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Evaluation of fingermark detection sequences on paper substrates

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ABSTRACT

It is generally accepted that the amino acid reagent consisting of 1,2-indanedione and a catalytic amount of zinc chloride, referred to as IND-Zn, is the single best method for the detection of latent fingermarks on paper substrates and that ninhydrin is of limited value when used in sequence after this reagent. However, recent research has suggested that the sequence 1,8-diazafluoren-9-one (DFO) followed by ninhydrin may actually produce a greater number of fingermarks than IND-Zn on its own or IND-Zn followed by ninhydrin.

This study focussed on the evaluation of two fingermark detection sequences for porous surfaces: (1) IND-Zn followed by ninhydrin, physical developer (PD) and the lipid stain nile red; and (2) DFO followed by ninhydrin, PD and nile red. The evaluation was undertaken using a range of latent fingermark donors and on a number of paper substrates that are commonly encountered in Australia. In addition, a pseudo-operational trial was completed on 5-year-old university examination booklets. Parallel studies were undertaken at two locations: Sydney (temperate, coastal climate) and Canberra (relatively dry, continental climate).

The results of the donor study indicated that there was a negligible difference in performance between the two sequences across all paper types and all time periods evaluated. When considering individual reagents, IND-Zn generally developed better quality fingermarks compared to DFO; however, ninhydrin had a greater enhancement effect on DFO developed marks than after IND-Zn. In the pseudo-operational trials, the IND-Zn sequence outperformed the DFO sequence. Nile red did not develop any additional marks at the end of each sequence and, as a result, the use of this technique at the end of a full sequence is of questionable value.

The overall outcome was that the sequence IND-Zn followed by ninhydrin and PD is recommended for the processing of common paper substrates under the conditions typically experienced at the two locations studied.

1. Introduction

The detection and enhancement of latent fingermarks requires the application of an appropriate sequence of methods that will depend on the nature of the surface, the circumstances of the case under investigation, and the resources available to the fingerprint technician. Such sequences, consisting of complementary detection methods from least destructive to more destructive, need to be optimised and validated under local conditions before casework implementation. For paper substrates, the generally accepted approach is to apply non-destructive optical methods first, followed by one or more amino acid reagents, then a method – such as physical developer – that targets any sebaceous material that may be present [1].

The traditional amino acid reagent for fingermark detection is ninhydrin, which was first proposed for this application in 1954 [2]. Ninhydrin remains the most common chemical method for the treatment of paper substrates despite significant research efforts directed at the synthesis of ninhydrin analogues [3,4]. The first potential alternative to ninhydrin to be introduced into routine casework was 1,8-diazafluoren-9-one (DFO), originally proposed as a fingermark reagent in 1990 [5]. However, rather than replacing ninhydrin, DFO proved to be effective when used in a sequence prior to ninhydrin treatment, with early indications that ninhydrin can develop additional fingermarks not detected by DFO [6].

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More recently, in 1997, 1,2-indanedione (IND) was introduced as a novel amino acid reagent that showed significant potential [7]. Various research groups around the world investigated the application of this reagent for fingermark detection on paper substrates, with some groups reporting superior results compared to DFO [8,9], while others found that DFO was more sensitive [10]. A breakthrough occurred when it was determined that the addition of a catalytic amount of zinc chloride to the IND working solution resulted in significantly improved results due to the preferential formation of the desired, highly luminescent reaction product [11,12]. This new formulation, referred to as IND-Zn, was subsequently adopted for routine use by a number of agencies including the Australian Federal Police [13]. As for DFO, IND-Zn can be used in sequence prior to conventional ninhydrin treatment; however, anecdotal evidence has indicated that the results achieved with IND-Zn are rarely improved by subsequent treatment with ninhydrin.

A recent study by Porpiglia et al. looked at the effectiveness of the ninhydrin analogue 5-methylthioninhydrin as a reagent for fingermark detection on paper substrates under UK conditions [14]. As part of this study, the authors compared a number of sequences, including IND-Zn→ninhydrin and DFO→ninhydrin, for their ability to develop fingermarks collected from 29 participants on six selected paper types. The indication was that IND-Zn was the most effective reagent of those studied if a single treatment is employed. However, the sequence DFO→ninhydrin developed 87% of the test fingermarks while the sequence IND-Zn→ninhydrin only developed 78%. The authors concluded that the sequence DFO→ninhydrin was more effective than the alternatives investigated.

Physical developer (PD), the preferred reagent for targeting sebaceous material in latent fingermarks on paper, was developed in the 1970s by the Atomic Weapons Research Establishment under contract to the UK Police Scientific Development Branch [15,16]. PD is used at the end of the detection sequence and it can develop fingermarks that remain undetected using amino acid reagents [1,17]. However, the technique is costly and time-consuming, and requires significant expertise to achieve optimum results. Single metal deposition (SMD) has also been proposed for use as a fingermark detection method on porous substrates [18]. While SMD is easier to apply than multimetal deposition (MMD), it remains a labour-intensive technique that has not been widely adopted at this point in time.

A number of research groups have investigated lipid stains such as Oil Red O (ORO) as a simpler alternative to processes such as PD or SMD [19,20]. While it has been suggested that ORO can be used in sequence prior to PD treatment, there is an adverse effect on the PD results due to higher background development [20]. A recent study by Braasch et al. indicated that the luminescent lipid stain nile red can be used in sequence after PD and may develop additional fingermarks [21]. However, further research is required before nile red can be considered for use in casework at the end of a full detection sequence on paper (i.e., including amino acid reagents as opposed to PD only).

The aim of this study was to evaluate two fingermark detection sequences, one incorporating IND-Zn and the other incorporating DFO (Fig. 1), on common Australian paper substrates and under Australian conditions. This was achieved by applying these sequences in donor trials, on fingermarks deposited by a number of individuals on 4 different paper substrates, and in pseudo-operational trials on pages taken from 5-year-old university examination booklets. The use of nile red was preferred over ORO as it can be used in sequence after PD, thus not impacting on the performance of PD, and it produces luminescent fingermarks rather than a simple coloration. The study was conducted in parallel at two different geographic locations (Canberra and Sydney) to determine if there were variations in the performance of each sequence due to climatic conditions.

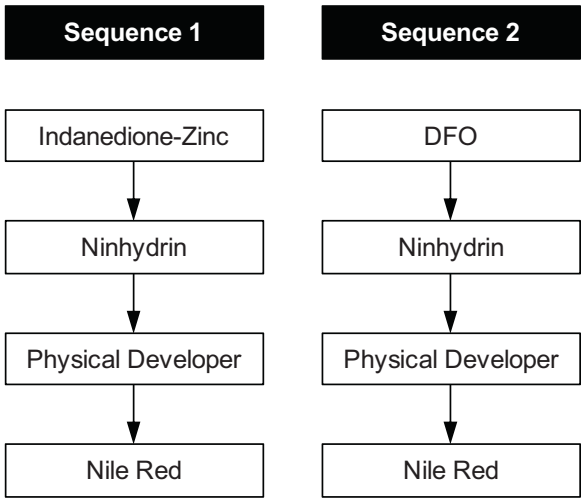

Fig. 1. The two sequences considered in this study for their ability to detect latent fingermarks on a range of paper substrates.

2. Materials and methods

2.1. Chemicals

IND, DFO, ninhydrin, n-dodecylamine acetate and Synperonic N were purchased from Optimum Technology (Canberra, Australia). Silver nitrate, citric acid, maleic acid, ammonium iron(II) sulphate hexahydrate, iron(III) nitrate nonahydrate and nile red were purchased from Sigma–Aldrich Pty. Ltd. (Sydney, Australia). Ethyl acetate, acetic acid, ethanol, methanol, and zinc chloride were purchased from Chem-Supply Pty. Ltd. (Gillman, Australia). HFE-7100 and HFC-4310mee were purchased from Novaline (Taren Point, Australia). For the Canberra study, high-purity water was obtained from a Satorius arium 611 water purification system. In Sydney, high-purity water was obtained from a high-throughput three-stage water filtration system (AKF 300 activated carbon filter; Bewades 58 LC UV disinfection system; Vertex SS-360HR reverse osmosis water purification system).

2.2. Fingermark detection methods

For IND-Zn, DFO, ninhydrin and PD, the reagent formulations and development procedures currently in use by the Australian Federal Police were employed [13]. IND-Zn treated samples were processed in a dry heat press at 160 °C (±5 °C) for 10 s. DFO treated samples were processed in a dry heat press at 180 °C (±5 °C) for 10 s. For ninhydrin treated samples, development was allowed to proceed at room temperature over 24–48 h. The PD process involved three initial deionised water washes, treatment in a maleic acid solution, a further water wash, PD development until optimum fingermark contrast was observed, and then three final deionised water washes. Nile red treatment was performed using the modified working solution and general development procedure described by Braasch et al. [21]. Developed fingermarks were visualised and digitally recorded under the conditions indicated in Table 1, with a Polilight PL-500 (Rofin Pty. Ltd., Australia) used as the light source.

2.3. Phase 1: donor trials

For the donor trial, four common paper substrates were chosen. These were: (A) white virgin (non-recycled) printer/copier paper (Reflex, Australia); (B) 100% recycled white printer/copier paper