected as the development method for subsequent testing.

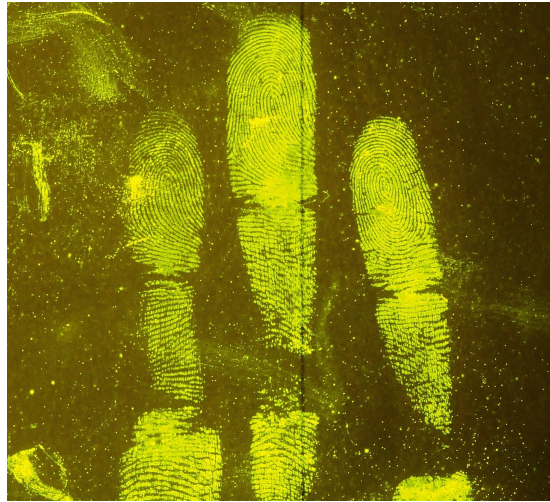


Figure 2: Development of secondary transferred fingerprint on a paper sample treated with indanedione-zinc with a 5.00 kg contact pressure applied for 24 hours.

The effect of contact pressure applied during secondary transfer was tested by comparing items commonly located on work desks. In this case, a hole-punch (0.30 kg), a hard covered diary (0.55 kg) and a ream of copy paper (2.50 kg) were used. Each item was placed for a period of 24 hours on a paper sample, which was placed on top of a piece of glass containing deposited fingerprints. Following treatment with indanedione-zinc, no transfer was detected with the 0.30 kg contact pressure, faint fingerprints were developed with the 0.55 kg diary and clear fingerprints were developed with the 2.50 kg contact pressure, as shown in Figure 3. Secondary transfer of fingerprints onto the paper sample is clearly dependent on the pressure applied, with clarity of the developed transferred mark increasing as the contact pressure is increased.

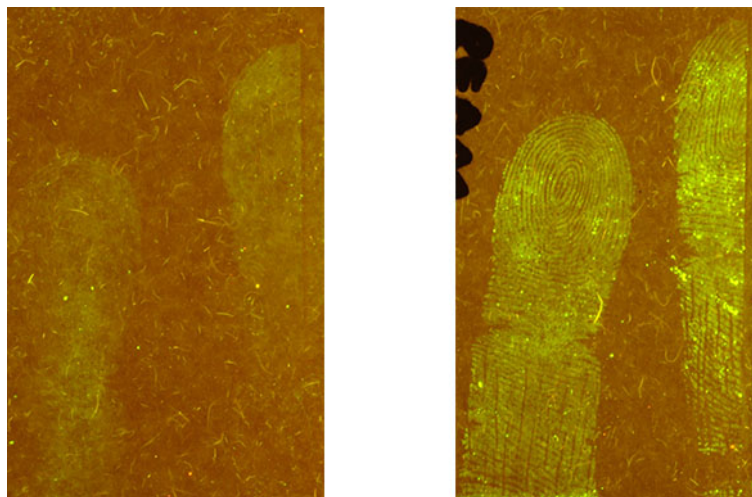


Figure 3: Development of transferred fingerprints on sample paper with indanedione-zinc with 0.55 kg (left) and 2.50 kg (right) contact pressures applied for 24 hours.

The length of contact with the original deposited fingerprint was tested to see how this time frame could affect transfer. Contact times of 2 minutes, 2 hours and 24 hours were tested with a constant 5.00 kg contact pressure. Samples with lower contact times of 2 minutes

did not produce any detectable transferred fingermarks, whilst those with the longer contact times of 2 hours and 24 hours, produced secondary transferred fingermarks that were developed with good clarity.

Preliminary tests utilised fresh fingermarks by immediately placing sample paper onto the glass pieces following fingermark deposition. Fingermarks deposited onto the glass substrate were left uncovered on top of the laboratory bench for 24 or 72 hours. This was to determine whether transferring fingermarks to a secondary surface after some period of time could affect the quality of the developed mark. The temperature and humidity in the laboratory were measured with an average temperature of 20°C and humidity of 38% recorded using a combined clock, temperature and humidity gauge (Mikati-Japan Indoor Outdoor weather station). After the relevant time had passed, paper samples were placed on the aged fingermarks with a contact pressure of 5.00 kg applied for 24 hours before treatment with indanedione-zinc. No transfer of fingermarks was detected on either one day or three day old fingermark deposits. It can be concluded from this that for secondary transfer to occur, the fingermark deposits on the non-porous surface must be fresh, meaning that it comes into contact with the secondary surface shortly after deposition.

Fingermarks are often lifted to provide contrast against the surface using an adhesive fingermark lifter. An adhesive lifter (P.S. Industry) currently used by fingermark experts was investigated for its ability to transfer secondary fingermarks. Fingermarks were deposited onto a glass surface before being lifted with the adhesive fingermark lifter. The fingermark was then transferred by placing the adhesive lifter onto a paper sample with a 2.50 kg contact pressure applied for 2 hours. Additionally fingermarks which had been deposited directly on to the adhesive side of the fingermark lifter were also tested. After 2 hours the adhesive fingermark lifters were peeled off the paper and both the paper and the adhesive lifter were treated with indanedione-zinc. Neither method was able to successfully develop the transferred fingermarks due to the strong luminescence produced on the sample paper where the adhesive fingermark lifter was placed (see Figure 4). This was in all likelihood due to reaction between indanedione-zinc and a component present in the adhesive of the fingermark lifter.

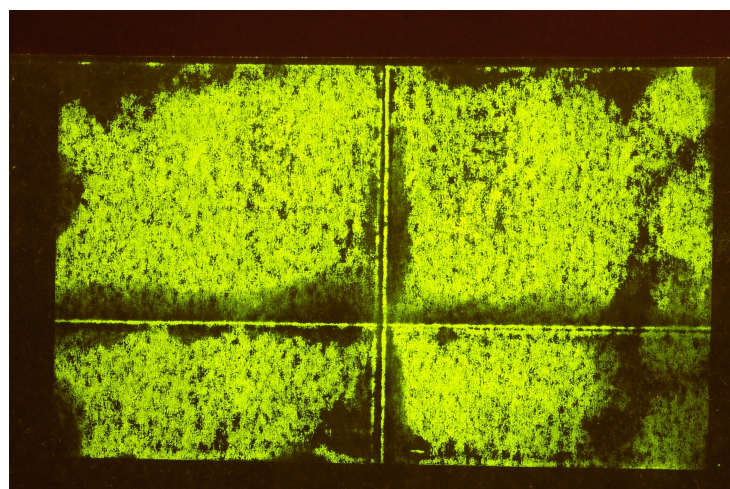


Figure 4: Strong luminescence on paper sample where an adhesive fingermark lifter with a 2.50 kg contact pressure applied for 2 hours.

A final preliminary test was conducted to assess whether secondary transfer was possible from a porous to porous surface. Fingermarks from six donors were deposited directly onto a paper surface with a second sheet of paper placed on top. A 5.00 kg contact pressure was applied for 24 hours, the fingermarks were then treated using indanedione-zinc. The results demonstrated that donors known to provide good quality fingermarks for detection with this method presented signs of secondary transfer with noticeable ridge definition. Those known to be weaker donors had no sign of secondary fingermark development. This implies that the chance of secondary transfer between porous surfaces is dependent on the composition and quantity of latent material deposited in the initial fingermark. Figure 5 demonstrates how the secondary fingermarks had noticeably lower levels of contrast when compared to their original marks, which can be explained by the tendency of a paper surface to absorb the water soluble components [13, 19, 20]. This would reduce the transfer onto a secondary surface, thus reducing the quality of the developed fingermark.

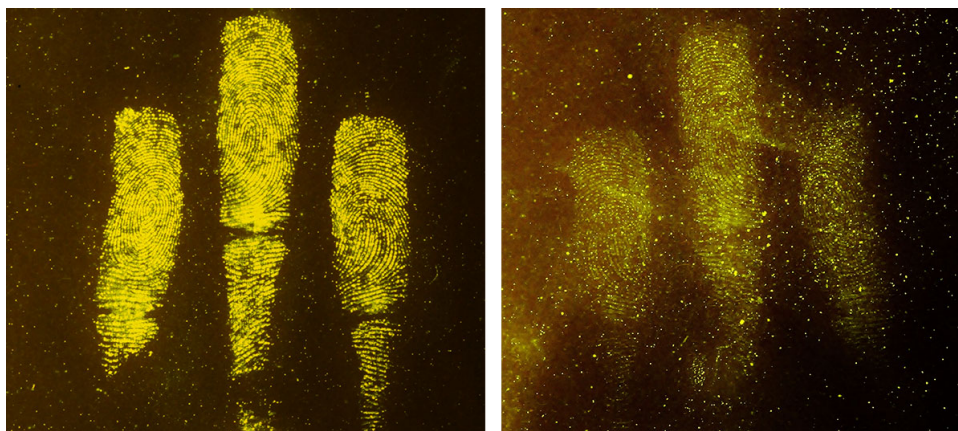


Figure 5: Original fingermark (left) and secondary fingermarks (right) deposited and transferred onto a paper surface using 5.00 kg contact pressure applied for 24 hours.

Following the results of the preliminary tests, research was conducted using the best case scenario of fresh fingermarks transferred by contact for 24 hours with a 5.00 kg contact pressure, testing both charged and uncharged fingermark deposits provided by three donors with four replicates. In addition to treating the sample papers with indanedione-zinc, ninhydrin treatments were also conducted on the split fingermark deposits obtained.

As expected, the variation of fingermark deposits varied from donor to donor. All paper samples treated with indanedione-zinc developed continuous ridge detail ranging from low contrast to strong contrast. By comparison, none of the paper samples treated with ninhydrin developed any visible friction ridge detail. This result with ninhydrin treatment is consistent with results achieved by Beaudoin, who conducted similar research on transferring undeveloped latent fingermark from a smooth surface onto paper with a contact time of 17 hours [4].

Figure 6 compares development of charged and uncharged fingermark deposits treated with indanedione-zinc, demonstrating adequate contrast and ridge definition. This suggests that both types of deposit transfer well from the glass surface onto the paper. The clarity of the developed secondary fingermark made it difficult to determine whether these marks are the original mark, made through direct handling of the paper, or a secondary transfer. The

only indication of a secondary transfer would be a reversed fingerprint. These results, which clearly demonstrate the potential of secondary transfer, can provide fingerprint experts with the background understanding for how and when fingerprints may be transferred and how they might be developed for analysis.

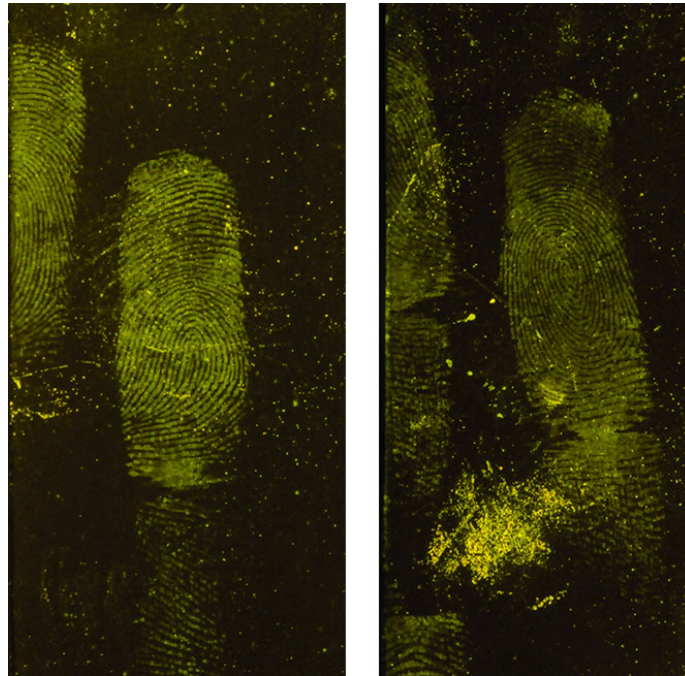


Figure 6: Side by side images of treated sample papers with indanedione- zinc. Uncharged (left) charged (right) fingerprint deposits.

Conclusion

In this work it was established that for successful detection of secondary transferred fingerprints to be achieved, the fingerprint deposit needs to be fresh to allow for the transfer of the water soluble components within fingerprint residue (amino acids). Increasing contact pressure and the time period that the pressure is applied for will increase the clarity of the secondary transfer, with a contact pressure of 5.00 kg applied for over 24 hours providing the best results of those tested throughout this investigation. Transferring undeveloped fingerprints from a glass surface using an adhesive fingerprint lifter was also investigated. However, this method of transfer did not result in any detectable fingerprints due to strong luminescence across the area where the adhesive fingerprint lifter was applied.

Fingerprints transferred from porous to porous surfaces were also detected, however the amount of residue transferred and available for development is dependent on the composition of the original mark. The marks detected in porous to porous transfer were noticeably lower in contrast due to the absorption of water soluble components into the porous surface of the original substrate.

Using the conditions for transfer determined throughout this investigation, final testing compared uncharged and charged fingerprint deposits for secondary transfer from a non-porous to porous surface. The secondary transfer on the paper samples were targeted using

indanedione-zinc and ninhydrin. The results established that under these conditions, only indanedione-zinc was able to develop the secondary transferred fingerprints for both uncharged and charged fingerprint deposits.

The results of this preliminary investigation provides evidence of secondary fingerprints, offering a likely scenario for the transfer and development of transferred fingerprints. This information can assist fingerprint practitioners when questioned in court on the potential of secondary transfer of latent fingerprints. It should be noted that further research should be carried out using various substrates and detection methods to establish a better understanding of secondary transfer of fingerprints and the circumstances under which it would be likely to occur.

Acknowledgements

The authors would like to thank all of the fingerprint donors who participated in this study, as well as Amanda Frick (Curtin University, now at Université de Lausanne) for the preparation of the Oil red O and Casey Moate, (Western Australia Police Forensic Fingerprint Bureau) for the preparation of ninhydrin. This project has been approved by the Curtin University Human Research Ethics Committee (Approval Number SMEC-46-13)

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