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Dating of Fingermarks: Fiction or Reality?

"When was this fingermark left? Is it fresh?" These questions are frequently asked at the crime scene, during the investigation and also in the courtroom. They are particularly relevant if the suspect admits having left his or her fingermark at the crime scene, yet claims that this did not happen during the crime, rather before – or after – the criminal activity. In other words, the dating of a fingermark can represent an important part of the investigation if the suspect does not question the identification of his or her fingermark, but rather the time at which it was left. An international case study has found that fingermark experts sometimes give fairly accurate answers when asked about the age of a fingermark. However, are such statements permissible? Can the age of a fingermark really be determined? The aim of this article is to answer this question through a practice-oriented discussion of current research results. Therefore, the issue of the temporal dimension in forensic science is addressed first. Then, cases in which the age of fingermarks found at crime scene played an important role are discussed. Subsequently, the key international research results on fingermark dating will be presented, with particular focus on studies that examine the aging of specific, intrinsic, physical characteristics and chemical components over time using optical and analytical methods. Towards the end of the article, the extent to which these research results can be used in practice is finally discussed and an outlook on the future of fingermark dating is presented.

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1. INTRODUCTION: DATING IN FORENSIC SCIENCE

Time is and remains an aporetic term for sciences which have been trying to describe it for centuries (e.g. physics or philosophy) because it is, by nature, intangible, irreversible and relative (Lloyd 1972; Margot 2000; Lausberg 2005; Müller 2007; Callender 2010). This indefinable time, however, enables the expression of various concepts, amongst other things, duration, consequence and simultaneity (Margot 2000), which interact constantly in our daily lives. Therefore, time actually plays an important role in the development and application of any science, even if it does not constitute the main object of research, such as, for example, in linguistics (When did this language become extinct?), in chemistry (How long does water take to evaporate?) or in law (How old was the victim at the time of the crime?). Consequently, time is also an integral part of forensic science, which is defined as follows:

"Forensic science, or forensics, applies a scientific approach and technical methods in the study of traces that come from a criminal activity, or from a contentious activity in the field of civil, regulatory or administrative matters. It helps the judiciary to take position about causes and circumstances regarding this [criminal] activity" (translated from Ribaux/Margot w.d.).

Thus, the goal of forensic science is to reconstruct a situation (the criminal or contentious activity) a posteriori. This situation has the following temporal properties (adapted from Kind 1987):

- it has existed for a certain duration at a certain time (duration),
- it is the consequence of a series of past events (consequence),
- it will influence a series of future events (consequence),
- it varies according to simultaneous events (simultaneity).

The issue of time in the context of forensic science plays a specific role if, inter alia, the time of a crime should be elucidated (e.g. in the case of a burglary while the residents are absent), the age of a person must be determined (e.g. if the age of the perpetrator is unknown and the question arises as to whether reduced penalties for young people are applicable), or the age of an object or mark is relevant to the investigation.

Two authors attempted to formalise the issues relevant to forensic science in order to offer research strategies for the dating of events and marks (Weyermann/Ribaux 2012). According to this study, there are three different, complementary approaches that should focus on investigations of the temporal dimension in forensic science:

- Numeric or contextual time markers: the former includes, for example, the date and time of an event on the video of a surveillance camera, the later includes the date when an object is put into circulation or a person's date of birth; if this information is available and its authenticity can be verified, absolute indirect dating can take place.
- Chronology: includes the identification of the order of the relevant criminal events as well as the marks left at the crime scene, in particular using non-destructive optical or analytical methods; this is also called relative dating because events/ marks are related to each other and dated without any absolute age being determined.
- Kinetics: involves the determination of the rate of chemical or physical processes and especially concerns biological traces, the chemical or physical properties of which change over time (e.g. fingermarks, blood traces, saliva); if these changes are reproducible and modellable, an absolute dating of the traces is possible.

As previously mentioned, the kinetics approach mainly refers to the dating of biological traces. This aspect is of particular concern in practice if the time of the crime scene marks being left is questioned – i.e. when it must be decided whether a trace is relevant for the investigation in the specific case or not. A relevant trace is defined as a trace which is connected to the crime (Hazard 2014) or was left by the perpetrator during the criminal activity (Stoney 1991). The dating of traces therefore enables their relevance to be decided.

There are mainly kinetics-based studies on the dating of inks (Aginsky 1996; Bugler et al. 2008; Weyermann et al. 2008; Koenig et al. 2015), gunshot residue (Andersson/Andrasko 1999; Andrasko et al. 1998; Gallidabino et al. 2013), blood traces (Andrasko 1997; Bremmer et al. 2011; Edelman et al. 2012) and fingermarks (Girod et al. 2012; Cadd et al. 2015) in international literature. Among these traces, fingermarks are particularly interesting in the context of crime scene investigation because they are found and collected the most often at various crime scenes. Therefore, questions on fingermark dating are not new and scientific studies were published as early as the beginning of the 20th century, e.g. Heindl's work on the longevity of fingermarks exposed to outdoor conditions (Heindl 1927). Several papers on fingermark dating have been published since this early article and have basically focused on the following three main sources of information:

- Investigative information: these are used as contextual time markers, enabling indirect dating (Weyermann/Ribaux 2012; Champod et al. 2004). If it is, for example, certain that a substrate on which a fingermark has been secured is thoroughly cleaned every week, the maximum age of this mark can be determined; in this case, the mark can be one week old at most.
- Modification of physical characteristics: these are studied using optical methods and should enable direct dating based on aging models. According to the literature, these characteristics are, amongst other things, the number, the type and the form of the minutia and pores, the width and height of the ridges, and the general quality of a fingermark (Schwabenland 1992; De Alcaraz-Fossoul et al. 2013; ibid 2017; De Alcaraz-Fossoul/Barrot Feixat et al. 2016; De Alcaraz-Fossoul/Mestres Patris et al. 2016; Barros et al. 2013).
- Modification of chemical characteristics: these are mostly studied using analytical methods (e.g. chromatography or spectroscopy) and should enable objective direct dating based on aging models. According to the literature, these characteristics are, amongst other things, the absolute or relative amount and distribution of intrinsic fingermark components, e.g. amino acids or fatty acids (Girod et al. 2012; Girod/Ramotowski et al. 2016).

However, most scientific papers have, to date, been published in English. This original version of this article offered one of the first overviews of the subject in German. It cites concrete case studies and the most important research results from the author's perspective and discusses their use in practice in order to then outline future developments in the form of an outlook.

2. FINGERMARKS DATING IN REAL CASES

In the United States, many experts have given a concrete answer in court when asked about the age of a fingermark. They have mainly relied on their experience to justify their statements, and suspects have often been charged on the basis of these statements (Girod/Ramotowski et al. 2016). The cases of Hearn vs. State (burglary, 1972), Commonwealth vs. Schroth (murder, 1981) and Armstrong vs. State (burglary, 1987) can serve as examples. In these three cases, the defence claimed that their fingermarks had been left at the crime scene but that they had no connection with the subsequent act. However, the prosecution's experts stated that the fingermarks collected at the crime scene had been left "10 to 24 hours", "6 to 12 hours" or "a short time" before. In order to be able to make these statements, the three experts relied on the quality of the marks after their enhancement with powder. Interestingly, the expert in the Commonwealth vs. Schroth case initially stated that there were no reliable methods for dating fingermarks, yet subsequently gave a very accurate estimate of age (6 to 12 hours old). Similar concrete expert statements can also be found in more recent cases, e.g. in the case of Pouncy vs. State (burglary, 2002) or State vs. Clinkscale (murder, 2011), where the experts stated that the fingermarks had been left at the crime scene less than "48 hours" or "a short time" before.

While expert assessments led to prosecution in the above cases, the question of fingermark dating led to acquittal in other cases in the United States, for example in United States vs. Collon (armed burglary, 1970) and "Matter of J.M.C., Jr. (burglary, 1985)". In these cases, the question arose about dating fingermarks which had been collected from a city map marked with the address of the crime scene and from a room fragrance bottle. The experts stated that it was impossible to determine when these marks had been left and that they might have been on these substrates for several months or for several years. The competent courts stressed that these objects are movable industrial products that could have been touched by a wide variety of people for various reasons not related to the crime. The information obtained via the marks was therefore not considered sufficient for a conviction.

In contrast to the situation in the United States, it is difficult in some European countries (e.g. Sweden, Austria or Switzerland) to find published documents on court cases in which the age of fingermarks played a central role. Access to investigative documents is strictly regulated, and most judgements or decisions do not even mention the age of fingermarks, although it is actually put into practice time and again worldwide. It is only possible to speculate why, for example, in some European legal proceedings, comparatively little is asked about the age of a fingermark or at least why this issue is not mentioned in published documents. One explanation could be that the issue of a fingermark's age is usually addressed by the defence, which should therefore appoint fingermark experts outside the state institutions as private experts. This can be difficult in Austria or Switzerland, for example, as almost none exist. In the United States, on the other hand, there is usually access to fingermark experts (Langenburg 2012), which possibly simplifies or even encourages addressing the dating issue. Moreover, even if there were private assessors available, the question would arise as to whether commissioning a private expert report actually makes any sense. Such expert reports are usually very expensive and, inter alia, only permitted to a limited extent as evidence in Austria, since the expert report from the expert appointed by the court or by the public prosecutor is relevant in the first instance (Attlmayr 2013).

Apart from this, the fundamental question of whether and how information about the age of fingermarks should be given remains controversial within European forensic science. According to personal communication, some experts believe that information could be provided by looking at the quality of the fingermark after enhancement (usually with powder), in line with the motto "the better it looks, the fresher it is". Others assume that the age of fingermarks cannot be reliably estimated and certainly not determined. The same discussion can be observed in Israel and New Zealand. Therefore Fingermarks' dating is a worldwide problem that has been and is being actively researched internationally.

3. METHODS FOR DATING FINGERMARKS

3.1 Research on the modification of physical characteristics

As mentioned above, the number, type and form of the minutia and pores, the width and height of the ridges and the general quality of a fingermark change over time. These characteristics have been investigated within the framework of various studies as potential aging parameters, i.e. parameters which could be used to draw conclusions about the age of a fingermark.

The vast majority of these publications, however, tend to neglect the influence of external factors (Midkiff 1992; ibid 1993; Wertheim 2003). However, the physical characteristics of the fingermarks are already influenced by various conditions at the time they are left (e.g. pressure, length of contact) and environmental conditions (e.g. temperature, light) also play an important role over time (Girod/Spyratou et al. 2016). The general quality of the fingermark is often considered a relevant aging parameter and is also used in practice, although the visual appearance of the fingermark depends more on environmental conditions than on time elapsed. In fact, several cases and studies have been reported where old fingermarks (e.g. 2, 15 or even 55 years old) were enhanced and demonstrated very good visual quality (Bluhm/Lougheed 1960; Barnett/Berger 1977; Balloch 1977; Belcher 1982; Greenlees 1994; Involdstad 1976; Hoye 1977; Illsley 1984; Clements 1986; Bowman 2003). In one study, it was even reported that fingermarks enhanced with cyanoacrylate fuming and secured with gel lifters could be collected 559 times (each time with a fresh gel lifter) before a significant quality deterioration was visible (Illsley 1984). This was also reported in a real case (Clements 1986): in August 1983, a suspect was arrested, prosecuted and sentenced for breaking into a church. A fingermark expert from the Los Angeles Police Department (LAPD) collected two fingermarks (left middle and ring fingers) near the door of the point of entrance. About a year later, the LAPD was called to the same church because of another burglary. Another fingermark expert collected a left middle and ring fingermark near the front door at the crime scene. Does this description sound familiar? Yes, it does, because the two fingermarks could be matched to the same person who was still imprisoned for the first burglary and therefore could not have committed the second one. One year later, the second fingermark expert thus collected exactly the same fingermarks, which were still of very good quality.

Source: Girod-Frais

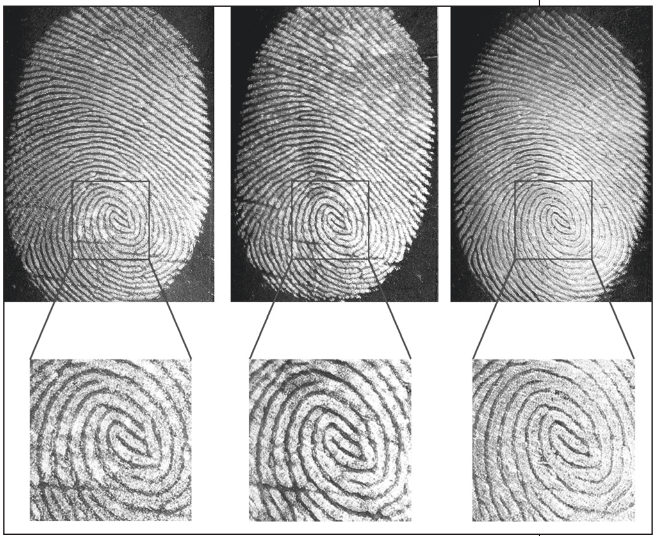

Figure 1: Natural fingermarks at 10 minutes, 1 day and 5 weeks (from left to right), photographed in transmission mode[1]

The years between 1960 and 1980 were characterised by several studies that focused on the quality of the fingermark as

Source: Girod-Frais

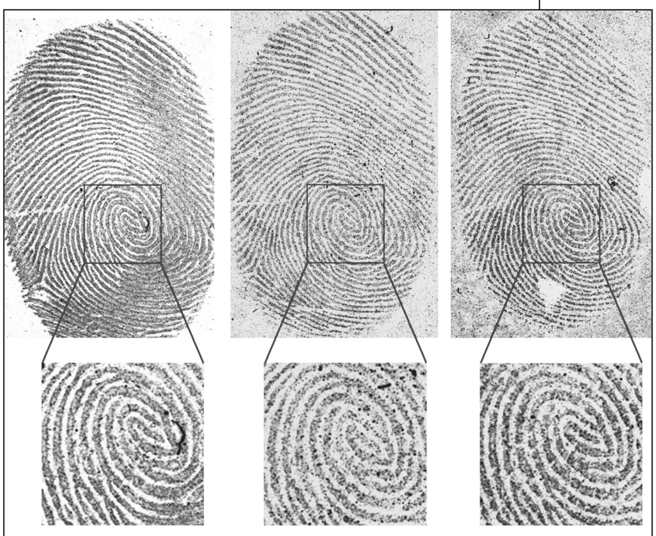

Figure 2: Natural fingermarks at 10 minutes, 1 hour and 6 weeks (from left to right) enhanced with argentoratum (aluminium fingermark powder) and secured with gel lifter[2]

an aging parameter. Less on this has been published since then; however, the belief among those involved in the criminal justice system (police, prosecution, courts) and even among fingermark experts that a "good-looking" fingermark is a fresh one and is still very strong. This belief is, however, not based on scientifically proved facts and is wrong, as clearly illustrated in Figure 1 (see page 25): there are no significant variations in quality between the fresh and five-week old natural fingermarks (without enhancement technique). When fingermarks are enhanced with powder, there is a difference in contrast between totally fresh and older fingermarks as the powder sticks to the background because of dust and dirt, but the intrinsic quality of the fingermark (visibility of ridges and minutia) does not change (see Figure 2, page 25).

Various influence factors, such as the nature of the substrate and the environmental conditions, play a very important role in terms of the quality of the physical characteristics of fingermarks and must therefore be taken into account in studies on dating. An American research group studied the influences of the type of finger residue (water-soluble or fat-soluble component), the substrate (glass or plastic), the light (darkness, shadow or direct light) on the number of minutia, the colour contrast between the ridges and the background and the continuity of the ridges over six months using standardised photographs (De Alcaraz-Fossoul/Mestres Patris et al. 2016; De Alcaraz-Fossoul/Barrot Feixat et al. 2016; De Alcaraz-Fossoul et al. 2017). However, these publications have a striking methodological weakness: it was not the same mark that was studied over the selected time period, but different marks, because the physical characteristics were only evaluated after the enhancement of the fingermarks using titanium dioxide powder. This means that a different mark was considered for each age studied. It is well-known that different marks, even if made by the same fingermark donor, have different compositions and therefore react differently to enhancement techniques (Girod/Spyratou et al. 2016). Furthermore, the use and application of powder itself also influence the physical characteristics of the fingermarks. Therefore, these results cannot be used to draw practical conclusions about the aging of fingermarks.

It should not go unmentioned that a German research group has overcome the weakness of the studies summarised above by studying the aging of fingermarks with a contactless chromatic white light sensor (CWLS) and a confocal laser scanning microscope (CLSM) and processing the data using statistical time-series analysis (Merkel et al. 2012; Merkel et al. 2017). The aging of several marks was documented over three years. It was demonstrated that the contrast and height of the ridges decrease regularly over time. Aging models were also calculated. However, this method is currently only applicable on smooth substrates (e.g. glass, metal). Moreover, when several factors (e.g. different fingermark donors, pressure, environmental conditions) were tested, the aging models became less reproducible. Therefore, a practical application of this method is currently impossible. Nevertheless, the development of this method should be pursued in the future, as it is probably the most promising method focusing on physical characteristics.

3.2 Research on the modification of chemical characteristics

The chemical characteristics of fingermarks include, inter alia, the absolute or relative amount and distribution of intrinsic water-soluble (e.g. amino acid) or fat-soluble (e.g. fatty acid) chemical components. The chemical composition of fingermarks has been explored in several studies, and component lists have already been published in various literature surveys (Ramotowski 2001; Girod et al. 2012; Cadd et al. 2015). Fingermarks consist of various compounds that are secreted mainly by the sweat and sebaceous glands present in the dermis. Sweat glands release water-soluble substances (e.g. amino acids or proteins) while sebaceous glands release fat-soluble substances (e.g. fatty acids or cholesterol). In addition, a small proportion of the fingermarks' compounds consists of residues from the desquamation process of the epidermis. Thus, the composition of fingermarks is a very complex and variable system, which first arises after the contact of a finger with a substrate and then changes over time. In addition, this composition is influenced by various factors that can be divided into five groups (Girod et al. 2012): the characteristics of the fingermark donor (e.g. age, nutrition), the deposition conditions (e.g. pressure, duration of contact with the substrate), the nature of the substrate (e.g. smooth, porous), environmental conditions (e.g. temperature, light) and enhancement techniques (see Figure 3).

Source: Girod et al. 2012

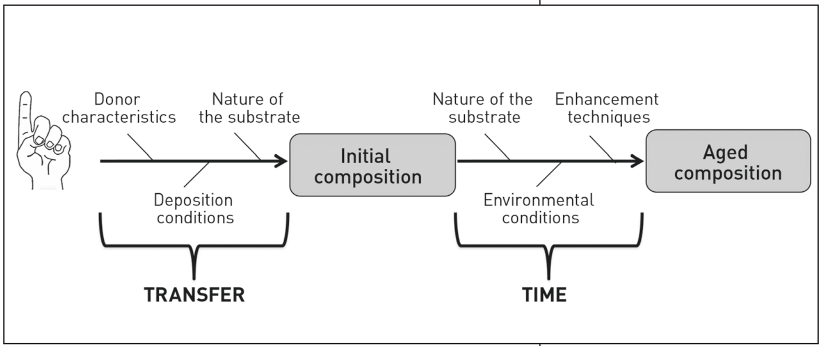

Figure 3: Schematic representation of the chemical composition of fingermarks and its influence factors[3]

Many research attempts have failed due to the variability of the chemical composition of fingermarks. In the 1960s, for example, Angst (Angst 1962) had already attempted to study the width of diffusion of chloride ions in paper using silver nitrate in order to develop a dating methodology. His hypothesis was: "The wider the diffusion, the older the fingermark". However, he quickly abandoned his attempts because the variability of the diffusion of the ions proved to be far too large. This study was the first publication to mention fingermark dating experiments based on their chemical characteristics.

Since the question of the age of fingermarks is very important for practical applications, in practice, further research was carried out. Between 1970 and 1990, most studies were conducted using high performance liquid chromatography and thin layer chromatography, alone or combined with fluorescence spectroscopy (Dalrymple et al. 1977; Duff/Menzel 1978; Dikshitulu et al. 1986; Olsen 1987; Menzel 1992). However, no practice-relevant results were obtained, mostly because of the variability of the parameters studied. However, thanks to technological advances, various research group were able to further develop fluorescence studies (Lambrechts et al. 2012; van Dam et al. 2013; ibid 2014; Akiba et al. 2018). Aging models were constructed based on the fluorescence intensity of proteins and their oxidation products, which enable dating of fingermarks up to 21 days old. However, several fingermarks were placed on top of each other for these studies because the fluorescence intensity of individual fingermarks turned out to be too low. Therefore, a practical application of these results is currently not possible.

Since the end of the 1990s, chemical-analytical methods, such as gas chromatography coupled with mass spectrometry (GC/MS), have developed rapidly. The composition and aging of fingermarks were subsequently investigated in several studies using GC/MS (Archer et al. 2005; Croxton et al. 2006; ibid 2010; Weyermann et al. 2011; Koenig et al. 2011; Pleik et al. 2016). Further aging models have been published as part of the author's dissertation; these are based on fat-soluble components and enable interesting dating under certain conditions (Girod/Spyratou et al. 2016; Girod/Ramotowski et al. 2016). The prerequisite here is that the dating only takes place after the identification of a suspect. In this case, comparison materials are taken from this person under the same conditions as the crime scene mark and case-related aging models are developed. Fingermark donors, substrates and enhancement techniques are thus known influence factors, while the deposition conditions and environmental conditions are regarded as unknown influence factors (known/unknown influence factors according to Girod/Spyratou et al. 2016). In this context, aging models were calculated based on a probabilistic approach (Bayesian network) that enable to compare two different temporal hypotheses against each other, i.e. in this case, to decide whether test fingermarks were "≤10 days old" or "≥14 days old". As a result, 75 % to 100 % of the test marks were ordered correctly over a period of 36 days. However, these models should currently not be used in practice, as more data need to be collected to achieve a potential validation.

From the 2000s, the chemical composition of fingermarks and their aging were often studied using Fourier Transform Infrafred Spectroscopy (FTIR) (Williams et al. 2004; Chan et al. 2005; Hemmila et al. 2008; Mou/Rabalais 2009; Antoine et al. 2010; Williams et al. 2011; Fritz et al. 2013; Bright et al. 2013; Banas et al. 2014; Girod et al. 2015; Johnston/Rogers 2017). Compared to other analytical methods, as for example GC/MS, one advantage of FTIR is that the analysis of the samples can take place without preparation stages and without destruction. The cited studies enabled the identification of spectral bandwidths, with which aging models could be calculated and constructed. These were, however, not used to estimate the age of test marks, so this method should be developed further before a decision can be made as to its practical applicability.

Advanced mass spectrometry techniques, in conjunction with various ionisation techniques and chemical imaging techniques, have developed over the last ten to fifteen years and have, therefore, also been used in fingermark research. The matrix-assisted laser desorption ionisation (MALDI) method combined with mass spectrometry and imaging (MALDI/MSI) has enabled, for example, to follow the aging of a lipid compound over a period of seven days (Wolstenholme et al. 2009). This method has also been used to record the temporal diffusion of lipids within fingermarks. However, this was unsuccessful because the reproducibility of diffusion was influenced by strong interactions between the lipids and the substrates tested (O'Neill/Lee 2018). In addition, a pilot study using infrared spectroscopy (FTIR) in conjunction with chemical imaging (FTIR/CI) was conducted by the author to visually follow the aging of fingermarks for up to 50 days (Girod 2015). This method enabled chemical images of fresh and older fingerprints to be obtained, especially at the spectral bandwidth of 2850 to 2950 cm^{-1}. Although the aging was visible due to the decrease in the intensity of the peaks on the individual FTIR spectra, it could not be observed on the chemical images (see Figure 4, page 29). Therefore, this method does not seem to be currently suitable for studying the aging of fingermarks up to 50 days old. Finally, one last study which dealt with the identification and temporal representation of unsaturated triglycerides and their degradation products should be mentioned. In this research, several advanced analytical methods were combined: liquid chromatography coupled with mass spectrometry (LC/MS), high-resolution tandem mass spectrometry ($HRMS^2$) and MALDI/MSI (Pleik et al. 2018). A practical application of the models developed has not yet been tested.

In summary, most of the studies mentioned above have the potential to develop a fingermark dating methodology based on the chemical composition. However, none of these methods are currently advanced enough for practical implementation. Based on the above detailled information, the final section of the article explores the question of the future of fingermark dating in practice.

Source: Girod-Frais

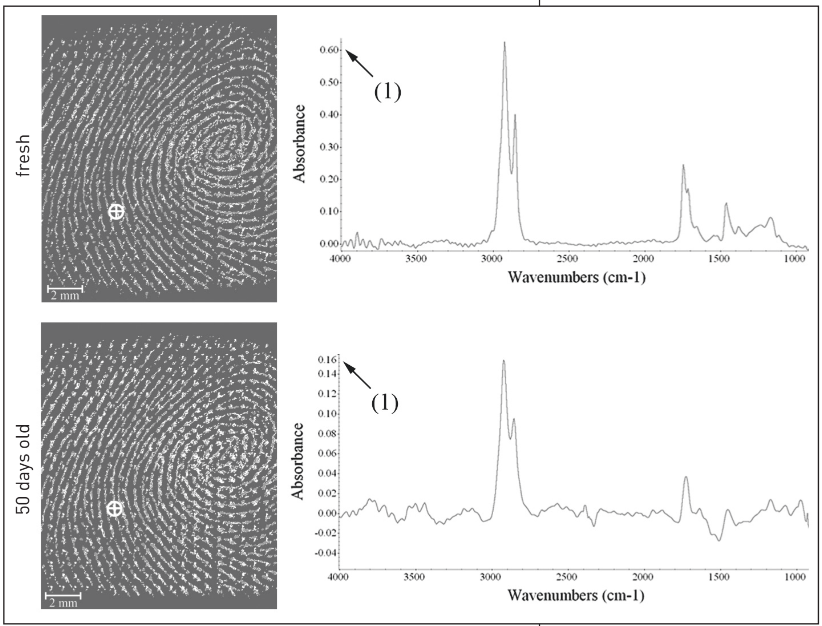

Figure 4: Examples of chemical images of fresh and 50 days old fingermarks obtained by FTIR/CI (spectral bandwidth of 2850 to 2950 cm^{-1}). The FTIR spectra were extracted from the white targets[4]

4. OUTLOOK: THE FUTURE OF FINGERMARK DATING

The time of deposition of a fingermark on a crime scene can be of uppermost importance for investigations and trials, but as highlighted in the previous section, there is no consensus among fingermark experts on how to adress this issue. This is probably (also) because none of the recognised international forensic institutions (e.g. International Association for Identification [IAI], European Network of Forensic Science Institutes [ENFSI] or International Fingerprint Research Group [IFRG]) have published clear official guidelines on this topic. Therefore, it is necessary to clarify that the current state of research does not provide a generally accepted valid method for determining the age of a fingermark. Thus, fingermark experts should not make any statements about the age of a fingermark because this can, at best, be based on the “experience of the experts”, which, however, does not permit a valid age estimation. In practice, fingermarks are most often “dated” based on their visual quality at the crime scene or in the laboratory, based on the motto “the better it looks, the fresher it is”. However, this assumption has never been confirmed scientifically. Therefore, an observation made with naked eye did not enable the estimation of a fingermark’s age.

Over time, several studies have focused on the issue of fingermark dating and, as demonstrated, many have achieved new and relevant results. However, other research has ignored the practical forensic context and focused strongly on the technological aspects. This became particularly clear in light of the withdrawal of an article that was first published in the scientific journal Science and Justice. This study (Amorós/de Puit 2015) reported on a dating methodology for fingermarks based on the aging of fat-soluble components, which the authors believed should have been used in practice in the near future. However, all experiments in this study

Source: Girod/Ramotowski et al. 2016

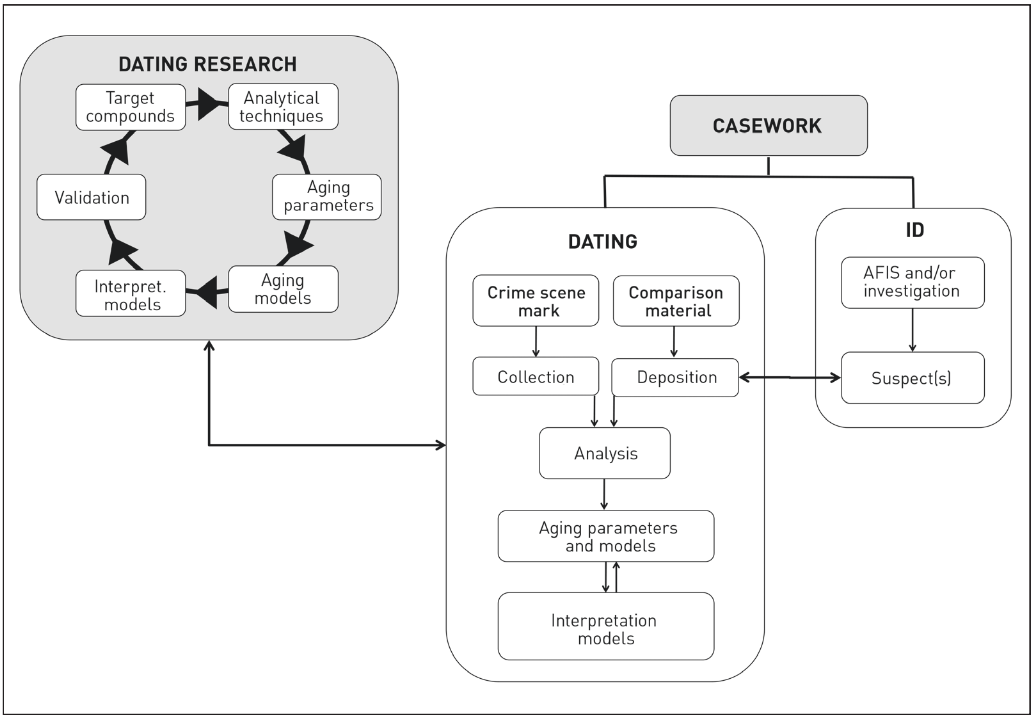

Figure 5: Proposed procedure to address the issue of fingermark dating scientifically and systematically[5]

were performed on synthetic components rather than on real fingermarks. Of course, this greatly affects the results because it is impossible to mimic the variability of fingermark composition using synthetic components. Despite the withdrawal of this article, further studies in which experiments were also based on synthetic components were published (Johnston/Rogers 2018). Such research is a waste of resources. Dating methodologies must be developed using real fingermarks, otherwise there is a risk that they will not be applicable in practice (Almog et al. 2014).

In order to further develop fingermark dating research, studies should be coordinated to avoid inefficient resource allocation. The research stages should include six key elements that should be studied step-by-step and repeatedly, i.e. iteratively. These elements are: (1) target characteristics (chemical or physical), (2) analytical method, (3) aging parameter (e.g. combination of different lipids), (4) aging models, (5) interpretation models and (6) validation (Girod/Ramotowski et al. 2016).

From the author's point of view, the chemical characteristics combined with aging models based on a probabilistic evaluation are currently the best option for developing a practice-oriented dating methodology, for the following reasons: (1) various chemical characteristics have been studied extensively, (2) there are several low-cost analytical methods available (FTIR, GCS/MS), (3) potential aging parameters and models have already been investigated and (4) probability models have already been tested and have enabled a balanced evaluation of temporal hypotheses. A combination with physical characteristics, which would, for example, be analysed using CWLS, is conceivable, but only if these technologies are compatible with a practical forensic application.

Moreover, the influence factors mentioned above will always play an important role in fingermark aging, so future procedures should try to limit their impact. Therefore, aging models could be constructed on a case-by-case basis, so that the known influence factors (donor characteristics, nature of the substrate and enhancement technique) are largely eliminated. This would mean that fingermark dating could only take place after their identification. This process would be entirely compatible with practice because the question of the age of a fingermark usually only arises when the suspect has been identified but claims that it was left before or after the criminal activity.

However, it will probably never be possible to determine an exact absolute age of a fingermark, because the unknown influence factors (i.e. deposition and environmental conditions) will always influence the composition of fingermarks. Therefore, aging and interpretation models are very important for the development of a future dating methodology. Furthermore, the way to communicate the obtained results to other actors of the justice system is also of uppermost importance. In forensic science, one hundred percent certainty can never be delivered as a result, even though the contrary is sometimes claimed, because marks are incomplete per se. Therefore, the communication of results based on probabilistic calculation should be learned and practised.

At the end of this article, we propose a systematic and iterative approach to the issue of fingermark dating in forensic science in order to enable a practical application in the future. This proposed procedure is summarised and shown schematically in Figure 5 (see page 30). For the time being, fingermark dating remains a forensic dream, which should not be confused with reality during investigation or in the courtroom. However, if the international forensic community coordinates its medium to long-term research efforts, this dream could probably become reality.

[1] *Natural fingermarks placed on glass slides, stored in a closed box for 10 minutes, 1 day and 5 weeks (from left to right) and then photographed in transmission mode with black background.*

[2] *Natural fingermarks placed on glass slides, stored in a closed box for 10 minutes, 1 hour and 6 weeks (from left to right) and then enhanced using argentoratum (aluminium fingermark powder) and secured with gel lifter.*

[3] *Schematic representation of the chemical composition of fingermarks and its influence factors. The initial composition arises after the contact of a finger with a substrate and develops into the aged composition. The following influence factors play an important role: donor characteristics, deposition conditions, nature of the substrate, environmental conditions and enhancement techniques.*

[4] *Examples of chemical images obtained by FTIR/CI (spectral bandwidth of 2850 to 2950 cm^{-1}). The fingermarks were placed under controlled deposition conditions onto aluminium foil and analysed immediately (fresh) or stored under normal room conditions for 50 days (after 50 days). A FTIR spectrum was extracted from the marked sites (white targets). The intensity difference of the main peaks (1) is clearly visible, whereas the chemical images show no significant differences.*

[5] *Proposed procedure to scientifically and systematically tackle the issue of fingermark dating by further developing research on six key elements in order to enable a case-by-case application in the forensic practice, based on comparison material, aging and interpretation models.*

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