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The Detection and Enhancement of Latent Fingerprints

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INTRODUCTION

Despite advances made in areas such as DNA profiling, fingerprints are still considered to be the best form of personal identification for criminal investigation purposes. Fingerprint detection has improved significantly over the last 20 years due to concerted efforts by a number of research groups around the world. The purpose of this presentation is to give an overview of the current techniques available to law enforcement agencies for the routine detection and enhancement of latent fingermarks on different surfaces.

Areas to be covered in this talk will include:

- 4# a general approach to fingerprint detection and enhancement;
- 4# the importance of optical techniques and specialised light sources;
- 4# the types of fingerprint evidence that may be encountered;
- 4# the detection of fingerprints on porous surfaces;
- 4# the detection of fingerprints on non-porous surfaces;
- 4# fingerprint detection at the crime scene;
- 4# sequencing of fingerprint detection techniques with other forensic procedures; and,
- 4# future prospects.

GENERAL APPROACH TO FINGERPRINT DETECTION AND ENHANCEMENT

A wide range of optical, physical and chemical techniques is available for the detection and enhancement of latent fingermarks. The best results are generally obtained if a logical sequence of techniques is applied. The application of more than one technique or reagent can often increase the number of prints detected, or improve the quality of those already developed. However, it is imperative that each process is applied in a systematic, predetermined order as the incorrect choice or application of one method can preclude the later use of another technique or lessen its effectiveness.

For a given set of circumstances, the choice of the best detection techniques, or sequence of techniques, will depend on several factors that include:

- 4# the nature of the surface (eg, porous, non-porous, rough or smooth);
- 4# the presence of any particular contaminants (eg, blood);
- 4# environmental factors (eg, whether or not the surface is or has been wet);
and,
- 4# the likely age of any evidential fingermarks.

In any fingerprint detection sequence, heavy emphasis should be placed on optical techniques, as these are non-destructive and may significantly improve the results obtained by physical or chemical methods. Other techniques must be applied with caution, and developed prints recorded at each opportunity, as fingermarks are fragile and readily destroyed.

Several publications are available that describe systematic approaches to fingerprint development on different surfaces. These include:

- 4# the UK Police Scientific Development Branch publications 'Manual of Fingerprint Development Techniques' and 'Fingerprint Development Handbook';
- 4# Lee and Gaensslen's recent edition of 'Advances in Fingerprint Technology'; and,
- 4# Our own workshop manual on fingerprint detection and enhancement. (A limited number of copies of this publication are available at this symposium and additional copies can be obtained directly from the Australian Federal Police.)

OPTICAL TECHNIQUES AND SPECIALISED LIGHT SOURCES

The simple observation of an object under white light may disclose a visible fingerprint that can be recorded without any further treatment. On the other hand, more complex optical detection methods may reveal otherwise invisible prints that may not be developed by other techniques. A fingerprint detection sequence should always start with optical techniques. In addition, prints developed using a physical or chemical process can generally be further enhanced using an appropriate optical method depending on the characteristics of the treated marks (eg. colour or luminescence).

The value of fingerprint luminescence has become well understood since it was first studied in the late 1970's. While latent fingerprints are rarely luminescent, a number of modern detection techniques result in the generation of luminescent prints. The heavy emphasis on luminescence is due to the much higher sensitivity that can be achieved when compared to conventional processes that result in a coloured print.

The application of luminescence techniques requires the use of high-intensity light sources. While large, expensive, laboratory-based lasers were proposed in the early 1980's for this work, there are now a number of versatile, cost-effective alternatives such as filtered arc lamps. Within the Australian Federal Police, our principal light source for fingerprint detection and enhancement is the Polilight, an Australian system that resulted from AFP-funded research conducted in the 1980's. This light source is portable and provides a range of high-intensity light bands from the ultraviolet through to the near infrared. In addition, each band can be fine-tuned through the tilting of high-quality interference filters built into the system. This function has now been duplicated in other light sources on the market. Alternatives to the Polilight include the Spex, the Quaser, the Dactylight, and portable lasers such as the Scene Sweeper. Lasers are restrictive in that they only operate at a limited number of wavelengths.

Ultraviolet reflection techniques have proven to be useful for detecting latent fingerprints on a number of surfaces. Unfortunately, UV imaging equipment is still relatively expensive and the technique requires the use of short-wavelength UV light. This can be damaging to the skin and eyes, and prolonged use may interfere with any subsequent DNA profiling.

TYPES OF FINGERPRINT EVIDENCE

There are three main types of fingerprint evidence that may be present at a crime scene. The first is the indented (or moulded) fingerprint, which is a 3-dimensional fingertip impression in a malleable substance such as putty or candle wax. Such impressions can generally be enhanced using oblique lighting. The second type is the visible fingerprint, which may be positive or negative depending on whether the fingers were contaminated with a coloured material (such as blood), or whether coloured material (such as dust or soot) has been removed from the surface by the fingerprint ridges. Enhancement of such marks can often be achieved optically, depending on the properties of the contaminant in question. Blood is a special case where specific optical and chemical enhancement procedures exist.

The most common type of fingerprint evidence, and the one that causes the most problem, is the latent fingerprint. Such marks are largely invisible, and generally require some form of physical or chemical treatment to differentiate them from the substrate material. A typical latent fingerprint deposit is a complex mixture of natural secretions and contaminants from the environment. Knowledge of the major constituents of this deposit is essential for effective fingerprint detection. Consideration of how these constituents are affected by different environmental conditions is also important.

The detection of latent fingerprints is actually quite a challenging analytical problem. What is required is the detection of very small quantities of specific chemical compounds. In general terms, fingerprint powders are the least sensitive of the available techniques, with 500 to 1000 ng of material required in the latent mark for successful detection. Colour development using a chemical process such as ninhydrin normally requires 100 to 200 ng of material. On the other hand, luminescence detection using a chemical reagent such as DFO is sensitive down to the 1 to 10 ng range.

Latent fingerprint deposits behave differently on different substrate types. In addition, some detection techniques are effective on some surfaces but not on others. As a result, the surface type is a major consideration when selecting a sequence of fingerprint detection techniques for a particular set of circumstances.

DETECTION OF FINGERPRINTS ON POROUS SURFACES

A typical sequence for porous surfaces such as paper and cardboard is given in the flow chart. Following the application of optical techniques, the choice of development method will depend on whether or not the item has been wet. If the item has been wet then water-soluble component of the latent fingerprint deposit will no longer be present. In such a case, physical developer will be the method of choice. In other cases, techniques that can be applied include DFO, ninhydrin, and metal salt treatment. Physical developer can then be applied at the end of the sequence.

Ninhydrin is a chemical reagent that reacts with amino acids to give a dark purple coloured product known as Ruhemann's Purple. First proposed for fingerprint development in 1954, ninhydrin has become the most widely used technique for fingerprint detection on paper surfaces. The treatment generally involves dipping the items in a ninhydrin solution and then leaving the prints to develop over 24 to 48 hours. Prints more than 50 years of age have been developed by this process.

Over the last 30 years, different carrier solvents for ninhydrin formulations have been proposed, the most well known and the most successful being CFC-113, also known as Arklone or Fluorisol. Being an ozone-depleting substance, this solvent is no longer manufactured and its use is now prohibited in a large number of countries. Ideally the carrier solvent should be non-toxic, non-flammable, non-polar (so that ink running on documents is minimised), and relatively inexpensive. Alternatives such as pentane or hexane are to be avoided due to their high flammability. As well as being flammable, solvents such as acetone cause excessive ink running on treated documents. Several research groups around the world have studied CFC-replacement solvents such as HFE-7100 and HFC-4310 and a number of formulations based on these two alternatives are now in use. Unfortunately, both of these solvents are expensive, which limits their use in some laboratories.

Fingermarks treated with ninhydrin can be further enhanced by treatment with a zinc or cadmium salt solution. The coordination complex that is formed results in a colour change and gives a print that is luminescent under certain conditions. At low temperature and with appropriate excitation from a high-intensity light source considerable fingerprint enhancement can be achieved.

In 1990, the chemical reagent 1,8-diaza-9-fluorenone, commonly known as DFO, became available as a more sensitive technique for fingerprint detection on paper. DFO reacts with amino acids in the latent fingerprint in much the same manner as for ninhydrin. However, heat is required for successful development and the reaction product is much paler in colour than that achieved with ninhydrin. The advantage of DFO is that developed prints are highly luminescent at room temperature without any additional treatment. Studies have shown that up to three times the number of fingerprints can be developed with DFO in comparison with ninhydrin. DFO can be used before but not after ninhydrin processing. The disadvantages of DFO include the requirement for a specialised light source, the relative high cost of the reagent, and the unsuitability of the technique for luminescent substrates.

Physical developer is a technique that can be applied on porous surfaces that have been wet or as an additional treatment after DFO and ninhydrin processing. PD is an aqueous solution similar to a silver-based photographic developer. When a document is placed in the reagent, silver is deposited from the solution onto any latent fingerprints that may be present. This deposition is catalysed by water-insoluble components of the deposit. Developed prints appear as dark grey images against a light grey background.

The PD solution contains a ferrous/ferric redox system plus silver nitrate and citric acid, stabilised by a surfactant. Once prepared, the solution is unstable and has a short shelf life. Although time-consuming to prepare and apply, PD can give results where other techniques are unsuccessful. Even if documents have not been wet, the use of PD after DFO and ninhydrin is advised for all serious cases as it may reveal additional fingerprint detail.

DETECTION OF FINGERPRINTS ON NON-POROUS SURFACES

Typical non-porous surfaces include glass, plastic, metal, and gloss-painted surfaces. A range of techniques can be applied to such surfaces, with the main techniques indicated in the flow chart. As for any fingerprint detection sequence, optical techniques should be employed before applying any other treatment. For fixed surfaces at the crime scene, powdering is still entrenched as the primary fingerprint detection method despite its low sensitivity. For wet surfaces at the crime scene, small particle reagent can be employed as a wet powdering method applied with a spray. Items that can be transported should be returned to the laboratory for processing. Cyanoacrylate fuming has, since the late 1970's, become a popular laboratory-based technique for the routine treatment of non-porous surfaces. Developed prints can be subsequently enhanced by the application of a luminescent stain. Alternatively, for laboratories where it is available, vacuum metal deposition can be particularly effective for older prints or for difficult surfaces.

Fingerprint powdering has changed little as a detection technique over the last 20 years. It is still the most cost-effective method for treating fixed surfaces at a crime scene. A range of different powders and different brushes are available and the choice generally comes down to personal preference based on experience.

Aluminium flake powders have long been considered to be particularly effective, while magnetic powders, applied using a magnetic wand, are considered to be the least destructive. The recent development of iron flake powders has increased the sensitivity of magnetic powders. For multicoloured surfaces, a range of different luminescent powders is available.

Wet non-porous surfaces at a crime scene can be treated using small particle reagent, a suspension of molybdenum disulfide in a detergent solution. The suspension is generally applied with a spray and then rinsed with water to remove excess powder. Developed prints are dark grey in powder. A white small particle reagent, based on zinc carbonate powder, has also been developed for dark surfaces.

Cyanoacrylate esters, sold commercially as quick-setting 'superglue', have proven effective for developing latent fingermarks on non-porous surfaces. The object is treated with cyanoacrylate vapour, resulting in the formation of a hard white polymer on any latent print deposit that may be present. It is believed that the polymerisation is catalysed by moisture and ionic material present in the deposit.

Fuming with cyanoacrylate can be achieved by several means, from inexpensive home-made chambers through to large, expensive commercial units. Portable fuming systems are also available. As apposed to development achieved at atmospheric pressure, a number of research groups have reported superior results when cyanoacrylate development is conducted at reduced pressure.

Contrast is often a problem with marks developed by cyanoacrylate fuming. Some form of enhancement is generally required. There are optical methods for enhancing such prints that should be employed before any further processing. Contrast may then be improved by the application of a powder or, preferably, the application of a luminescent stain such as rhodamine 6G. Luminescent staining can significantly enhance cyanoacrylate-develop prints.

Probably the most sensitive technique for fingerprint detection on non-porous surfaces such as glass and plastic is vacuum metal deposition. In this process, the item is placed under vacuum and coated with thin layers of gold and zinc. The deposited gold penetrates the latent fingerprint deposit producing a uniform layer, whereas the zinc will generally deposit on the substrate but not on the print ridges. VMD units necessary for the application of this technique are expensive and their use requires significant experience for optimum results. When applied correctly, excellent results can be obtained even on old, degraded fingermarks.

VMD can be effective on difficult surfaces where other techniques fail. Polymer banknotes are in circulation in Australia and a number of other countries, including New Zealand, Malaysia, Indonesia, Thailand, and Singapore. This substrate, because of its semi-porous nature, has proven difficult for latent fingerprint detection. Extensive research in our laboratory has determined that the best sequence for fingerprint detection involves cyanoacrylate fuming followed by vacuum metal deposition and application of a luminescent stain. Prints more than 6-months old have been developed using this sequence. Cyanoacrylate fuming alone will only detect prints that are up to one week old.

FINGERPRINT DETECTION AT THE CRIME SCENE

The general approach to fingerprint detection at the crime scene is to apply optical techniques initially, to transport items back to the laboratory for processing where possible, and to treat the remaining surfaces with a suitable development technique (or sequence of techniques). For non-porous surfaces, fingerprint powders are traditionally the method of choice. Porous surfaces, such as wallpaper, can be treated with a ninhydrin solution. For scenes of a more serious nature, chemical processing with a technique such as the iodine/benzoflavone spray may be considered. This technique can successfully develop prints on a range of porous, semi-porous, and non-porous surfaces. In addition, iodine/benzoflavone treatment does not preclude subsequent powdering or ninhydrin treatment. At the end of the sequence, blood enhancement reagents (such as amido black) may be applied if blood marks are present.

SEQUENCING OF FINGERPRINT DETECTION TECHNIQUES WITH OTHER FORENSIC PROCEDURES

Fingerprint detection should not be considered in isolation from other forms of forensic evidence. The effect of fingerprint treatment on other examinations must be taken into consideration. With respect to document examination, solvent-based reagents such as ninhydrin and DFO may cause ink-running on treated documents and may destroy any indented impressions that may be present. A document examiner should be consulted before processing any documents that may require detailed document examination.

The effect of different fingerprint treatments on DNA profiling is very topical and has been the subject of many research projects using blood as the DNA source. For fingermarks in blood, we have found that only a small number of detection methods may cause problems. For example, the prolonged use of short-wave UV light may destroy any DNA evidence. Physical developer can significantly reduce the likelihood of successful DNA profiling simply because of the number of washing steps involved in the process. Magnetic powder may interfere with DNA amplification. Otherwise, fingerprint treatment may simply lower the final DNA yield. The best advice is to consult with a forensic biologist before proceeding and, if possible, to collect a biological sample before processing the item for fingerprints. The effects of fingerprint processing on 'trace' DNA has not been extensively studied and more research is required in this area. One such project is currently under way in our laboratory.

FUTURE PROSPECTS

To conclude this presentation, we believe that future prospects in the field of fingerprint detection and enhancement include the following:
the replacement of ninhydrin and DFO with indanediones for fingerprint detection on porous surfaces (as these compounds combine the ease of application of ninhydrin and the sensitivity of DFO but at a potentially lower cost);
the increased use of on-site optical and chemical enhancement techniques with reliance on high-intensity specialised light sources and UV-imaging equipment; and,
the increased use of digital recording and image enhancement techniques.

These advances will be complimented by better information technology to facilitate the remote, real-time searching of scene fingermarks against automated fingerprint identification systems.

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Section on Hairs – Addendum to Biological Evidence Item

James Robertson

A number of significant events have taken place since the 1998 symposium, in relation to hair examination.

The first book has been published (Robertson, 1999) which deals exclusively with the forensic examination of hair. The contents include chapters on physiology and growth, forensic and microscopic examination, typing of DNA, elemental analysis, drug analysis, cosmetic treatment, and the evidential value of hair examination. A very useful Atlas of Human Hair has also been published (Ogle & Fox, 1999). These two books are valuable resources for those seeking to learn more about the basis for forensic hair examination.

Technical guidelines for the forensic examination of hair have been produced by the US based Scientific Working Group for Materials Analysis (SWGMAT). The US National Forensic Science and Technology Centre (NFSTC) are currently working on an approach to produce physical standards and exemplars for hair features which can be used for training and for proficiency testing. It is anticipated these will be available in 2002.

There have only been a limited number of papers in the scientific literature dealing specifically with microscopic based examination of hairs. Crocker (1998) describes a very simple technique for the rapid simultaneous examination of medullae and cuticular patterns of hairs. A useful paper by Linch et al (1998) evaluates human hair root morphology for successful nuclear DNA typing. Linch and Prahlow (2001) review post-mortem changes observed at the proximal end of human head hair concluding that hair roots do not decompose after fresh removal from the scalp and exposure to the outside elements.

Literature dealing with mitochondrial (mt) DNA is dealt with elsewhere in this review. With respect to hairs De Zinno et al (1999) review the typing of DNA derived from hairs with particular emphasis on mt-DNA. Allen et al (1998) discuss sensitivity and matching probabilities for mt-DNA sequencing of shed hairs and saliva from robbery caps. Jehaes et al (1998) evaluate a decontamination protocol for hair shafts before mt-DNA sequencing. Baker et al (2001) discuss a saliva based mt-DNA extraction method applied to hair shafts and teeth. Fridey et al (1999) question the validity for the use of mt-DNA to individualise cats and dogs due to the very high levels of heteroplasmy.

A series of short reviews on hair appear in the Encyclopaedia of Forensic Sciences (2000). Gandette presents an overview and papers on hair transfer, persistence and recovery, identification of human and animal hair and on the significance of hair evidence. Bisbing discusses microscopic comparison and Yoshino et al, DNA typing. These short papers give an excellent introduction to hairs. Kintz in the Drugs of Abuse section of the Encyclopaedia of Forensic Sciences discussed the use of hair for drug analysis. Drug analysis using hair is also reviewed by Tebbett in Chapter 5 of The Forensic Examination of Hair (Robertson, 2000). There have been numerous papers dealing with different aspects of hairs as a medium for drug analysis. As this is outside the scope of this review these are not listed. From time to time papers presented at the International Meeting of the Society of Hair Testing are published. The most recent compilation appeared in 2000 as a special edition of Forensic Science International, Volume 10, Parts 1-3, 1-394. Some other papers of interest include:

- 4# Andrea et al, 1998, dealing with the transfer of animal hair during simulated criminal behaviour;
- 4# Panayiotou and Kokot, 1999, dealing with the use of FT-IR micro spectroscopy and chemometrics to match and discriminate single human scalp hairs;
- 4# Prokopec et al, 2000, dealing with changes in hair pigmentation in young children;
- 4# Tanada et al, 1999, dealing with GC/MC analysis of oxidation dye components in hairs; and
- 4# Exline, 1998, dealing with the frequency of pubic hair transfer during sexual intercourse.

This review does not include papers appearing in the general medical literature. However, one paper of special interest by Ahmad et al (1998) deals with a mutation in the human *hairless* gene associated with one form of male pattern baldness.

Finally, there have been a number of 'discussion' fora in the worldwide web on the value of hair evidence and in relation to specific cases. Most of these are cases from the USA and relate to issues arising from rules of evidence relating to Daubert.

In conclusion it is now clear that whilst mt-DNA is a useful addition to the armoury of the hair examiner it is an expensive technique and that microscopic examination will remain as the core technique for hair examination. There is also a wider recognition of the need for more proficiency testing and greater standardisation and 'tools' to place hair examination on a sounder science base to meet the challenges arising out of Daubert.

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