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Microscopic examination of fingermark residues: Opportunities for fundamental studies

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ABSTRACT

Despite significant ongoing research, a substantial proportion of latent fingermarks remain undetected in casework. Therefore, to improve existing detection techniques and to allow the development of new approaches, it is important to gain a better understanding of detection mechanisms rather than solely focusing on method formulations. As a starting point, it is crucial to gain a deeper understanding of the fingermark residue itself. Even if the chemical composition is reasonably well understood, little research has been reported on the physical aspects related to the deposition of fingermarks and their interactions with the environment and underlying substrates.

This study aimed at exploring various techniques that can be used for the non-destructive visualisation of fingermarks before applying detection techniques. Both light and electron microscopy were investigated. Phase contrast imaging and environmental scanning electron microscopy, coupled with energy-dispersive X-ray spectrometry, proved to be essential tools for the study of latent fingermark deposits. These methods can be used to gather fundamental information that will add to our body of knowledge in this field.

1. Introduction

When bare hands (including fingers) touch an item, substances present on the skin are transferred, reproducing the complex ridge patterns of the palm and the fingers. The resulting marks are often latent and must therefore be detected before being exploited for comparison purposes. The choice of a particular detection technique is related to the substrate, the type of mark, environmental conditions and even the circumstances of the case at stake. Moreover, in order to improve the chances of detecting a mark, several techniques are typically applied in a sequence to successively target the various components present in the secretions. Dozens of detection techniques have been investigated and optimised to date [1,2]. Emerging technologies such as nanotechnology [3] and immunodetection techniques [4,5] have also been applied in the field, leading to the discovery of new, highly promising detection methods. But, despite the numerous available options and current endeavours to find increasingly more effective methods, a general lack of sensitivity and specificity has been noted. According to Jaber et al., 50% of the available marks remain undetected on porous substrates [6]. Despite significant ongoing research, it seems that the field has reached its detection threshold; no major realistic advances or ground-breaking discoveries have been made these past few years.

This situation can be explained by the fact that researchers are mainly focused on results, rather than on the understanding of principles underlying the techniques. Historically, the vast majority of the detection methods have been adapted from pre-existing ones in other fields. Biology offers a glaring example since molecules such as ninhydrin were firstly used to detect amino acids on thin-layer chromatography plates. The formulation was then adapted to detect amino acids found in fingermark secretions on porous substrates (Fig. 1a) [7]. The same can be said for lipid stains such as Oil Red O (Fig. 1b) and Nile Red used in histochemistry and adapted to detect the lipid fraction of fingermark residues originating from sebaceous glands [8–10]. Other fields have also impacted on the range of available fingermark detection techniques. For example, the 'physical developer' (PD) technique was originally adapted from a photographic developer used to process photosensitive films. Its formulation was then further optimised to trigger silver reduction onto fingermark ridges (Fig. 1c) [11,12].

This trial-and-error approach has led to the development of highly sensitive techniques currently used worldwide. However, it

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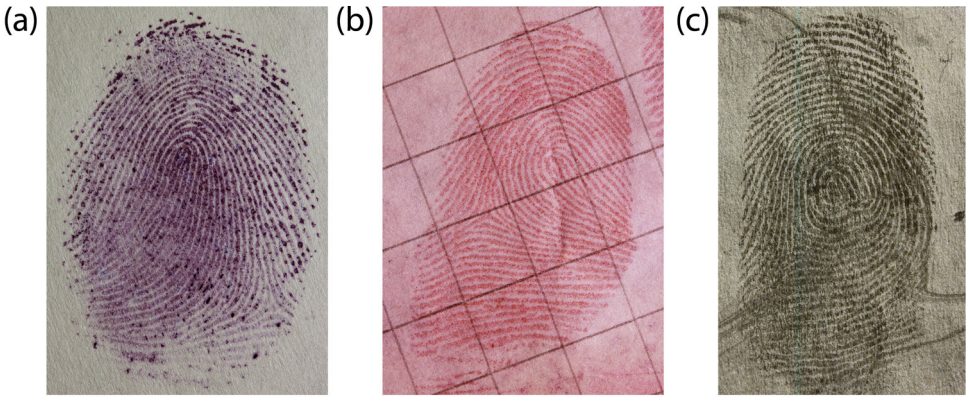

Fig. 1. Illustration of fingermarks detected on paper with (a) ninhydrin, (b) Oil Red O, and (c) physical developer.

has also several downsides: the optimisation itself is time consuming; it cannot be generalised to every substrate; and it often leads to the development of techniques that are not fully understood (with PD being an excellent example of this). The optimisation of a technique implies mandatory and very tedious lab work since each parameter involved in the procedure has to be adjusted independently. Problematic situations can arise where techniques perform effectively on certain substrates but not on others. Even worse, some formulations are effective in some parts of the world but are unsatisfactory elsewhere, which can be due to environmental factors such as humidity levels or substrate differences from variations in primary materials used in manufactured products [13]. Without a deeper understanding of the mechanisms involved in the process, unwanted background staining or a failure to detect marks cannot be adequately explained and the optimisation of relevant techniques can be problematic.

There is a current trend to improve our understanding of certain detection mechanisms, such as amino acids reagents [13] or the interaction occurring between nanoparticles and fingermarks [14]. Until now, however, only a small number of techniques are fully understood. In order to improve our knowledge in the field, it is important to pursue this trend by refocusing on a fundamental understanding of the latent fingermark itself.

From a chemical perspective, the fingermark residue has been extensively investigated. The dermatological studies of the components present on the skin and excreted by the glands (eccrine, apocrine and sebaceous) offer a good starting point. Nonetheless, they are not entirely representative of the actual composition of fingermarks, since the residue is affected by numerous parameters after its deposition. Extensive studies of the residue itself have been conducted and reviews are available [15,16]. The chemical decomposition processes within the residue are currently under study by several research groups around the world, mainly for age estimation purposes [17–19]. Even if the chemical composition of fingermarks represents critical information to determine which components to target specifically, it is not sufficient in itself. Physical information such as morphology of the fingermark ridges, distribution and accessibility of the components within the residue, as well as interactions with the substrate and with the environment are important considerations. This knowledge remains restricted to only a handful of studies conducted nearly four decades ago [20–23] and should therefore be investigated more thoroughly.

To study the residue itself, the first step is to find techniques that enable the collection of extensive data *in situ* on a wide range of substrates, without altering the fine details of the pattern and the distribution of components within ridges. To preserve the initial aspect of the residue, these observations have to be performed before the application of any fingermark detection technique. This paper reports various instruments and imaging techniques that can be applied to study the fingermark residue *in situ*; preliminary observations were also obtained from fingermarks deposited on several substrates. A deeper understanding of fingermark physics will not only help optimise current fingermark detection techniques and determine optimal parameters, but will also shed light on the lack of results on certain substrates. Better in-depth knowledge of the residue, encompassing both chemical and physical properties, will facilitate the development or reformulation of more efficient and more effective detection techniques. This study is a first step in this direction.

2. Materials and methods

2.1. Fingermark samples

This study was limited to one male donor since it was focused on the various possibilities for fingermark visualisation and imaging rather than on a comparison of their quality. Three different types of marks were collected: sebaceous, natural and eccrine marks. Sebaceous marks were artificially enriched with sebum not naturally present on the friction ridge skin surface. Before fingermark deposition, the donor was asked to rub his fingers on his forehead to enrich the amount of sebaceous material already present. This type of mark contained a higher quantity of secretions than a natural mark, which in turn was collected without any particular preparation of the fingers and for which no artificial enrichment was applied. For natural mark collection, the donor was asked not to wash his hands for 1 h prior to deposition and to rub his hands together to homogenise the secretions already present on the skin. This type of mark therefore consisted of a natural mix of both eccrine and sebaceous secretions. Finally, to collect eccrine marks, the donor was asked to thoroughly wash his hands twice with soap and warm water to remove any sebaceous secretions. The fingers were then air dried. After 15 min avoiding touching anything, the fingermarks were simply deposited on the substrates. In order to observe the influence of the surface type, marks were collected on a variety of non-porous substrates as listed in Table 1.

Table 1
Description of the substrate samples used for this study.

Substrate	Composition
Microscope slide (Livingstone Pathology Grade)	Glass
Thick document protector (Marbig)	Polyvinyl chloride (PVC)
Thin A4 sheet protector (Cumberland)	Polyvinyl chloride (PVC)
Cling film (GladWrap)	Polyethylene (PE)
Tape, non-adhesive side (Scotch Police)	Polypropylene (PP)