Chapter 2
Forgeries of Fingerprints in Forensic Science

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Abstract The objective of this chapter is to provide an account of the considerations made in forensic science regarding issues associated with potential forgeries of fingerprints. We will start with a clarification of terms and define the production of forgeries and the fabrication of evidence based on fingerprints. A short historical account will be given to highlight that the raised issues coincide with the early days of fingerprinting. Various methods of production of forged fingers as published in the forensic literature will then be exposed, distinguishing the techniques requiring the cooperation of the donor and the techniques without the cooperation of the donor. Examples of the various types of forgeries with associated images will be shown. The ability of forensic experts to distinguish between genuine marks and fakes will then be discussed. Although manual inspection techniques, they may also provide a reference to biometrics practitioners in their development of computerised techniques.

2.1 Introduction

To introduce this chapter, we felt the need to provide at the outset some clarification on the terms that are used rather loosely in the forensic literature to discuss the issues associated with fingerprint spoofing. It will lead us to reaffirm the need to distinguish forgeries from fabrications and marks from prints. The forensic scenario considered later will be the case of the recovery of forged marks from a donor left intentionally by a third party on objects associated with a crime and whether or not these marks can be distinguished from genuine marks left unintentionally by its legitimate donor. A few documented instances of such cases will be presented.

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The chapter will then elaborate on the techniques used to prepare forged fingers along side with illustrations for most of these techniques. The stigmates used as clues by forensic experts to detect forgeries will then be discussed. These clues are considered by experts in their decision-making process in a rather unstructured and nondocumented way. They form a part of the clues used in an holistic decision process. The final decision regarding the genuineness of a mark remain largely based on the training and experience of the forensic examiner. The reliability of experts to reach conclusions will also be discussed. To conclude this chapter, we will tentatively offer some parallels between the issues raised in forensic science and the search for spoofing detection system in biometric research.

2.1.1 Forgeries and Fabrication of Evidence: A Clarification of Terms and Cases

Even though papillary lines (or friction ridge skin—FRS) are found on more areas than the fingertips (they can also be found also on phalanges, palms, and soles), we restrict our presentation to fingers as they are the most targeted area. Friction ridge skin (FRS) refers to the original area of papillary lines that may be subject to forgery, e.g. the finger itself. The term "print" is reserved to the inked (of livescan) impressions taken under controlled conditions from either a genuine area of FRS or from a forgery. When fingers are involved, these prints will be named fingerprints. The term "mark" is used to describe the result of the apposition of impressions from the FRS or its forgery on a surface, generally in the context of a criminal activity. These marks can be left as 3D impressions (e.g. in mastic) or as 2D impressions that are either visible (e.g. in blood) or latent (e.g. left in the form of a natural sweat residue). When left by fingers, we will refer to them as fingermarks. The main distinction between marks and prints is that prints are left under supervised conditions (or under specific deposition instructions or mechanisms), whereas marks are left in an uncontrolled environment and are often latent (not visible to the naked eye). This chapter will concentrate on the risks posed by forgeries used to intentionally leave marks in forensic contexts. Scenarios involving prints, for example as a mean to attack a livescan device, are covered elsewhere in this book.

As pointed out by Bonebreak in 1976 [1], it is important to distinguish between the use of forgeries of fingers and the fabrication of evidence involving a fraudulent use of genuine marks. Both categories received little coverage in the forensic literature, whereas it could be expected (and even more so in the future) that any fingerprint specialist should be familiar and ready to discuss these matters in court [2]. In the literature, the most exhaustive papers are from Wertheim [3, 4] and Geller et al. [5]. Since these contributions, few additional researches (beyond case studies) have been presented in the forensic domain. In the light of the increased possibilities offered by new casting materials, there is merit in revisiting the subject on a regular basis.

Forged fingerprints are generally used by individuals committing a crime who will deposit forged marks of an innocent party in an attempt to implicate a third party or at least to divert the investigative process. To achieve that objective, a forged representation of the target portion of FRS is used as a stamp applied on the objects or surfaces of interest to leave marks. The issue of identity is generally not at stake here; what distinguishes genuine marks from forgeries is the mechanism whereby the marks have been deposited. A genuine mark is the result of the direct contact of an area of FRS on a receiving substrate. This contact generally does not involve any control or willingness of the donor (quite the contrary in criminal cases). The contact will leave a residue that will be visualised or detected using appropriate detection techniques. A forged mark however will be left using a reproduction of FRS that will be applied by a party to mimic the genuine production of a mark. These marks (we chose to name them marks still) will be left intentionally by the forger with the hope for them to be successfully detected by the investigators. This intention will have a bearing on the number, location, and extend of the marks deposited.

Cases involving forged marks have to be distinguished from the cases involving the fabrication of evidence. Cases of fabrication of evidence will take the form of a representation of a genuine mark (with some evidential benefits) that has never existed on the surface from which it purportedly came. Cases of fabrication of evidence are generally associated with police officers who engage into such activities to frame an individual by producing a compelling case with fingerprints. A few cases are worth mentioning (others can be found in [3, 6]):

The 1943 murder of Harry Oakes in the Bahamas is one of the most well-known cases of fabrication. Two corrupt police investigators lifted a fingermark from a drinking glass used by the defendant "Alfred de Marigny" during a police interview. The investigators then testified that the mark came from the dressing screen from Oakes' bed and filed that evidence to incriminate De Marigny. The defence was ultimately able to show the inconsistency between the background of the lift bearing the mark (a lift is an adhesive surface that is used conveniently to take up a mark developed by powdering on a substrate) and the texture of the piece of furniture from the scene from which it allegedly originated [7].

William DePalma was convicted in 1968 based on the fabrication of fingerprint evidence by Sgt. James Bakken who used a forged mark produced from a lift taken from a Xerox copy of a print from DePalma taken in 1957 for a minor offence [8].

Some cases do not necessarily involve deliberate wrongdoing but may simply be the consequence of mislabelling of the fingermark lift. In England, Alan McNamara is claiming that the mark that has been used to associate him with a burglary scene had been lifted from a vase that he touched under completely innocent circumstances and not from a wooden jewellery box (http://news.bbc.co.uk/2/hi/programmes/panorama/1426720.stm). Despite all his efforts to demonstrate the error (with the support of two recognised fingerprint experts), he served 30 months in prison for burglary.

In the case of the murder of Inge Lotz, it is alleged that the police detected marks corresponding to the defendant Mr van der Vyver from a drinking glass and then indicated that that mark was developed with powder from a DVD cover found on the crime scene [9].

A few instances of alleged misconduct have not been settled and are often linked with high profile cases [10].

Another use of fraudulent prints is to avoid identification by producing a friction ridge skin that will not be associated to any known print, either because of being a mirror image of a genuine fingerprint [11], or a synthetic image (no instance of occurrence known at the moment). The cases involving altered fingerprints with a view to avoid detection (in the context of border control, for example) are not covered in this chapter, as they are not considered as forgeries. The same will apply to other anecdotic usage of toeprints instead of fingerprints [12] to hinder the identification or to side-track the investigation.

The intent of the manipulation associated with the production of fake is generally beyond dispute. In the case of fabrication, an intent is difficult to establish as the process can easily be committed either because of chain of custody procedures that are not tight enough or simple inadvertent mix-up of exhibits, without any intent to mislead.

In the range of possibilities to attempt to incriminate someone based on fingerprint evidence, using forged marks is not the most convenient option, compared to the diverted usage of genuine marks or prints, either by placing an object bearing the marks in interest on a crime scene or by placing on the police file marks allegedly connected to the events under consideration.

Actual cases of known fingerprint forgeries are very seldom. Wertheim [6, 13] presented two cases: the Nedelkoff case in the 1940s [14] and the alleged forgeries of Pollock's fingerprints that received recent media attention.[1] Hence, as Wertheim rightly pointed out, most of the disputes are related to case of alleged fabrication of evidence. This is not to say that defendants never make allegations of forgery. A few cases are worth mentioned hereinafter:

In England, in 1938, a defendant David Pearce demonstrated to his jury the possibilities to transfer a genuine mark from one surface to another using an adhesive surface. Despite his efforts, Pearce was found guilty [15].

The 1980 s Mickelberg case (a.k.a. "Perth Mint Swindle") is well known in Australia. Raymond Mickelberg has been charged of fraud for using stolen checks. The prosecution case is based, in part, on a partial fingermark developed with ninhydrin on one of the checks and identified to him. The defendant claimed that the evidence was fabricated by the police using a silicon cast of his hands that he had produced as part of his hobby. The case was portrayed as a miscarriage of justice [16]. After years of controversies, the conviction has been quashed by the Supreme Court of Western Australia (MICKELBERG -v- THE QUEEN [2004] WASCA 145), without however any stance taken of the claim of forgery.

[1] "The Mark of a Master", David Grann, The New Yorker, July 12, http://www.newyorker.com/reporting/2010/07/12/100712fa_fact_grann.

The forensic literature on forged finger can be quite confusing because of lack of clear distinction between forgery and fabrication of evidence (see for example [17]). The purpose of this chapter is to focus only on forgeries.

2.1.2 A Short Historical Perspective on Fingerprint Forgery

As mentioned previously, documented cases of the use of forged fingerprints by criminals are very seldom. A few anecdotic cases have been reviewed by Wertheim [3] and chronologically in [5]. This is despite the presence of forged fingerprints in fiction and the publicity given throughout the years to the successful production of fake fingers. For example, in 1994, a TV program broadcasted in Holland showed the production of a forged finger of the Minister of Justice used afterwards on a livescan device [18]. We will not attempt here an exhaustive historical account, but will focus on few key papers published in forensic science to argue why the whole issue of forgery did not gain a lot of attention over the years.

The possibility of facing forged fingerprints has been raised immediately at the start of the 20th Century when fingerprint evidence obtained from crime scene marks gained its momentum in various jurisdictions. De Rechter published his early attempts to produce forged fingerprint directly from his own finger using a first mould in plaster followed by counter moulding in latex [19]. However, the risks posed by such productions were quickly considered as limited by the author at the time. Indeed, it was recognised that if a villain decided to produce a forged mark in order to pervert the course of an investigation and focus the attention on a different individual than himself, it would be much more easier to wear gloves in order to avoid leaving any incriminating marks. Goddefroy conceded that marks could be forged but hastily concluded that distinguishing the genuine mark from the fake production was trivial when pores and ridge edges are carefully examined. Indeed, at the time, the moulding materials were not allowing the fine resolution for a faithful reproduction of pores and ridge edges [20].

Carlson in 1920 [21] stressed on the need for an expert to be in a position to exclude the allegation of forgery during his testimony to the identity of a mark and a print. The author highlighted the risks posed by casting materials can be used to produce marks in any matrix of interest (natural secretion or blood).

In 1923, Wehde and Beffel published the first public alert against fingerprint forgeries [22]. They popularised the photo-etching technique for the production of forged fingers without the cooperation of the donor. They claimed that their production was so simple that it will put the whole fingerprint discipline at danger. That claim did not materialise in practice. It is also in the 1920 s that the first accounts of the possibility to transfer marks from one surface (a glass plate) to another flat surface were made [23].

The response from the forensic practitioners at that time has been that fingermarks made from forged fingers could easily be detected and such line of inquiry should not be pursued in every cases unless specific circumstances dictate. Clearly the burden of proof regarding the activity associated with the deposition of the mark was shifted from the prosecution side to the defence. Prosecution will then not explore systematically the avenue of forgery unless the defence suggests that possibility. Despite the early invitation by Lee [24] to admit such a possibility and discuss its consequences in court, very few fingerprint examiners were (and still are) prepared to entertain such a debate in court. Cummins stated what is still valid today [25]: only some fingerprint experts having extensive experience in manufacture of counterfeit and their study can make a distinction between a genuine mark and a mark felt by a forged finger based on the characteristics shown by the mark itself.

2.2 Production of Fingerprint Forgeries in Forensic Science

The chart in Fig. 2.1 summarises various options available to produce forgeries. These methods are detailed in the next section.

2.2.1 Production of a Stamp

2.2.1.1 Production

Based on an image of a target area of FRS or of a mark, rubber (or polymer) stamps can be easily produced through commercial channels using laser engraving for example.

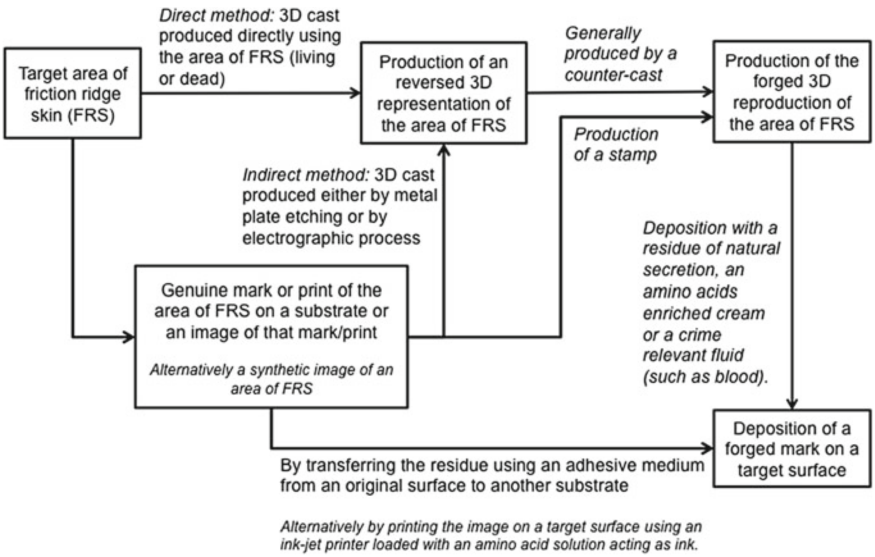

Fig. 2.1 Various options available to produce forgeries

Fig. 2.2 Comparison made by Morisod [26] between a genuine mark left in a glass surface and two forged marks left using sebaceous secretions on the same substrate

It leads to forgeries that lack flexibility but that can be used to leave marks on surfaces. Normally commercial producers of stamps should decline when asked to reproduce fingerprints, but practice has shown that professionals may not follow the line (or rule).

2.2.1.2 Example: Production of Fakes Using Stamps

Morisod produced marks left by a rubber stamp commercially produced from an starting black and white image of the target fingerprint [26]. Such a stamp can be used to leave marks composed of a greasy residue (the natural sebaceous secretion from the front head will suffice) left as contaminant on the surface of the forgery (Fig. 2.2).

Morisod also showed that on marks developed with DFO (an amino acid reagent), a clear difference in the amount of residue and its distribution can be seen (Fig. 2.3). This is due to the difficulty on forgeries to reproduce the distribution of the fingerprint eccrine residue along the ridges. Eccrine residue being secreted through the sweat pores of the friction ridge skin, a richer concentration is expected at the location of pores, giving on genuine marks a detection of ridges that appears as a succession of dotted points, especially when visualised in photoluminescence mode.

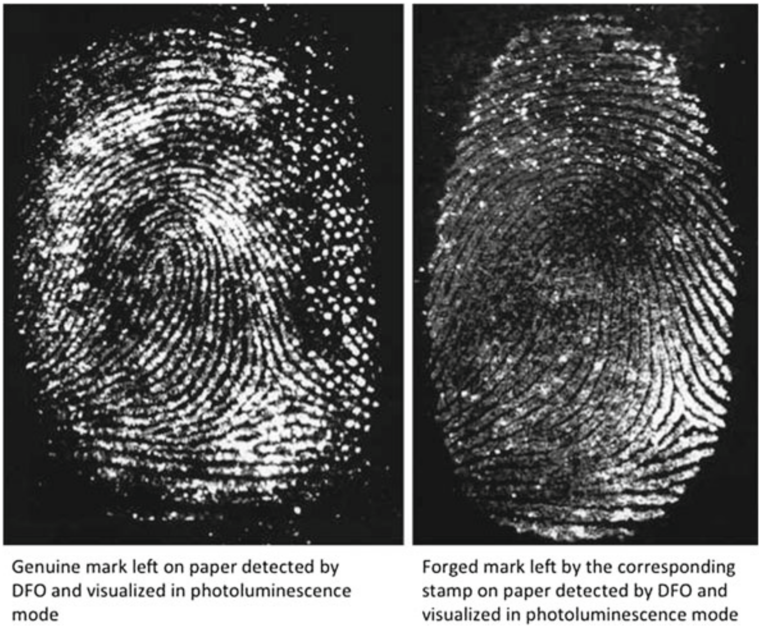

Fig. 2.3 Comparison made by Morisod [26] between a genuine mark deposited on paper and detected with DFO and a forged marks also detected with DFO. Note the dotty appearance of the ridges on the genuine mark

2.2.2 Casting of a Donor Finger Followed by Counter Casting

2.2.2.1 Production

This method ultimately leads to the production of a 3D cast reproduction of the FRS area of the donor. Impressions are then left as marks by the cast simply by greasing it and placing it on the target surface.

The direct casting technique requires some collaboration (or at least the availability of the surface of FRS of interest) of the donor to produce the first mould of the FRS. The material used for this first mould can vary but very good results have been obtained using a thermoplastic material [27]. Other types of material tend to either produce too limited depth of valleys or air bubbles that will then be visible on the counter cast and ultimately on the forged marks. The resolution and the ability to reproduce sweat pores will also depend on the chosen casting material.

Alternatively, and without the cooperation the donor, the initial mould can be obtained indirectly either through the covert capture of a mark that will serve as a blue print for the production of a 3D mould of the ridges. From a 2D image of the target mark, the mould is produced either by a photocopying process (the deposited and fixed toner offering enough relief to allow a subsequent counter-cast), or by metal plate etching.

Once the master cast is obtained, a counter-cast can be produced (simply by pouring another moulding material in the first cast) with various materials: silicon white glue, polyurethanes, latex, or gelatine. One critical aspect to obtain quality forgeries is the care in choosing casting materials that are compatible and limit the production of artefacts or defects.

Very good reproductions can be prepared with gelatine, however they need to be stored in a cool environment and their shelf life is rather limited (less than 5 weeks). A glucose-based formulation allows increasing the shelf life well above 11 weeks [28].

2.2.2.2 Example: Casting Techniques with the Cooperation of the Donor

It is important to state that the quality of the forgery will critically depend on the choice of the casting material. The production of artefacts dues to air bubbles depends on the couple of moulding materials used, as shown in Fig. 2.4.

In 2011, Ioan Truta (Boston police department) presented to the forensic community forged marks produced using casting: the first cast of the finger is made in putty, the second mould being produced with AccuTrans® casting medium (polyvinyl siloxane). Marks are then layed down on a smooth surface (white backing cards), developed with black magnetic powder and lifted with transparent adhesive. Figure 2.5 shows a few instances of forged marks compared against genuine marks. When the clarity of the marks is high, some clues of forgeries can be seen (shapes corresponding to air bubbles). However, when the clarity of the marks reduces, these

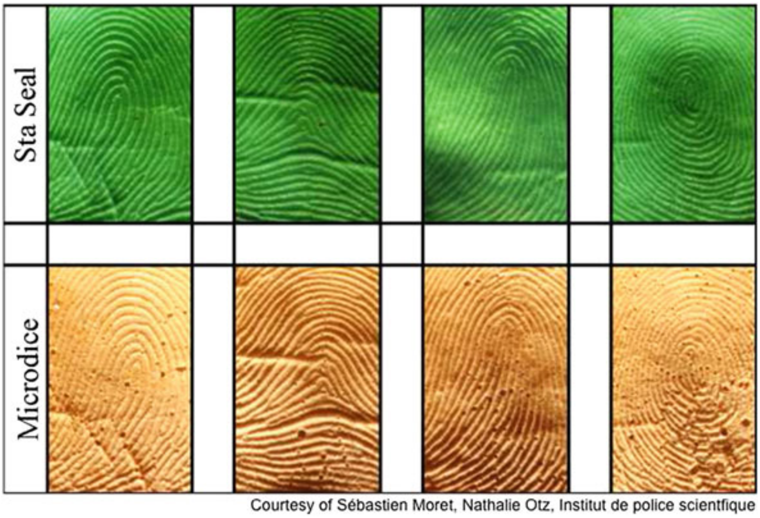

Fig. 2.4 Examples of first moulds obtained in our laboratory with four different donors using respectively two casting materials: Sta Seal (a silicone-based moulding material from Detax Dental GmbH & Co, Germany) and Microdice (a dental plaster from Dentsply Odoncia, France)

Fig. 2.5 Genuine and forged marks deposited by Ioan Truta (Boston police department) on *white backing cards* and detected with *black magnetic powder*. The forgery has been prepared using a double casting technique with the cooperation of the donor, the first mould in putty and second mould with AccuTrans

features cannot be distinguished from the usual background issues associated with marks.

The ability to reproduce pores also depends on the choice of materials and to some degree on the donor (who will also impact upon the visibility of pores on genuine marks). Figure 2.6 illustrates a case with very high quality reproduction of the pores.

2.2.2.3 Example: Casting Techniques Without the Cooperation of the Donor

Without the cooperation of the donor, the first step consists in obtaining an inversed blueprint of the target FRS. It is done by the acquisition of a genuine mark of high clarity and the preparation of a blueprint using image processing. That process is shown in Fig. 2.7.

Then the blueprint is printed on acetate sheet on a laser printer and a counter-mould is poured using gelatine, glue, or latex. Under pristine deposition conditions, the prints are of very high quality and it is very difficult to observe intrinsic features allowing to distinguishing the genuine from the fake (Fig. 2.8).

When marks are produced, the task of distinguishing genuine from fake is even more difficult even on very high clarity marks, as shown in Fig. 2.9.

Fig. 2.6 Comparison between a genuine and a forged finger acquired on an optical livescan device. The forgery has been prepared using a double casting technique with the cooperation of the donor, the first mould is made in a thermoplastic (UtilePlast, Pascal Rosier, France), the second is a silicon molding paste (Siligum, Gédéo, France)

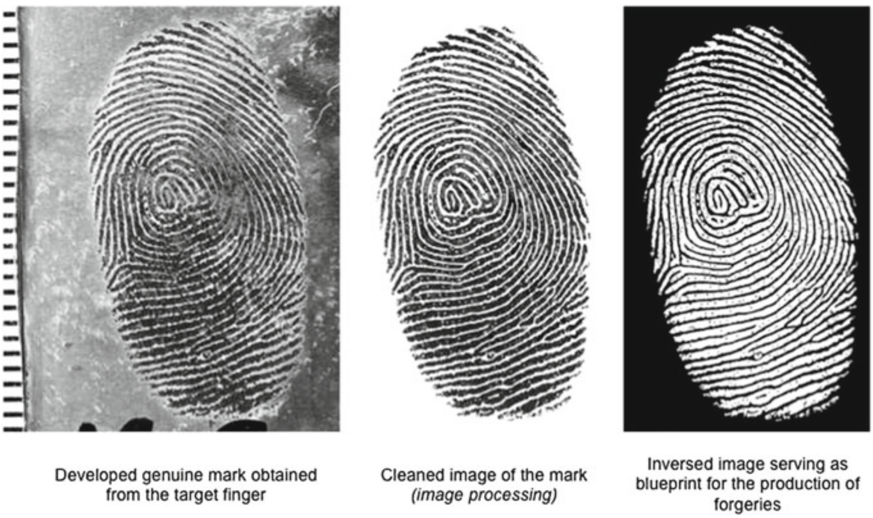

Fig. 2.7 Preparation of the blueprint (tonally reversed with *white ridges black furrows*) that will serve for the preparation of the forged marks without the cooperation of the donor

Fig. 2.8 Comparison between a genuine and a forged finger acquired on an optical livescan device. The forgery has been prepared without the cooperation of the donor starting with a mark detected optically on a glass surface and a latex cast (Gédéo, France)

2.2.3 Metal Plate Etching (Photo Engraving) Followed by Counter Casting

2.2.3.1 Production

Techniques commonly used to produce printed circuit board (PCB) can be used once an image of the target FRS is available. Hence, this technique does not require the cooperation of the donor. By simply reversing the contrast of the target image, printing it on a transparent media, the valleys (now in black) will protect the copper surface, the rest of the photo sensible layer being exposed to UV light. The chemical acidic etching process will occur on the exposed ridges, producing a 3D mould of the target FRS.

2.2.3.2 Example: Metal Plate Etching (Photo Engraving) Followed by Counter Casting, Without Cooperation of the Donor

An example of a mark obtained using a forgery obtained by metal plate etching is given in Fig. 2.10.

Fig. 2.9 Comparison between a genuine and a fake mark left on glass and visualised using optical techniques [29]. The forgery has been prepared with the cooperation of the donor. Note the appearance of the somewhat uneven widths of valleys and ridges, but the reproduction of pores on the forgery

2.2.4 Transfer of Fingerprint Residue or Powder from One Surface to Another

2.2.4.1 Production

In this process, the residue of a genuine mark is lifted by an adhesive material (such as an adhesive tape or a fingerprint lifter) and then transferred to another receiving surface. The technique comes conveniently into play when no collaboration from the donor is required. Technically, it could be said that such a mark is not a forgery, as it will show the transferred attributes of the original mark. However, on the grounds that fraudulent intent is evident, we will consider it as a forgery [30], but the technique has been used in cases of fabrication of evidence. Harper has stressed on the loss of residue during the process but also showed the high quality of the forged mark so produced [30] when examined directly under the microscope (without any detection techniques that would normally muddy the water even more). Harper very rightly stressed upon the importance of considering the context in which the marks were recovered. Identifying forgeries based on the sole intrinsic attributes of the mark is not sufficient to guide reliably on that matter.

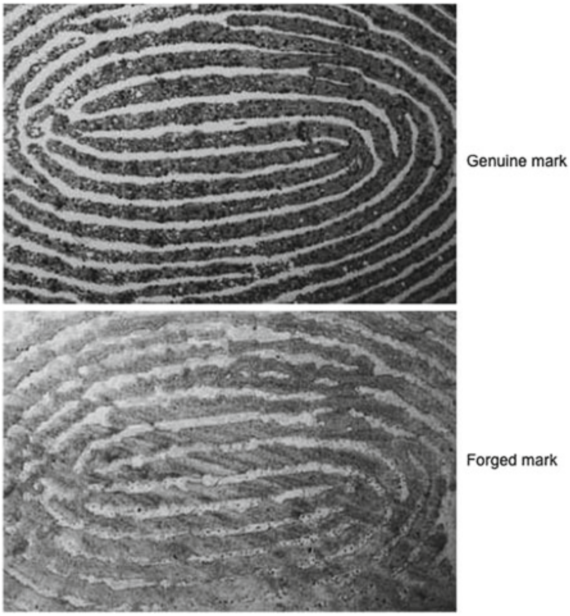

Fig. 2.10 Comparison between a genuine and a fake mark left on glass and visualised using optical techniques [29]. The forgery has been prepared without the cooperation of the donor using a metal plate etching technique. Note forgery the poor reproduction of the edges of the ridges

The operational success rate of such a transfer of residue is low. Some ideal conditions, difficult to meet in practice, are required: an appropriate mark on a smooth surface with enough mark residue to ensure the transfer and a clean smooth receiving surface [31]. An alternative method consists in transferring with adhesive tape a genuine mark developed with dusting powder (such as black or grey magnetic powder) [32].

2.2.4.2 Example: Transfer of Latent Mark from One Surface to Another

Morisod showed (Fig. 2.11) the possibility of such a transfer, successful only when the mark is particularly rich in residue [26]. Artefacts due to the use of the gelatine lift (or any other adhesive) can be observed (edges of the adhesive foil used, air bubbles and deposition of adhesive residue).

2.2.5 Direct Impression of a Fingermark to Produce a Forgery

That type of forgery has been suggested very recently [33]. However, to our knowledge, no known forensic cases involving that process has been uncovered in forensic casework. Due to the advances in printing technology, it is conceivable for an image of a fingermark to be printed with an "ink" chosen to simulate the residue of interest (or

Fig. 2.11 Forged marks developed with aluminium powder by Morisod [32]. The mark originates from a genuine mark of sebaceous residue left on glass and transferred onto another piece of glass using a gelatine lifter (note the marks left by the edges of the lifter and the air bubbles left during the transfer process)

targeted by the detection technique). This method of production of forgeries is directly inspired from a modification of an inkjet printer used to produce artificial deposition amino acids at varying concentrations for quality management purposes [34]. The technique has then been adapted to print images of fingerprints with an inkjet printer replacing the ink with an amino acid colourless solution. It produces forgeries that will be visualised once amino acid reagents are used (such as ninhydrin, DFO, or indanedione/Zn). Kiltz and colleagues documented the differences in image quality observed between forged and genuine marks and suggested the use, on flat surfaces, of a contact-less CWL sensor for an optical acquisition prior any application of a physical or chemical technique [33]. A Hough-Circles algorithm has been used to help with the task of distinguishing genuine from fake [35]. They suggested a shape analysis of the dots constituting the detected marks. It applies to nonporous surfaces (marks were printed on overhead foils) and on images captured with a contact-less CWL sensor. Using horizontal and vertical dot distance measures, they detected a high dot density for genuine fingerprints and a low dot density for forgeries obtained using that printing process. Taking advantage of the high resolution (12,700 dpi) of a CWL sensor, Hildebrandt and coworkers [36] showed that both for marks optically acquired from nonporous surfaces or for marks on paper developed with ninhydrin, an analysis of the texture allowed a successful classification between genuine and fake.

2.3 Fingerprint Anti-spoofing in Forensic Science

The detection of forgeries in forensic science relies solely on the visual assessment made by a fingerprint examiner. To our knowledge, there is no systematic measurement techniques that have been proposed to assist the examiner in that task. The approach is holistic and, at present, not fully articulated. We will first review the clues for forgeries upon which the examiners generally rely during their examination and then we will present some data regarding the ability of experts to distinguish between genuine and forged marks.

2.3.1 Artefacts (or Clues) Associated for Forged Marks

Artefacts (or clues) of forgeries are described in the specialised literature [3]. It is worth distinguishing the intrinsic features (visible on the mark itself) from the extrinsic features (i.e. the context in which the mark(s) is(are) detected). Needless to say that the intrinsic features are easier to observe using optical techniques rather than following a sequence of detection techniques that may hinder the visibility of fine features such as pores or ridge edges.

The following intrinsic features may be found on forged marks (based on [37] and also on [26, 29]) helping to distinguish them from genuine marks. We will distinguish between the general features observed without any particular magnification and more particular feature that will require appropriate magnification (5x–10x).

General features observed on forgeries:

- Background noise (a type of halo effect) around the mark itself or in areas without ridges. This is due to an interaction on the surface of the mould material bearing no ridge and the substrate.
- An overall shape of the mark that is inconsistent with the natural deposition of a finger.
- Clear and well-defined external contours of the mark, either partially or entirely, as a function of their deposition. Ridges will end abruptly at the boundaries of the forged mark, whereas comparatively, on genuine marks, ridges coming to the border of the mark will tend to fade gently.
- Missing section of ridges, or section of ridges that are of lower clarity compared to highest clarity of the neighbouring (adjacent) ridges.
- Smudged or distorted friction ridges in areas that are not compatible with the dynamics of a natural deposition of a finger on a surface.

- Unexpected appearance of the ridges following the detection technique used. For example, amino-acid reagents tend to develop genuine marks as a series of dots leading to the appearance of papillary lines. Forged marks are laid down with a film of residue that hardly mimics the succession of rich-residue pores.

Particular features observed on forgeries (when the clarity of the mark allows):

- The presence of air bubbles and defects due to the casting material. Note that a careful choice of the casting material can diminish the occurrence of artefacts due to air bubbles.
- The absence of visible sweat pores. Some authors give a lot of weight to the presence of pores attesting the authenticity of a mark (e.g. [31]), but again an adequate choice of the casting materials allows reproducing pores.
- Very narrow valleys compared to the ridges or uneven widths of ridges and valleys.
- The presence of reproducible artefacts on multiple marks from the same area of FRS.

Forged marks may present some specific extrinsic features (very well described as early as 1933 by Lee [38], Harper [30] and reaffirmed in the subsequent forensic literature). They are:

- The detection of the mark from one finger in situations where an associated detection of the marks left by the other fingers or palm would be also expected.
- The detection of multiple apposition of marks representing the same area of friction ridge skin, at times even to the point that they overlap completely and share the same shapes of pores or ridge edges.
- The detection of a mark in an anatomical position that is not consistent with the natural pre-emption of the receiving object.
- The forensic evidence in the case is based only on these fingermarks.

2.3.2 Ability of Forensic Expert to Detect Forgeries

Cummins [25] has been the first to test the ability of forensic examiners to distinguish genuine from forged prints (i.e. obtained following an inking process). Eight experts were invited to study four prints. Out of 32 opinions, Cummins counted 20 right answers, 1 doubtful and 11 wrong determinations. Keeping in mind that the forged prints were produced under pristine conditions, it may be expected that the ability to distinguish genuine from fake will diminish when dealing with marks developed using methods that may affect the clarity of marks. Senay submitted forged marks to five examiners who did not show much success in their detection, especially when forgery was not prompted as an issue to consider [31]. It is fair to say that the mere possibility of forged marks is not at the forefront of the consideration of fingerprint experts. For them, the first issue to assess is the question of source. The possibility of a forgery is not explored systematically and it will be waited for the allegation to be made for it to be considered any further. It means that training and experience in this area is rather limited, very ad hoc at best.

Geller et al. [39] reported, following a survey conducted among 152 examiners, that even though a majority (85 %) of professionals were aware of the possibility to forge fingerprints, 57 % only indicated that the threat was credible and 45 % of them indicated that they would not be in a position to distinguish genuine marks from forged marks.

In 2011, Bourquin investigated the risks posed by forgeries and the ability of forensic practitioners to detect them [37]. She elaborated forgeries without the cooperation of the donors. The forgeries were prepared from genuine marks developed with cyanoacrylate fuming, prepared and printed on acetate sheets. The final moulds were obtained with various casting materials. The use of cyanoacrylate fuming as a detection technique allows obtaining in one step an inverse image (white ridges on a dark background). The production of the blueprint is presented in Fig. 2.12.

Forged marks were prepared by apposing the moulds contaminated with an amino acid enriched cream on target surfaces (paper or glass). Marks were detected either with aluminum powder on smooth surfaces or with an amino acids reagent (indanedione/Zn) on porous surfaces. 18 marks (Eight genuine mark and Ten forgeries) had been submitted to 78 fingerprint examiners (from the USA and from Switzerland). Half of the respondents received beforehand a broad guide to help them with the assessment, the other half were just given the task without any guidance. The

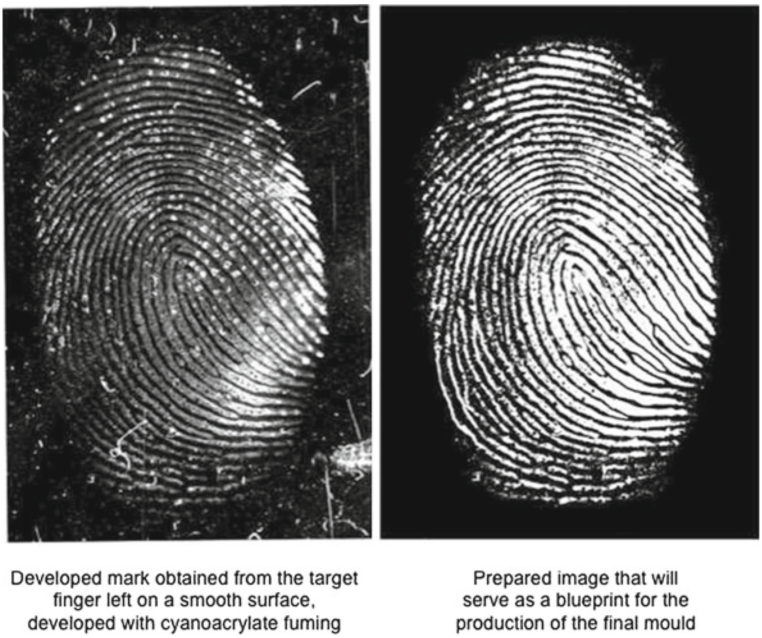

Fig. 2.12 Preparation of the blueprint that will be used to produce forged moulds for the study by Bourquin [37]

main lines of the guide were similar to the previous section on the intrinsic features associated with forgeries. The results are given in Table 2.1.

The results confirm how difficult it is to detect forgeries, regardless of the availability of the guidance note. The guide improves slightly the detection power but to the cost of increasing the rate of misclassification of genuine marks as forgeries. The guide put examiners in an “awareness state” that makes them increase their claims of forgeries.

Some examples of the marks (genuine or forged) that led to the most difficulties in terms of classification are given in Fig. 2.13.

Table 2.1 Results on the test carried out by Bourquin [37] on a population of 78 fingerprint examiners, half of them having some initial guidance, half of them without

Examiners (78)	With the guide (39)		Without the guide (39)	
	Forged marks (10)	Genuine marks (8)	Forged marks (10)	Genuine marks (8)
Declared as genuine (%)	63	55	53	67
Declared as forgery (%)	37	45	47	33

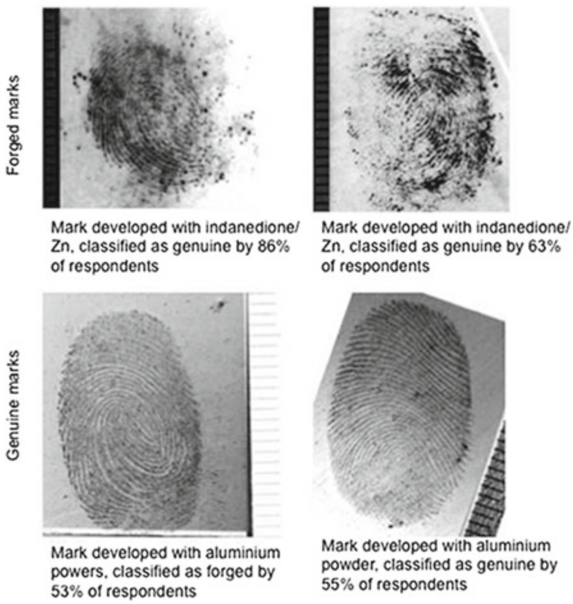

Fig. 2.13 Examples of genuine and forged marks used in the study by Bourquin [37]

2.4 Conclusion

In this chapter, we focused mainly on the issue of forgery of friction ridge skin to intentionally leave marks to be detected in association with the investigation of crime. These fake marks will be visible or latent and left intentionally on substrates that will be the focus of the forensic investigation. The aim of such endeavor is to divert the investigation on a noninvolved third party. Although the possibility of such forgeries have been raised sporadically from the early days of fingerprinting, the number of known cases involving such productions is very limited. To the point that the issue of forgery is not considered in every forensic case, the burden of raising the issue is left entirely to the defense.

This is in contrast with the number of cases involving the fabrication of fingerprint evidence (often based on genuine marks). Fabrication of evidence usually does not require forging friction ridge skin, but will involve the claim that a genuine mark recovered under “innocent” circumstances is associated with the crime under investigation. It is more often achieved by tampering with the chain of custody, than by resorting to the use of a forged area of friction ridge skin. Cases of evidence fabrication are often the results of dishonest police practice.

The techniques used produce forgeries have been reviewed and illustrated. In our view, only casting techniques can produced forged marks that will be very difficult to detect, even more so when the donor is cooperative. The appropriate casting techniques are cheap, easy to operate and do not require specialist knowledge.

The attributes of the forged marks have been listed distinguishing between the intrinsic features (obtained directly from the mark(s) itself) from the extrinsic features (associated with the context in which the mark(s) has been discovered). The forensic practitioners should consider both aspects when the issue of forgery has to be evaluated.

Some forensic practitioners may think that the detection of forgeries based on the intrinsic features shown by the detected mark is an easy task. Results from past and more recent tests have shown the complete opposite. When forged marks have been produced using carefully chosen techniques, they cannot be distinguished from genuine marks even when the forgery has been obtained without the cooperation of the donor. That state of affair simply put more weight on the whole crime scene investigation that should provide other extrinsic evidence to help guiding on the genuineness of the collected marks.

The above may offer also some useful parallels to the biometric research community. It is fair to say that as soon as a forgery has been prepared with carefully chosen molding materials, there are, based on intrinsic features, very limited ways to distinguish genuine from fake even when the deposited mark is of very high clarity. Fingerprint experts, despite their expensive exposure to marks (mainly genuine), have shown limited ability to resolve this issue. This state of affair will not improve given the rapid progress made in material technology and printing technology. We suggest that spoof detection research in the context of biometric systems should focus less on intrinsic features but more on extrinsic features. Promising lines in inquiry may be more towards the detection of attributes of the living finger or the spoof material than on the fingerprint features displayed by the acquisition system. Forensic scientists have to rely on the contextual elements surrounding the detection of the marks than on the specific attributes of the acquired images. The same may apply to the biometric world: the prevention or detection of spoofing may benefit more from a careful assessment of the processes underpinning the use of the biometric system than on technological advances.

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