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Review

Techniques that acquire donor profiling information from fingermarks — A review

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ABSTRACT

Fingermarks are among the most important types of evidence that can be encountered at the scene of a crime since the unique ridge pattern of a fingerprint can be used for individualization. But fingermarks contain more than the characteristic pattern of ridges and furrows, they are composed of a wide variety of different components that originate from endogenous and exogenous sources. The chemical composition can be used to obtain additional information from the donor of the fingermark, which in turn can be used to create a donor profile. Donor profiling can serve at least two purposes i) to enhance the evidential value of fingermarks and ii) to provide valuable tactical information during the crime scene investigation. Retrieving this additional information is not limited to fingermarks that have been used for individualization, but can also be applied on partial and/or distorted fingermarks. In this review we have summarized the types of information that can be obtained from fingermarks. Additionally, an overview is given of the techniques that are available addressing their unique characteristics and limitations. We expect that in the nearby future, donor profiling from contact traces, including fingermarks will be possible.

Contents

Abbreviations: ATR, attentuated total reflectance; DART, direct analysis in real time; DESI, desorption electro spray ionization; DNA, deoxyribonucleic acid; ECL, electrochemiluminescence; EDDP, 2-ethylidene-1,5-methyl-3,3-diphenyl-1-pyrroline; EGF, epidermal growth factor; FTIR, Fourier transform-infrared spectroscopy; GC, gas chromatography; GLC, gas–liquid chromatography; HPLC, high-performance-liquid-chromatography; HSI, hyper spectral imaging; IR, infrared spectroscopy; LC, liquid chromatography; MALDI, matrix-assisted laser desorption/ionization; MS, mass spectrometry; MSI, mass spectrometry imaging; PCA, principal component analysis; PETN, pentaerythritol nitrate; PLS, partial least squares; PLS–DA, partial least squares–discriminant analysis; RDX, hexahydro-1,3,5-trinitro-1,3,5-triazine; RS, Raman spectroscopy; SALDI, surface-assisted laser desorption/ionization; SERS, surface enhanced Raman spectroscopy; SIMS, secondary ion mass spectrometry; ssDNA, single stranded DNA; THC, Δ9-TETRAHYDROCANNABINOl; TNT, 2,4,6-trinitrotoluene; TOF, time-of-flight.

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1. Introduction

Fingermarks contain an enormous amount of undisclosed information on the donor of the mark. One source of information can be deoxyribonucleic acid (DNA), which can give us personal identity information. But despite its presence in fingermarks, to our knowledge, DNA profiles obtained from fingermarks are seldom successfully used in forensic case work and in court, because of the low amount present. Nevertheless developments on DNA collection and typing are ongoing to make identification possible [1]. A limitation that should be kept in mind is that the collection of DNA from fingermarks is destructive to the pattern. In some cases, fingermarks can be photographed without any interference of a development technique. However, in most cases the fingermarks are latent and need to be developed. Most of the standard fingermark detection techniques can be used in sequence with DNA profiling, therefore a fingermark can be photographed before being swabbed for analysis [2–4]. However, after development, not all fingermarks can be used for the identification process, as they may be smudged or distorted, in which case it is preferred to collect the fingermarks for DNA analysis as the present DNA might still reveal the identity of the donor. Additionally, successful DNA collection and typing depends on many variables including the age of the mark, the carrier of the fingermark and the fingermark development technique used as reviewed by Kumar et al. [5].

Besides the individualization of a donor, also donor characteristics such as race, hair colour, eye colour and height can be determined from the DNA as well [6,7]. Besides DNA, excreted metabolites, proteins, peptides and also exogenous components contain information about the donor, such as gender, blood group type, age, diet, drug use and health [8–14]. Currently, the challenge is to reliably retrieve this information from fingermarks as it is a minimal sample of complex origin.

Since the acquisition of donor profiling information from contact traces is not integrated in crime scene investigation, we would like to bring the use of chemical composition of a fingermark to the attention of the forensic field by summarizing the different types of intelligence that it can contain. By highlighting the most relevant literature on the topic we would like to discuss the current state of donor profiling.

2. Fingermarks and their composition

The friction ridge skin present on the soles of our feet, palms of our hands and tips of our fingers and toes is composed of ridges and grooves. When touching a surface with the fingertip, a specific pattern is left behind and is called a fingermark [15]. Fingermarks can be used for individualization and thus identification purposes, based on the assumption that the friction ridge pattern is characteristic for each individual, including the ridge pattern of identical twins, and that the friction ridge skin does not change over time, except in case of injury that affects the deeper layers of skin [16]. In crime scene investigation, the pattern of fingerprints has been used as an identification tool since the late 1800s [16]. Currently, fingermarks found at crime scenes are used for identification, verification and/or for mark to mark comparison using the pattern that is left behind. However, fingermarks contain more information than the ridge pattern only. Chemical knowledge on the composition might be used to increase the evidential value and obtain more information about the donor. With increasing the evidential value we mean that donor profiling may be used to get an indication about the donor's characteristics in case of unknown donor, such as the gender or age of the donor and/or to assess a (witness) testimony. When the donor of the fingermark is known, information like drug usage or handling of certain items, such as explosives, may help in the verification or falsification of testimonies. Also, when individualization of the fingermark is not possible, for instance in case of a distorted or a badly developed fingermark the chemical composition of the fingermark can still be used to obtain tactical donor profiling information or even evidence when it is accepted as such by a judge.

Fingermarks are composed of material derived from sweat excreted via the pores, which are present on the ridges, but can also be contaminated with other material originating from touching different body parts and exogenous components, such as food, cosmetics and drugs [15,17]. An excellent review on the different components present in fingermarks has been published by Girod et al. [18]. In short, the major source contributing to the composition of fingermarks is sweat, which can originate from the eccrine, sebaceous and/or apocrine glands. Eccrine glands are present all over the body and in highest density on the soles of the feet and palms of the hands and are therefore the main contributor to the chemical components present in the fingermark. Inorganic compounds, including ammonia, sodium, phosphate, fluoride and chloride and organic compounds, such as proteins and lipids, are excreted via the eccrine glands [17]. Sebaceous glands are located in areas of the body containing hair follicles and are most abundant in the facial region and are not present on the hand palms, fingertips and soles of feet. These glands secrete sebum, an oily material. As human behavior involves touching the face and other skin areas containing sebaceous glands, sebum can be found in fingermarks. Sebum components include triglycerides, squalene, wax esters, cholesterol and free fatty acids. The apocrine glands are highly distributed in the armpits and genital region and are the least studied glands, since contamination of apocrine excretion products with sebum complicates the study of the excretion products of apocrine glands [17]. Sweat is not the only source that contributes to the chemical composition of fingermarks. Environmental contaminants and endogenous body material, such as saliva, can also affect the composition of fingermarks. From all these components originating from different sources, donor profiling information can be obtained that may aid in the forensic investigation.

3. Donor profiling information from fingermarks

Donor profiling information is defined here as information additional to the fingermark ridge pattern which can tell us something about the donor. Types of intelligence gained by donor profiling can include DNA, gender or age determination, diet, blood group, drug use, explosives handling or even health status. How these types of intelligence can be obtained and how they may contribute to a case will be discussed in the sections below.

3.1. DNA

One of the constituents in fingermarks is DNA, which can be used for individualization, but also contains additional information about the donor of the fingermark. The amount of DNA is in most cases much too low to ensure reliable analysis and varies from no detectable DNA to hundreds of picograms [2,19–22]. Most of the standard fingermark detection techniques can be used in sequence with DNA profiling, therefore a fingermark can be captured before being swabbed for analysis [2–4]. However, to our knowledge, DNA profiles obtained from fingermarks are seldom successfully used in forensic case work and in court [23–25]. Other morphological characteristics such as race, hair colour, eye colour and height can be determined from the DNA as well.