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The *Reed-Stanton* press rig for the generation of reproducible fingermarks: Towards a standardised methodology for fingermark research

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ABSTRACT

In the search for better or new methods/techniques to visualise fingermarks or to analyse them exploiting their chemical content, fingermarks inter-variability may hinder the assessment of the method effectiveness. Variability is due to changes in the chemical composition of the fingermarks between different donors and within the same donor, as well as to differential contact time, pressure and angle. When validating a method or comparing it with existing ones, it is not always possible to account for this type of variability. One way to compensate for these issues is to employ, in the early stages of the method development, a device generating reproducible fingermarks. Here the authors present their take on such device, as well as quantitatively describing its performance and benefits against the manual production of marks. Finally a short application is illustrated for the use of this device, at the method developmental stages, in an emerging area of fingerprinting research concerning the retrieval of chemical intelligence from fingermarks.

1. Introduction

After over 100 years and despite the advent of DNA technologies, fingerprinting still accounts for most of the identifications in the UK and worldwide [1]. Techniques for visualisation of fingermarks (different from fingerprints which are control prints) have evolved since the 1860s [2] and grown in number including emerging technologies detecting and mapping the chemistry of fingermarks [3]; this indicates an increased keen interest in this type of biometric identification.

However, with an increase of both the number of scientists researching into fingermarks and of fingermark detection and analysis techniques, the necessity to adopt standardised and consistent protocols, when investigating the efficiency and potential implementation of new methods, techniques or technologies, is not only desirable but essential. These protocols would also enable researchers to assess effectiveness, advantages and limitations compared with existing methodologies and a number of standardised tests (test strips or spot tests) have already been proposed as testimony to these needs [4,5], though they are not advised for assessment of operational use but rather for ensuring the reagents are correctly prepared [6]. The issue of the lack of a consistent approach, in the development of existing or new techniques for fingermark detection and analysis amongst the different research groups worldwide, was eloquently described by the Centre of Applied Science and Technology, CAST, Home Office UK in a recent publication [7] that also provided guidelines on minimum standards for scientists undertaking this type of research. This issue was also discussed at the recent International Fingermark Research Group (IFRG) in June 2013 (Israel) and a document has been produced, coordinated by Prof. C Lennard to provide further and more detailed guidance including requirements for publishing the results of the research [8].

One of the major issues, making protocols and techniques not comparable and hindering a valid assessment of a technique's effectiveness, was very well described by Sears and colleagues: "The fundamental issue that needs to be addressed in any assessment of a fingermark enhancement technique is the variability of fingermarks, both between the marks deposited by different people and between marks deposited by the same person over a period of time. If this variability is not taken into account in experiments, then a false impression of the effectiveness of the technique may be created" [7].

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This variability pertains to the chemical nature of the mark (eccrine, groomed, ungroomed), as well as to the contact time, pressure and angle of the individual's fingertip touching a surface to deposit the marks. The necessity to generate reproducible patent marks may introduce further variables that are difficult to control such as chemical composition of the contaminant, amount of the contaminant (e.g. blood, mud, grease, paint) prior to the transfer to the deposition surface and after the transfer to fingertips; this is also very well discussed by Farrugia et al. for the generation of footwear impressions [9]. Fingermark residue depletion is an additional factor to account for when depositing replicate marks; replicate marks are recommended by CAST and are necessary for a reliable interpretation of the results and trends to address fingermark inter-variability. The variable quantity and nature of chemical residue impacts on the evaluation of technique effectiveness because enhancement depends, in many cases, on interaction (or reaction) with chemical targets and on their abundance in the mark. Lack of robust research of the type recommended by Kent [6] could even lead to either some of the fundamental techniques being sidelined for newer techniques, or to newer technique being hastily discarded. The overall "donor effect" has been already highlighted by other researchers as severely hindering a meaningful technique intercomparison and the assessment of the influence of factors such as slight changes in protocols, surfaces and climate, if this is undertaken in different geographic locations [4,10,11]. However whilst the chemical composition variability can, to an extent, be controlled (depositing all the marks at the same time of the day for a standalone experiment that will not be repeated on other days, rubbing fingertips against each other prior to deposition to even the composition, selecting a type of sweat etc.), even replenishing the fingertip with material, by rubbing fingerprints against each other a defined amount of times, in between replicates does not fully address mark deposition variability due to inconsistent contact pressure and contact time which also lead to variability in the amount of deposit transferred.

Furthermore, it is not always possible to obtain a quantitative measure of fingermark inter-variability thus preventing accountability when assessing the effectiveness of the technique employed. One way to circumvent this issue in the first stages of development of a technique is using a device generating reproducible fingermarks such that the fingermark chemistry as well as the first and second levels of ridge detail remains the same throughout the number of replicate samples generated for the specific piece of research undertaken.

Fieldhouse captured very early the impact of the fingermark inter-variability issues [12] and published in 2011 [13] the first example of such device, named *fingermark sampler*, enabling the generation of fingermarks under controlled conditions of force applied, contact duration and contact angle during fingermark deposition. Through fingermark grading, following the 0–4 grading scale scheme [14], her work demonstrated consistently high quality in the fingermark deposition across a range of participants and superior reproducibility over "manual deposition".

In the same year, within the Engineering for Life scheme awarded by EPSRC and Sheffield Hallam University, a project was undertaken to engineer a device enabling homogeneous and contactless powdering of latent marks [15] involving an industrial designer, a software engineer, a forensic scientist (in the very early stages) and led by the corresponding author in the capacity of a mass spectrometrist. In order to assess powder homogeneity, fingermark inter-variability had to be taken out of the equation; independently from the work of Fieldhouse (the authors were not aware of this research at the time), another fingerprint generator had been conceptually developed and engineered to generate reproducible fingermarks. This alternative rig, that was named the *Reed-Stanton* press rig, is an electro-mechanical device comprising a number of custom and OEM parts. Though the rotation/orientation of the finger is managed in a similar way, this rig is configured and controlled to allow independent and variable load/pressure selection and independent setting of contact time. Differently from the Fieldhouse *fingermark sampler*, the *Reed-Stanton* press rig allows pressure regulation (as opposed to defined/fixed load (309 g)) as well as regulating the time/duration of the contact between the fingertip and the deposition surface (to 1/10th second rather than at the discretion of a manual operator) in addition to controlling the contact angle. These factors are controlled/regulated also when spiking fingertips with any substance before a fingermark is generated. This device and its configuration are reported in Fig. 1. As well as differences in the design, a fundamental difference in the assessment of the quality of the marks produced exists between the press rig described here and the *fingermark sampler*.

The present paper describes this alternative fingermark generator and its operation, quantitatively demonstrating superior performance against the most attentive manual deposition of fingermark replicates. Finally a brief extract of a larger piece of research is illustrated to describe one of the possible applications of this rig that is the investigation and determination of fingermark age. In the corresponding author's laboratory, Matrix Assisted Laser Desorption Ionisation Mass Spectrometry (MALDI MS), in both profiling and imaging modes, is used to investigate the chemistry of the fingermarks and provide a vast range of forensically relevant information [3], with fingerprint ageing being a very current, highly topical and a much needed area of investigation; accurately placing a suspect at the scene of crime, through the age determination of their fingermarks, would warrant the ability to steer the enquiry in the right direction at the early stages of an investigation as well as proving/disproving the defendant's claims in a court of law. However, this information is still considered the "holy grail" of forensic science; this is probably due to the necessity for very complex and comprehensive studies. These studies need understanding of the research question at a fundamental and molecular level as well as requiring the analysis and cross-reference of a number of environmental and deposition surface factors. For this reason, in preliminary studies, variables need to be minimised in order to gather insights into the feasibility of the technology and of the method being employed for this scope. The use of the *Reed-Stanton* press rig in this short study presented here indicated a feasible methodological route to investigate and determine fingermark age by showing statistically significant discrimination between fresh, 1, 4 and 8 day old simulated marks.

2. Materials and methods

2.1. Materials

Pre-coated TLC aluminium sheets, ethanol and glass slides were purchased from Sigma-Aldrich (Poole, UK). Latent print reference pads are sold by CrimeTech (http://stores.crimetech.net/latent-print-reference-pad-sebaceous-oil/). Pre-inked fingerprint strips were purchased from Crime Scene Investigation Equipment LTD (www.csiequipment.com). TFA, acetonitrile and α-cyano 4 hydroxicinnamic acid were purchased from Sigma (Poole, UK). Double sided conductive tape was obtained from TAAB.

The assembly of the press rig comprised a series of laser cut 5 mm thick clear acrylic sheets (Plasticsheets.com), 3D printed polymer components and off the shelf (OEM) componentry such as electromechanical switch gear and linear, 12 V DC, Continuous Duty actuating Push Type solenoids (RS Supplies, http://uk.rs-online.com/web/). A timing control PCB was used to manage fingermark deposition time.

2.2. Methods

2.2.1. Instrumentation and software

The Visual Spectral Comparator (VSC4CX, Foster & Freeman, Evesham, UK) was employed to visualise fingermarks at 254 nm and capture a jpeg image. Image annotation was achieved using Artweaver 3.1.6 (Boris Eyrich Software, Germany). Mass spectrometric Imaging analyses were carried out on a modified Applied Biosystems API Q-Star Pulsar *i* hybrid Matrix Assisted Laser Desorption Ionisation

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