THE ENHANCEMENT OF FINGERPRINTS ON KITCHEN KNIVES THAT HAVE BEEN THROUGH A WASH CYCLE IN THE DISHWASHER

By

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in

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Murdoch University

Supervisor: James Speers

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Declaration

I declare that this thesis does not contain any material submitted previously for the award of any other degree or diploma at any university or other tertiary institution. Furthermore, to the best of my knowledge, it does not contain any material previously published or written by another individual, except where due reference has been made in the text. Finally, I declare that all reported experimentations performed in this research were carried out by myself, except that any contribution by others, with whom I have worked is explicitly acknowledged.

Signed: Nathan Juriansz
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Abstract

During the committing of a crime, fingerprints can be deposited onto an endless number of substrates, and can be exposed to a vast range of environmental conditions. The substrate a fingerprint is deposited onto and the environment it is exposed to, affects the techniques that can be used to enhance that fingerprint as well as the persistence of that fingerprint, and therefore its ability to be identified and enhanced, by a forensic practitioner. This is particularly true for when a fingerprint is exposed to a destructive environment, either through the nature of the crime, or in attempt to destroy evidence by the perpetrator of the crime.

This literature review aims to explore the literature to consider the fingerprint enhancement techniques that could be used to enhance fingerprints deposited onto the metal and plastic substrates of a kitchen knife, and exposed to the wetting and washing environment of dishwasher. This literature review will therefore provide the background required to conduct experimental validation of this same purpose. The Results of this study will aid forensic investigators when making decisions on the possibility of recovering prints that were attempted to be cleaned and removed off an item, such as a knife, when suspected to have been used or important to an investigation and recovered from a dishwasher. Subsequently, it will aid in the decision of which enhancement technique to use in this situation.
1.0 Introduction

The use of fingerprints for the purposes of personal identification and use in forensics and criminal cases has a rich history as explained by Barnes (1). The advent of automated fingerprint identification systems, in the 20th century, is considered among the most important advances in forensic science for the identification of criminals (2). Fingerprints are the most common type of evidence collected across homicide and burglary criminal cases, and play an integral role in the investigation of criminal offences, in their ability to identify a person of interest or perpetrator and power to physically link them to a crime (3-5). Furthermore, Peterson et al (4, 5) found that the recovery and positive identification of evidence that successfully linked the suspect to the crime (including fingerprints) were significantly linked to trial convictions and to a significant increase in conviction sentence length.

This use of fingerprints to identify a criminal or person of interest, link a crime to a perpetrator or aid in the elimination of a person of interest relies on the permanence and persistence of the structure of the friction ridge skin on an individual’s hands and feet. This means that a print can be matched from a crime scene to an individual regardless of the time between deposition, collection and comparison of a print. The friction ridge skin gets its name due to the presence of its characteristic “ridges” and “furrows”, and it is the patterns created by these ridges that make up one’s fingerprint and what is used by forensic practitioners for fingerprint identification (6). The skin is comprised of three layers of cells: epidermis, dermis and hypodermis. The epidermis is the outermost layer of the skin, which we see as our fingerprint, while the dermis is the layer of connective tissue that
is connected to and gives support to the epidermis. It is this connection and the interplay between these two layers that give rise to the ridges and furrows of the friction ridge skin, by the primary and secondary ridges, also known as dermal papillae, that are present in the uppermost layer of the dermis (Figure 1) (6). It is this rooting of the ridges in the supporting dermal layer cells that allow for fingerprints to persist and remain permanent throughout one’s life from childhood, to adolescence and to adult (7-10) and the belief that fingerprints are unique to each individual that allows them to be used for forensic identification purposes (11).

Fingerprints can be deposited through different mechanisms, on a boundless range of porous, semi-porous and non-porous substrates, and can be exposed to a vast range of environments and environmental conditions. This interaction between fingerprint composition, deposition surface and environment is depicted and explained by Sears et al. (12) in the fingerprint triangle of interaction (Figure 2). This interaction concept describes that the technique or process to be selected and used to enhance latent prints is governed by the understanding of and the interplay between these three elements. As a result of this concept, there is a vast range of latent fingerprint visualisation and enhancement
techniques for the differing interactions between the fingerprint composition, substrate, and environment interactions (11, 13). However, despite this large list of visualisation and enhancement techniques, latent fingerprint visualisation and enhancement is never a guaranteed outcome due to the endless possible interactions that can take place from the three components of this fingerprint interaction concept.

Following Locard’s principle of exchange, that “any action of an individual, and obviously the violent action constituting a crime, cannot occur without leaving a trace” (14), when the friction ridge skin of the finger comes into contact with a surface a fingerprint is deposited into or on that surface. Fingerprints found at crime scenes can be characterised as either visible, impression or latent prints (15). Visible prints are prints which are deposited onto a surface by the transfer of an exogenous contaminate, such as blood, paint or foodstuffs. Impression prints are prints generated by the deformation of a soft substrate, such as wax, putty or wet paint, by friction ridge skin, thereby leaving an impression of the fingerprint in the substrate (16). The majority of prints found at a crime scene, however are latent prints (15). Latent prints are prints that are generated and transferred to a surface by endogenous sweat secretions from sweat glands found in the dermal layer of the skin.
Latent prints are so named as they are invisible to the naked eye unless enhanced by an optical, physical or chemical enhancement process. There are three main types of sweat glands found in the skin: eccrine, sebaceous, and apocrine. Eccrine glands are found all over the body; but are in highest concentration and the only gland of the three found in the friction ridge skin of the hands and feet. Eccrine glands produce a secretion that is mostly water, at about 98%, as well as range of trace amounts of inorganic compounds such as chlorides, metal ions and ammonia, and organic compounds, such as and amino acids, urea, chlorine and uric acid (11). Eccrine glands can not be controlled consciously and sweating from these glands is automatically triggered through thermal and psychologically stimuli, such as that experienced during committing a crime. The eccrine glands are innerved by the nervous system and sweat is secreted from the glands and out through the pores located along the ridges of the friction ridge skin (11, 17).

Although eccrine glands are the only secretory glands found in the friction ridge skin, eccrine sweat is not the only endogenous secretion found in fingerprint residue, as might be expected. This is because during normal day to day life, the fingers make regular contact with other parts of the body, namely the face and head, and pick up sweat secretions secreted from sebaceous glands (12). Sebaceous glands are located in areas containing hair follicles and on the forehead, eyelids and nose, among other areas, and secrete a greasy secretion, known as sebum. Sebum is made up of only organic components, the main constitute being lipids which include; fatty acids, alcohols and cholesterol, among others (16). The main constituents secreted from the eccrine and sebaceous glands are listed in Table 1.
### Table 1: Main constituents of secretions of sweat glands

<table>
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<tr>
<th>Source</th>
<th>Inorganic Constituent</th>
<th>Organic Constituent</th>
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<tr>
<td>Eccrine Glands</td>
<td>Chlorides</td>
<td>Amino Acids</td>
</tr>
<tr>
<td></td>
<td>Metal ions</td>
<td>Urea</td>
</tr>
<tr>
<td></td>
<td>Ammonia</td>
<td>Lactic Acids</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
<td>Uric Acid</td>
</tr>
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<td></td>
<td>Water</td>
<td>Chlorine</td>
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<tr>
<td>Sebaceous Glands</td>
<td></td>
<td>Fatty acids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alcohols</td>
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<tr>
<td></td>
<td></td>
<td>Cholesterol</td>
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</tbody>
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It is important for a forensic practitioner to know and understand the chemical composition of fingerprint residue and how they interact with the substrate they are deposited onto, as different visualisation and enhancement techniques target specific constituents present in sweat and thus the fingerprint residue (11).
2.0 Discussion

This section aims to summarise and evaluate the literature and knowledge of the physical and chemical methods of fingerprint enhancement that can be used on metal and plastic surfaces, and surfaces that have been wetted after the deposition of a fingerprint. The enhancement methods that will be considered are; powders and dusting, powder suspension and small particle reagent, cyanoacrylate fuming, and electrochromic development. Furthermore, this section will finish by assessing the literature regarding the work done on the enhancement of fingerprints on substrates that are exposed to destructive environments.

2.1 Powders and Dusting

Dusting fingerprints with fingerprint powder is one of the oldest, most widely used, and if used optimally, one of the most effective fingerprint enhancement techniques available for crime scene and laboratory fingerprint enhancement, accounting for the largest number of fingerprint identifications worldwide (18). Powder enhancement of fingerprints is a physical process that involves the use of an applicator to apply a dry powder to a substrate, suspected of containing a fingerprint on its surface. The powder develops and enhances fingerprints by preferential adhesion of the fine powder particles to the deposited fingerprint residue over the substrate, thereby coating the fingerprint and enhancing the visual contrast between the fingerprint and the surface (11). This preferential adhesion of the powder particles to the fingerprint residue is due the mechanical and physical attraction of the particles to the aqueous and oily components and nature of a deposited fingerprint. Particle shape, surface chemistry and electrostatic charge also play a role in this
preferential adhesion, and the overall adhesive effect is due to the combination of these factors (18).

The earliest record in the literature of fingerprint powders being used dates to 1891 were experiments were conducted by Forgeot into the use of powders and the powdering technique (19). Since then a large amount of research has gone into fingerprint powders and hundreds of powder formulations have been developed, and can be grouped into four main categories: metal flake powders, granular powders, magnetic powders, and fluorescent powders. These powders differ in their effectiveness depending on the physical and chemical properties of the powder (colour, shape, size, surface chemistry, electrostatic charge), the surface the print is deposited on, and the type of applicator used to deposit the powder. There is no one powder that will consistently out perform all other powders on all surfaces (11, 13).

Metal flake powders are flakes of metal roughly 10µm in diameter manufactured by the ball-milling spherical metallic particles (16). The increased surface area of the flakes as well as a coating of steric acid introduced during the ball milling processes increase the adhesive properties of the powder to fingerprint residue (20). Metal flake powders, along with metallic powders are the most widely used powders at crime scenes and are best applied using a glass-fibre, zephyr style brush for the former, and a magnetic wand applicator for the latter. (11).

Magnetic powders come in two main types of either magnetic flake powder or magnetic granular powder. Magnetic flake powders are smooth edged flakes of iron of a particle size of 10-60µm, manufactured by milling of spherical carbonyl iron, with stearic acid (13, 20). The iron flake particles are picked up by the metal applicator and brushed over the print,
whereby particles adhere to the print. Magnetic granular powders work in a similar way, however have a different microstructure. Magnetic granular powders have two components: the first being larger magnetic particles of spherical iron of particle size 20-200µm, and the second being smaller non-magnetic pigment powder particles of size 3-12µm (13, 20). The magnetic applicator then picks up the larger magnetic iron particles which act as a carrier for the non-magnetic pigment powder particles, thereby forming its own “brush” (16).

Granular powders are composed of irregular smooth colourant particles with a particle diameter ranging between 5-10µm and a binder for stability (11, 21). The most commonly used granular powder is carbon black, a black carbon-based colourant particle. Granular powders come in a range of colours, most commonly white, grey and biochromatic (a mixture of black granular and aluminium powder) (22). Granular powders are best applied using a squirrel hair, mop style brush, over the glass-fibre, zephyr style brush, although either can be used (11).

Fluorescent powders can be either granular or magnetic and are available in a range of colours such as green, orange, pink, and yellow. Fluorescent powders are small particles, that gain their fluorescent component from fluorescent dyes, mixed with a binder or carrier particle. Fluorescent powders will fluoresce when illuminated by an alternative light source, at a specific wavelength, depending on the colour of the powder. These powders are effective at producing good contrast on surfaces that metal flake, metallic, and granular powders do not provide good contrast on, such as multicoloured surfaces (21, 22).
A group of studies conducted by the Home Office Scientific Development Branch (HOSDB), of the UK (23, 24), compared the relative effectiveness of metal flake (aluminium and brass), magnetic, and granular powders on smooth and textured surfaces which included: glass, metal, u-pvc plastic, ceramic, painted and un-painted wood, laminate, and kitchen worktops. These studies found that flake powders are the most sensitive powder, as well as being the easiest to apply and develops good contrast on smooth surfaces. Of these powders aluminium flake powder showed to be the most effective on glass and non-silver metal, and shows similar performance on other smooth surfaces, whereas brass flake powder performed similar to aluminium flake but is only suggested on silver surfaces, where aluminium flake produces poor contrast. Black granular powder showed to be slightly less effective then metal flake powder on smooth surfaces, and showed little effectiveness on textured surfaces. Therefore, it is only recommended on silver metal surfaces where aluminium metal flake produces poor contrast, or if the examiner does not have metal flake powder available. White granular powder was also tested, however produced the weakest results of the powders, due to the lower sensitivity of the powder to adhere to the fingerprint residue, and therefore was not recommended for use over the other powders. Magnetic flake and magnetic granular powders proved to be the most effective on textured surfaces and similar effectiveness to the other powders on smooth surfaces. Figure 3 below shows the powder selection chart for the different surfaces generated from the results of the studies (25).
This chart provides as a useful aid to forensic practitioners for the adequate and effective selection of fingerprint powders for different surfaces. It should be noted that these powders used were selected based off a survey conducted in the UK in 2004 of crime scene examiners within each police force, and these powders are only a small subset of the powders available then and now (2017), and didn’t not include fluorescent powders, which are shown to be very sensitive and able to provide enhance contrast (16). A study by Sorah et al.(26) found that fluorescent powders out performed black granular powder on glass,
plastic and multi coloured paper. However, these studies conducted by HOSDB are the only comparative studies of their kind with powders and no large-scale study has been done with the range of powder types and formula available.

2.1.1 Effect of Wetting on Fingerprint Powder Enhancement

Fingerprint powders are considered the quintessential fingerprint enhance technique for forensic examiners, due to its effectiveness both porous and non-porous substrates, its ease of use at crime scenes and in the lab, and ability to not interfere with subsequent enhancement techniques and recovery of DNA. Fingerprint powder effectiveness like all enhancement techniques will be affected by the environment in which they are exposed too. If an item with in which a fingerprint has been deposited, is wet or has been wetted then fingerprint powder techniques become less effect. If an item is still wet, it is necessary to allow the item to dry before attempting to powder the item for prints. This is due to the fact the presence of water will inhibit and interfere with the desired preferential powdering of the print, and cause the brush and powder to get clogged and therefore leave the powder unable to fall off and adhere to the print residue. Even after the substrate has been dried the effective of powdering is diminished. This is due to the fact that, as mentioned above, powders adhere to aqueous and sebaceous components of fingerprint residue, and if a print is wetted then the aqueous components of the print are removed, thereby leaving less available components for the powder to adhere too, although enhancement is still possible and is reported in the literature (11, 27). Interestingly and conversely some studies have shown that even after substrate wetting, powders can still out-perform other
techniques tailored to enhance prints on wetted substrates such as small particle reagent and powder suspension or wet powder (28, 29).

2.2 Powder Suspension and Small Particle Reagent

Powder suspension and small particle reagent are believed to rely on the same development process to enhance fingerprints on non-porous substrates, and their names are used somewhat interchangeably throughout the literature (29-31), although they are defined separately by the UK Home Office Centre of Applied Science and Technology, in the Home Office Fingerprint Visualisation Manual (11). Both techniques rely upon the presence of powder particles suspended in a detergent solution, which is then applied to the non-porous substrate, where the particles preferentially adhere to the fingerprint residue (11). Although a detailed understanding of the mechanism is not understood, it is believed that the hydrophobic and hydrophilic nature of detergent or surfactant molecules aggregate together and form micelle structures in water that encapsulate the powder particles in solution and thereby allowing for their temporary suspension, when the concentration of the surfactant in the solution reaches above the critical micelle concentration for that surfactant (32). When the suspension is then applied to a surface, it is believed that a component or property of the fingerprint residue disrupts the micelles, allowing for the particles to interact with the fingerprint residue (13). However, a recent study published has posed two similar but alternative mechanism of interaction between the surfactant molecules and micelles and the powder particles (33).
The difference between these two techniques resides with the different physical and chemical properties of the particles and surfactant solution used. Small particle reagent utilises particles of roughly 1.5µ in size, typically molybdenum disulphide (MoS$_2$), with a dioctyl sulfosuccinate sodium salt surfactant solution, resulting in a grey-black enhanced print (11). Other particles and surfactants have been investigated, and can be used, although MoS$_2$ and dioctyl sulfosuccinate sodium salt, have shown greater consistency of performance (34, 35). However, despite this enhanced performance, due to the MoS$_2$ formula producing a grey-black print, the technique is not affective on darker substrates and therefore alternative white or fluorescent formula, which show good enhancement have been investigated and manufactured (35-39). The technique can be applied either by submerging the substrate in to the solution or spraying the solution onto the substrate (13). Studies have shown that the submergence method outperforms that of the spray method and is much easier and cleaner to apply (34). However, an explanation to the reason why it is more effect is not given and research as to why does not seem present in the literature.

Powder suspension utilises higher concentration of smaller particles of particle size between 100nm-1µm and higher concentration of surfactant solution (11, 40). Three main options for powder suspension are available: iron oxide-based black powder suspension, titanium dioxide-based white powder suspension, and carbon based black powder suspension. The carbon-based powder suspension is recommended for adhesive surfaces, while the iron oxide and titanium dioxide-based suspension are recommended for light and dark non-porous surfaces respectively. The solution is made up to a paint consistency and is applied to the substrate with a brush (11). Interestingly, a recent article published (2017) investigating the iron oxide based powder suspension and the surfactant solution
component, found that the concentration of the surfactant solution, currently recommended at 400 times the critical micelle concentration (c.m.c), can be reduced to 10 times the c.m.c, with minimal impact in the effectiveness of the technique. It was subsequently suggested that this could lead to the diluting of the solution to allow for a thinner solution that could be applied via spray (33). However, this research was conducted in a laboratory with clean, ideal substrates, and purposely deposited fingerprints and is noted by the author that extended trails on realistic surfaces and environments are needed to progress these findings.

Despite that both these techniques work effectively on dry and wet, smooth and rough non-porous substrates, it is recommended by the Home Office Centre of Applied Science and Technology that powder suspension is superior to SPR. This assessment is based on a few studies which investigated the comparative effectiveness between the two techniques, reporting that powder suspension out performed SPR on dry and wetted surfaces, and studies that showed that powder suspension produced equal and sometimes greater results to cyanoacrylate fuming and vacuum metal deposition (11, 13, 41-45). However, no large-scale comparative studies have been done on the new and larger range of formulas now available.
2.2.1 Effect of Wetting on Powder Suspension and Small Particle Reagent

The main advantage of powder suspension and small particle reagent over other non-porous enhancement methods, such as powdering and cyanoacrylate fuming, is their ability to effectively enhance fingerprints on non-porous surfaces that have been wetted (11, 13, 29, 42, 44, 46). This is hypothesised to be due to a reaction mechanism between the surfactant particle micelles and in-soluble sebaceous constituents of a fingerprint residue, that would not be washed by water. However, no studies have been conducted into this reaction mechanism and if the mechanism and interactions differ when the fingerprint and substrate has not been wetted and eccrine and sebaceous constituents are present. Despite this need for research it is still widely stated in the literature, albeit incorrectly, that small particle reagents mechanism of interaction is with the sebaceous component of fingerprints.

In contrast to the previous studies mentioned of the effectiveness of small particle reagent and powder suspension out performing conventional powdering and cyanoacrylate fuming on wetted non-porous substrates, there are few studies that acquired contrary results. A study by Trapecar (27), found that cyanoacrylate fuming outperformed small particle reagent on glass and metal surfaces, however no explanation and comparison with other results from other studies were given. The study examined 45 prints on glass surfaces for each technique (i.e 45 prints tested by SPR and 45 prints tested by cyanoacrylate) and 40 prints on metal surfaces for each technique, with a fraction of the total prints being examined at time intervals of 0, 1, 24, 48, and 168 hours after deposition for and glass substrates and 0, 4, 24, 48, 168 hours after deposition for metal substrates. Using this method at each time interval only 9 prints for glass substrates, and 8 prints for metal...
substrates were being compared for each technique, which produces a very small sample size for comparison. Furthermore, two different formulae of SPR were used for the glass and metal substrates, with the molybdenum disulphide (MoS$_2$) formula used for the glass substrate and a white titanium oxide (TiO) formula for the metal substrates, where the largest difference between the SPR and cyanoacrylate methods were found. Interestingly, it was previous studied by Kabklang et.al. (35) of different formula of SPRs on wet nonporous substrates, that the MoS$_2$ formula outperformed that of the white formulas, and of the white formulas tested TiO performed worse than the zinc carbonate formula.

2.3 Cyanoacrylate fuming

Cyanoacrylate fuming method for detection and enhancement of latent fingerprints was first report as possible enhancement technique for fingerprints in the late 1970s (13). It relies on the vapours of ethyl-cyanoacrylate (superglue) to form white deposits onto the latent fingerprint by the chemical and physical interaction between the vapours and the constituents of the fingerprint residue (47). The precise mechanism by which the cyanoacrylate vapours and the fingerprint residue interact is not clear, however early work determined that by heating the cyanoacrylate and inducing a higher humidity environment increased the speed of the reaction and the sensitivity of the white deposit (48-50). It was determined that a relative humidity of around 80% produced the optimum results. Deposits at this relative humidity under a scanning electron microscopic displayed high concentration of unidirectional noodle-like morphology on the deposited ridges and even higher concentration around the pores, whereas relative humidity above or below
produced worse results with increased background development and flat multi directional morphology (50).

The white deposits that are preferentially formed on the ridges are polycyanoacrylate, and are formed by the polymerisation of the cyanoacrylate monomers and initiated by a weak base. One hypothesised mechanism for this polymer growth on fingerprint deposits is by the initiation by water (a weak base) by the presence of the sodium chloride eccrine constituent (47). By elevating the relative humidity of the system to 80%, this is above the critical relative humidity of sodium chloride of roughly 75% (51), and at which point sodium chloride will absorb moisture from the environment. This absorbed water in the latent fingerprint can then acts as the initiator for the polymerisation of the cyanoacrylate monomer to the cyanoacrylate polymer and preferential deposition on to the print (13). This proposed mechanism is depicted below in Figure 4 (13).

![Figure 4: Schematic diagram of the superglue development and dyeing process](image)

However, other studies propose that water is not the initiator in this mechanism, and that other constituents of eccrine sweat present in the fingerprint residue, namely lactic acid
and the amino acid alanine are (52). Although it is understood what reaction is taking place and that humidity is playing an important, work is still required to determine the interactions taking place, and it is likely to be that there is more than just one factor that is influencing the reaction.

2.3.1 Efficiency and Effect of Wetting on Cyanoacrylate Fuming

Cyanoacrylate is an effective means of enhancing latent fingerprints on non-porous surfaces, however, as the technique enhances latent prints by the deposition of a white deposit, it was quickly identified that when not used on dark substrates the desired contrast between print with cyanoacrylate deposit and the substrate was not achieved. The use of fluorescent dyes to stain the deposit were identified and dyes: rhodamine 6g, basic yellow 40 (BY40), and basic red 14 (BR14), were observed to give the best results (13, 53). Rhodamine 6g was suspected of being a carcinogen, however it has since been shown to not be a human carcinogen, although it is toxic, therefore the BY40 and BR14 are the recommended dyes for cyanoacrylate enhancement (54). BY40 emits green/yellow fluorescence, while the BR14 emits an orange/red fluorescence and it is the noodle-like polymers formed at 80% RH that allow for the optimum retention of the fluorescent dye (11, 50). Recent developments of cyanoacrylate fuming have seen the literature reporting on novel fluorescently tagged cyanoacrylates, for the one-step processing of latent fingerprints, instead of the conventional two-step process (i.e. cyanoacrylate fuming followed by dye staining). However, results have been inconsistent, with some papers showing underperformance compared to the conventional method (55, 56), while others reporting the one-step fluorescent process equal to or outperforming the conventional
Based off the current studies, despite the time effectiveness of the one-step process of the conventional, more work is required in the development of these fluorescently tagged cyanoacrylate monomers before they could be suggested for operational use over the conventional two-step process.

Cyanoacrylate fuming method is considered through studies in the literature to be equal to that of powders and powder suspension techniques on non-porous surfaces, and outperforms powders on textured non-porous surfaces (13). However, the literature has shown that when investigating substrates that have been known to or suspected of being wetted, cyanoacrylate does not effectively compare to powder suspension (11, 13, 29, 42, 44, 46). This is attributed to the loss of the soluble eccrine deposit constituents by the wetting of the substrate, that is hypothesised to be the main and strongest initiators of the polymerisation of cyanoacrylate monomers, compared to the remaining presence of the in-soluble sebaceous constituents that it is hypothesised to be the main means of powder suspension interaction with latent prints (47). Interestingly, it has been shown by scanning electron microscopy, on groomed sebaceous fingerprints, that the morphology of the cyanoacrylate polymer deposited into the latent print ridges, is different to that of the “optimum” noodle-type polymer found in normal fingerprint residue. This is suggested to reinforce the hypothesis that the main initiator or component of this mechanism resides in the eccrine secretion constituents, as the polymer growth and subsequent enhancement of sebaceous prints is generally inadequate, due to the presence of only weak initiators (13, 47, 50, 59). However, as mentioned above there are few studies that report better enhancement of latent prints on wetted substrates by cyanoacrylate compared to small particle reagent (27).
2.4 Electrochromic Enhancement

The techniques mentioned above rely upon the relative components to either physically and/or chemically interact with the fingerprint deposit and its components to generate enhancement of the latent print. A new technique has been described and implemented on non-porous metal substrates by the interaction with the substrate as opposed to the print, coined electrochromic development or electropolymeric deposition (11, 29, 60-63). This technique relies on the electrochemical deposition of a polymer onto a metal substrate, whereby the fingerprint acts as an insulator that masks the substrate. Thereby the deposition of the polymer is inhibited along the fingerprint ridges but can preferentially deposit onto the exposed substrate between the ridges, generating a negative image of the fingerprint, opposite to that of the previously mentioned techniques. The polymer is generated potentiostatically in a three-electrode cell, with the metal substrate to be coated as the working electrode, by the electropolymerisation of monomers capable of forming conductive polymers on metal. The process can be seen schematically in Figure 5 (63).

Figure 5: Schematic representation of strategy for visualizing latent fingerprints by deposition of electrochromic polymer.
Panel a: surface with deposited fingerprint, prior to treatment; panel b: fingerprinted surface immersed in monomer solution, prior to initiation of film deposition; panel c: regions of bare (inter-ridge) surface covered with thin layer of polymer in early stages of deposition; panel d: surface optimally covered with polymer; panel e: excess polymer deposited, resulting in overfilling of trenches and partial obscuring of fingerprint deposit; panel f: sample after transfer to monomer-free electrolyte and held at a different potential, generating a contrasting image (via a colour change) to that in panel d.
The main advantage of this technique relies on the use of electrochromic conductive polymers. These polymers can undergo electrochromism, which is the ability for the material, in this case the polymer, to undergo a colour change through the application of a voltage, and the subsequent chemical switching of redox states (64). This has significant forensic relevance, as it allows for the enhancement of the print by changing and maximising the contrast between substrate and print. Recent studies have seen the successful use of the polymers polyaniline and poly-3,4-ethylenedioxythiophene (PEDOT), for the enhancement of prints on metal substrates of platinum, gold, silver, ergal (an aluminium alloy), and stainless steel (60, 61, 63, 64). Polyaniline polymer change colour between green and blue, while the PEDOT polymer changes colour between dark and light blue (65).

2.4.1 Effect of Wetting on Electrochromic Enhancement

As the monomer deposition and subsequent polymer generation occurs in solution in a three-electrode cell, the electrochromic technique by virtue of its methodology is able to enhance prints on substrates that have been wetted (62). A comparative study of the polyaniline and PEDOT polymers with powder dusting, powder suspension, and cyanoacrylate, after prints on stainless steel were exposed to a range of destructive environments (high temperature, submergence in water, acetone washed, soap washed) was conducted (29). It was reported that the electrochromic enhancement technique outperformed the other techniques in most scenarios, with powder dusting being the
second most effective technique followed by powder suspension and the superglue fuming. Electrochromic enhancement was hypothesised to have the best result since the technique only requires there to be an insulating fingerprint deposit of a few nanometres thick, whereas fingerprint deposits range from 10nm to 2 \( \mu \)m in thickness (66). Therefore, in destructive environments where the fingerprint is depleted there is still enough residue to ensure inhibition of polymer film development, whereas there is insufficient residue remaining for the other techniques to perform optimally. It should be noted however, that the fingerprints that were deposited were groomed sebaceous fingerprints, generated by the rubbing of fingers over the nose and forehead to increase the load of sebaceous constituents in the residue, and may have influenced the results. This was evident in that cyanoacrylate, which performed the worst across the destructive environments, also performed very poorly in the ambient condition scenario.

2.5 Environmental Effects and Destructive Environments

The environment in which the fingerprints are exposed will affect the persistence and composition of the fingerprint, its interaction with the substrate and the technique in which used to enhance that fingerprint. This environmental effect can be enhanced when the print is exposed to destructive environments, either through the nature of the crime scene or an intentional attempt to destroy evidence by the perpetrator of a crime. Various studies in the scientific literature have looked at the effect of different destructive environments and the possible techniques for the enhancement of the exposed latent fingerprints; such as those for the environmental effects of high temperature or arson (31, 67-70), burial in snow or soil (31, 71), and being wetted by or submerged in water (27-29, 31, 35, 36, 42, 72,
However, there is little work in the literature on the recovery of latent prints that have been exposed to or washed with soapy water (29, 73), and no studies on recovery of latent fingerprints after being washed in a dishwasher.

Maslanka (73) investigated the effect common household liquids (milk, wine, soft drinks, beer, orange juice, and soapy water) may have on latent prints and their subsequent enhancement. Prints were deposited onto glass substrates and were submerged in one of the liquids for 1, 12, and 24 hours. For the soapy water “nickel sized drops” of dishwashing liquid were mixed with 140ml of “lukewarm” water. After each time interval the latent prints were attempted to be enhanced with powder and small particle reagent. It was documented that all prints were able to be enhanced at all time intervals to a quality high enough to be used for identification purposes, except for the prints submerged in soapy water. After 12 hours it was reported that there was a significant decrease in the fingerprint quality and by 24 hours, only very few ridges were visible, with no difference in enhancement potential between the two techniques.

Beresford, et.al. (29) studied the effect of the exposure of latent fingerprints to different environments that represented plausible evidential scenarios, on the subsequent enhancement of the deposited prints. Prints were deposited onto stainless steel and then exposed to one of the environments, which included being washed in soapy water by “rubb[ing]” the substrates with warm (40oC) soapy water. The prints were attempted to be enhanced by fingerprint powder, powder suspension, cyanoacrylate fuming, and electrochromic enhancement. It was reported that all methods produced very low recovery
rate of the prints, with the electrochromic enhancement technique being the only technique to enhance some of the prints to a level suitable for fingerprint identification.

These studies conducted by Maslanka and Beresford demonstrate that soap or soap cleaning agents have an impact and effect on the quality and enhancement of latent prints, however these results were obtained from laboratory trials, whereby a loose control of the washing protocol variables was demonstrated. In the study conducted Maslanka (2016), it is stated that “nickel size drops” of Dawn Ultra Original Liquid Soap were mixed with 140ml of “lukewarm” water to create the soap water mixture used to submerge the prints. The use of “nickel size drops” and the 140ml of “lukewarm” water used to make up the soap water mixture is vague, which presents the chance of variation between trials, and the repeatability of this experimental trial difficult. Furthermore, the ratio used for this soap water mixture may not represent the detergent concentrations and ratios found at a crime scene if evidence suspected of holding a latent print is accidently or intentionally submerged in a detergent water mixture. The results obtained by Maslanka for the soap water immersion are still viable, assuming the number of drops of liquid soap and therefore the ratio of soap to water were kept constant and controlled for the two aluminium pans used for the soap water submergence. However, care should be taken when considering the result for this test of this experiment outside of this experiment, without stricter measuring of the variables and the use of only one soap water ratio.

The study by Beresford (2012) simply states that the stainless-steel substrates with fingerprints deposited on were rubbed in warm, 400C soapy water for 30 seconds, before being rinsed, dried and tested for prints. Similarly, to Maslanka, in the study by Beresford, the experimental conditions and variables are vaguely explained, with no mention of which
brand of soap or amount of soap and water used to make the soapy water wash. Furthermore, there is no clarification to the force used to “rub” the substrates and prints in the simulating of the substrates and prints being washed. As with the study by Maslanka, the results obtained by Beresford for the soapy wash are viable within the experiment, assuming that the concentration of the soapy wash and force applied in rubbing was consistent, however care should be given when extrapolating the results based of this soapy wash.

Furthermore, both studies only utilised sebaceous prints, whereby prints are deposited on the substrates after the subjects wash their hands with soap and water, dry them and then rub their fingers on the nose to collect sebaceous sweat on the fingers. This process, known as grooming prints, significantly changes the composition of the prints deposited, and are less representative of the prints encountered during forensic work (12, 74). Again, this needs to be considered when considering the wider application of these results.

No studies were found in the literature that investigated the effects on the recovery of latent prints by the washing and wetting environment of a dishwasher or equivalent, which in a domestic setting, would present as a plausible means of washing a knife if used as a weapon. To further put this into a forensic and real-life context, from a report by the Australian Government on homicide between 2002 to 2012 (27) domestic homicide presented as the highest type of homicide at 41% of all homicides, at the count of 1088, and of those homicides, stabbing as the cause of death presented as the highest means of the homicide at 38%, a count of 447 stabbing homicides.
3.0 Experimental Design

The following section will outline the experimental design to be undertaken to attempt to test the effect that the washing of a dishwasher will have on fingerprints, by the subsequent enhancement of the fingerprints by different enhancement techniques.

3.1 Fingerprint deposits

Fingerprints will be taken from different donors, with the donors varying in age and ethnicity. Fingerprints will be deposited as ‘natural’, ecrine groomed and sebaceous groomed prints, as described by Sears, et.al (12). Ecrine groomed prints will be generated by the donor first washing their hands with soapy water and then wearing powder free nitryl gloves for 20-30 minutes, before deposition of their fingerprint onto the test substrate. Sebaceous groomed fingerprints will be generated by first the donor washing their hands with soapy water, then rubbing their fingers on their nose before deposition. Natural prints will be deposited onto the substrates with no previous hand washing or post ecrine or sebaceous grooming of prints. This range of donors and fingerprint generation will allow for the replication of real life scenario, as different people will sweat different amounts and have different concentration of fingerprint constituents in their pints. Furthermore, sweating is affected by one’s physiological state, and it would stand to reason that the committing of crime could affect the amount of sweat secreted (17).
3.2 Substrate

Fingerprints will be deposited onto stainless steel knives, typical of that found in a home. The knives will be first washed with warm soapy water, and dried before the deposition of fingerprints.

3.3 Washing

The knives will be washed in a conventional household dishwasher. Different trials will be done using a range of dishwasher settings. Dishwasher settings will be selected to represent a “low”, “medium” and “high” intensity wash.

A range of common dishwashing detergents, either as tablet and/or liquid will be used to investigate whether different washing detergents have different effects on the fingerprint residues.

3.4 Enhancement techniques

After washing, fingerprints will be enhanced by a range of enhancement techniques. Enhancement techniques used will be conventional fingerprint powdering, powder suspension, cyanoacrylate fuming with BY40 fluorescent dye staining, and electrochromic enhancement by PEDOT polymer. These techniques have all been reported to be able to enhance prints on items that have been wetted, as outlined above, and the reason why they will be employed.
3.5  Fingerprint enhancement evaluation

After enhancement techniques are applied, resulting fingerprints will be graded based on the quality of developed detail to compare the relative enhancement of the fingerprints, using the grading scheme devised by the Home Office, Centre for Applied Science and Technology, Table 2 (12).

Table 2: Grading system of enhanced fingerprints developed by the Centre for Applied Science and Technology

<table>
<thead>
<tr>
<th>Grade</th>
<th>Level of Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence of mark</td>
</tr>
<tr>
<td>1</td>
<td>Weak development; evidence of contact but no ridge details</td>
</tr>
<tr>
<td>2</td>
<td>Less than 1/3 of mark showing clear ridge detail</td>
</tr>
<tr>
<td>3</td>
<td>Between 1/3 and 2/3 of mark showing clear ridge detail</td>
</tr>
<tr>
<td>4</td>
<td>Over 2/3 clear ridge detail</td>
</tr>
</tbody>
</table>

4.0  Experimental aims and objectives

In light of the research presented in the literature review, it is evident that there are a range of techniques that are available to enhance fingerprints on non-porous wetted surfaces. The value of recovering and enhancing fingerprints found at a crime scene can be invaluable in leading to the identification of a person of interest in relation to a crime. There is work throughout the literature investigating the effects and the possibility of enhancement of fingerprints exposed to various destructive environments, however there is no work investigating the possible enhancement of fingerprints on items exposed to the washing effects from a dishwasher. The experiment therefore, aims to determine if it is possible to enhance latent fingerprints after being exposed to the washing effects of a
dishwasher. Subsequently, the best enhancement technique to enhance fingerprints after exposure to this environment will be identified from; powdering, powder suspension, cyanoacrylate fuming, PEDOT polymer electrochromic enhancement.

**5.0 Conclusion**

Fingerprints are the most commonly encountered and collected evidence from crime scenes and play an integral role in forensics. Due to the persistence of fingerprints throughout one’s life, they provide forensic investigators with the power to identify a perpetrator of a crime or person of interest. Fingerprints deposited at a crime scene are made up a combination of eccrine and sebaceous sweat, and it is the interaction between the constituents of this sweat, the substrate they are deposited on, and the environment that they are exposed to, which determine the technique selected to enhance the print.

Fingerprints deposited onto non-porous substrates and exposed to some form of wetting can be enhanced by fingerprint powder, powder suspension, small particle reagent, cyanoacrylate fuming, and electrochromic enhancement, although each technique will not be as efficient as another.

The literature review has established that there are little studies completed on the enhancement of fingerprints after being washed with soapy water, and there are no studies on the enhancement of fingerprints from items after they have been washed in a dishwasher, which stands as a very real scenario that could be encountered by forensic investigators. Subsequently an experimental design has been established to investigate the enhancement of fingerprints from this scenario. Results from this study could be found
beneficial to forensic investigators, to aid in the correct technique selection if and when they encounter such a scenario in the field.
6.0 References


THE ENHANCEMENT OF FINGERPRINTS ON KITCHEN KNIVES THAT HAVE BEEN THROUGH A WASH CYCLE IN THE DISHWASHER
Abstract

Fingerprints are the most common type of evidence encountered and collected across homicide criminal cases and can provide invaluable information in identifying a person of interest. However, items potentially containing fingerprints may be exposed to detrimental conditions or environments by the perpetrator, in an attempt to destroy evidence, such as fingerprints. This study aims at investigating the effect of and potential recovering of fingerprints exposed to such an environment, in the wetting and washing effect of a dishwasher. Prints were deposited on common kitchen knives and washed with and without detergent in a dishwasher. Prints were examined using a white light source, and then enhancement of prints was attempted by using regular fingerprint powdering, powder suspension, small particle reagent, and cyanoacrylate fuming. Prints were found to be degraded by the washing effects of the dishwasher, regardless if detergent was or was not used, and all techniques were unsuccessful in enhancing the prints after being washed. However, some success in visualising prints after washing was achieved using a white light source.

Keywords: forensics, fingerprints, wetting, washing, dishwasher, powder, powder suspension, small particle reagent, cyanoacrylate.
Introduction

The use of fingerprints for the purposes of person identification and use in forensics in the investigation of criminal cases has a rich history as explained by Barnes (1). The advent of automated fingerprint identification systems, in the 20\textsuperscript{th} century, is considered among the most important advances in forensic science for the identification of criminals (2). Fingerprints are the most common type of forensic evidence collected in the investigation of criminal offences, in their ability to identify a person of interest or perpetrator and power to physically link them to a crime (3-5). Furthermore, Peterson et al. (4, 5) found that the recovery and positive identification of evidence that linked the suspect to the crime (including fingerprints) were significantly linked to trial convictions and a significant increase in conviction sentence length.

During the committing of a crime, fingerprints can be deposited through different mechanisms, on a range of porous, semi-porous and non-porous substrates, and can be exposed to a range of environments and environmental conditions. This interaction between fingerprint composition, deposition surface and environment is depicted and explained by Sears et al.(6) in the fingerprint triangle of interaction. This interaction concept describes that the technique or process to be selected and used to enhance latent prints is governed by the understanding of and the interplay between these three elements. As a result of this concept, there is a vast range of latent fingerprint visualisation and enhancement techniques for the differing interactions between the fingerprint composition, substrate, and environment interactions (7, 8). However, despite this large list of visualisation and enhancement techniques, latent fingerprint visualisation and
enhancement is never a guaranteed outcome due to the possible interactions that can take place from the three components of this fingerprint interaction concept.

Following Locard’s principle of exchange, that “any action of an individual, and obviously the violent action constituting a crime, cannot occur without leaving a trace”(9), when the friction ridge skin of the finger comes into contact with a surface a fingerprint is deposited into or on that surface. The majority of prints found at a crime scene are latent prints (10). Latent prints are prints that are generated and transferred to a surface by endogenous sweat secretions from sweat glands found in the dermal layer of the skin. Latent prints are so named as they are invisible to the naked eye unless enhanced by an optical, physical or chemical enhancement process.

The environment in which the fingerprints are exposed too will affect the persistence and composition of the fingerprint, its interaction with the substrate and the technique in which used to enhance that fingerprint. This environmental effect can be enhanced when the print is exposed to destructive environments, either through the nature of the crime scene or an intentional attempt to destroy evidence by the perpetrator of a crime. Various studies in the scientific literature have looked at the effect of different destructive environments and the possible techniques for the enhancement of the exposed latent fingerprints; such as those for the environmental effects of high temperature or arson (11-15), burial in snow or soil (11, 16), and being wetted by or submerged in water (11, 17-24). However, there is little work in the literature on the recovery of latent prints that have been exposed to or washed with water and cleaning agents (19, 24), and no studies on recovery of latent fingerprints after being exposed to the wetting and washing environment in a dishwasher.
Maslanka (24) investigated the effect of a soapy water mixture on the quality and enhancement of the fingerprints, by submerging fingerprints on glass substrates in to the soapy water mixture for 1, 12 and 24 hours. Beresford et al. (19) studied the effect of the exposure of latent fingerprints to different environments that represented plausible evidential scenarios, on the subsequent enhancement of the deposited prints. Prints were deposited onto stainless steel and then exposed to one of the environments, which included washing in soapy water by “rubb[ing]” the substrates with warm (40°C) soapy water. These studies conducted by Maslanka (2016) and Beresford et al. (2012) demonstrate that soap or soap cleaning agents have an impact and detrimental effect on the quality and enhancement of latent prints. However, these studies were conducted as laboratory trials, and a weak control of the washing protocol variables was demonstrated. Both studies gave vague descriptions and measurements of their washing protocol variables and methods, with Maslanka stating that “nickel size drops” of detergent and “lukewarm” water was used, and Beresford et al. neglected to mention the amount of soap and water used to make up the soapy water wash.

Furthermore, both studies only utilised sebaceous prints, whereby prints are deposited on the substrates after the donors wash their hands with soap and water, dry them and then rub their fingers on the nose to collect sebaceous sweat on the fingers. This process, known as grooming prints, significantly changes the composition of the prints deposited, and are less representative of the prints encountered during forensic work (6, 25).

Finally, it is noted that in many of the studies investigating the effects of water environments on the recoverability of latent prints (12, 18, 19, 21-24), the substrates with deposited prints are just simply placed in the water environment with no means of
agitation, with the exception of the study by Beresford, whereby substrates were rubbed with soapy water (19).

No studies were found in the literature that investigated the effects on the recovery of latent prints by the washing and wetting environment of a dishwasher or equivalent, which in a domestic setting, would present as a plausible means of washing a knife if used as a weapon. To further put this into a forensic and real-life context, from a report by the Australian Government on homicide between 2002 to 2012 (26) domestic homicide presented as the highest type of homicide at 41% of all homicides, at the count of 1088, and of those homicides, stabbing as the cause of death presented as the highest means of the homicide at 38%, a count of 447 stabbing homicides. In this study, fingerprints deposited onto common kitchen knives will be examined to test the wetting and washing effects of a wash cycle in a dishwasher on the enhancement of the fingerprints using fingerprint powder, powder suspension, small particle reagent, and cyanoacrylate fuming.

**Materials and Methods**

**Fingerprint Deposition**

Fingerprint deposits were collected from 5 individuals, 2 females and 3 males, with varying ethnicity, and aging from 22-51. Donors deposited fingerprints as natural, groomed eccrine, and groomed sebaceous prints, as described by Sears et, al. (6). Natural prints were deposited by donors after they had gone about their normal activities, with a minimum time of 30 minutes since washing their hands or touching food. Groomed eccrine prints were generated and deposited by donors after thoroughly washing their hands with soapy
water and then wearing powder-free nitryl gloves for a minimum of 30 minutes. Groomed sebaceous prints were generated and deposited by the donors after thoroughly washing their hands with soapy water and then rubbing their fingertips over their nose. Before deposition of a print, donors rubbed their fingertips together to ensure an even deposition of the sweat across their fingertips. A total of 216 prints was deposited, consisting of 72 normal prints, 72 eccrine prints and 72 sebaceous prints. Prints were deposited with a medium to hard pressure to replicate the presumed pressure that would more likely occur in a real-world scenario if a knife was used as a murder weapon.

Substrate

Fingerprints were deposited onto kitchen knives consisting of a stainless-steel blade and polymer handles, typical of that found in a home. Knife blades and handles measured at either 12.5cm or 9cm, and 10.5cm in length respectively, and 2.2cm, and 1.7cm at maximum width respectively (Kmart LTD, Triple Rivet Paring And Utility Knife Set [http://www.kmart.com.au/product/triple-rivet-paring-and-utility-knife-set/700551]).

Fingerprints were either deposited onto the blade or handle of the knives, as seen in figure 1. The knives were first washed with warm soapy water and dried before fingerprint deposition.
**Substrate Washing**

The knives were washed in an AEG Electrolux dishwasher, model number FAVORIT 60850 ViM. The knives were laid down on the top drawer of the dishwasher, with prints facing up, and no other items were present in the dishwasher. Knives were washed on the “30 min” wash setting, with and without detergent, in separate trials. The “30 min” wash setting, consists of a main wash and final rinse and utilises 9 litres of water at a temperature of 60°C (figure 2 (27)). The detergent used was Powerball® All In 1 detergent tablet. After the knives were washed, they were left to dry before processing. The dishwasher was not new and was normally used on a daily basis for the washing of normal home dishes.

<table>
<thead>
<tr>
<th>Dishwashing-cycle</th>
<th>Suitable for:</th>
<th>Type of soiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 MIN (60°C)¹⁾</td>
<td>Dishes, excluding saucepans</td>
<td>just used, lightly to normally soiled</td>
</tr>
</tbody>
</table>

*Figure 7: Dishwasher 30 Min wash cycle*

**Enhancement Techniques**

The fingerprints were enhanced using Fingerprint Powder, Powder Suspension/Wet Powder, Small Particle Reagent, and Cyanoacrylate fuming.

**Fingerprint Powdering**

Prints deposited on the blade were developed with black granular fingerprint powder (Lightning Black Powder), and prints deposited on the handles were
developed with bi-chromatic powder (Lighting Bi-Chromatic™ Powder). Both powders were applied using a Zephyr® Fiberglass Brush.

*Powder Suspension/Wet Powder*

Prints deposited into the blades were developed using Black Powder Suspension. Black Powder Suspension was made up using a mixture of iron (II/III) oxide nanopowder, 50-100nm (Sigma-Aldrich), laboratory grade Triton X-100 (Sigma-Aldrich), and ReagentPlus ≥99% Ethylene Glycol (Sigma-Aldrich). These reagents were used in accordance with the Centre for Applied Science and Technology (CAST) Fingerprint Visualisation Manual (7).

Prints deposited onto the handles were developed using White Wet Powder™ (Kjell Carlsson Innovation), as per the manufacturer’s protocol (28).

*Small Particle Reagent*

Prints deposited onto the blade and handle were developed with Black Small Particle Reagent, SPR1001 (SIRCHIE™), and White Small Particle Reagent, SPR2001 (SIRCHIE™), respectively. Small Particle Reagent was applied in accordance with the manufacturer’s protocol (29).
Cyanoacrylate Fuming

Cyanoacrylate fuming was undertaken in a superglue fuming cabinet at 80% relative humidity, and superglue heated at a temperature of 120°C, as per the protocol described in the Fingerprint Visualisation Manual (7).

Evaluation and Grading

The quality of the fingerprints was evaluated after washing, before enhancement and after enhancement, using a white light source and the enhancement techniques respectively. Print quality was evaluated using the grading scheme developed by the Home Office, CAST (6), and can be seen in Table 1.

Control prints were deposited on unwashed knives and enhanced by each technique before used on the washed knives. Each control print was visualised as a grade 4.

Table 3: Fingerprint grading scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Level of Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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</tr>
<tr>
<td>4</td>
<td>Over 2/3 clear ridge detail</td>
</tr>
</tbody>
</table>

Results and Discussion

To investigate the effects a washing cycle of a dishwasher has on fingerprints, a total of 216 fingerprints (72 normal, 72 eccrine, 72 sebaceous) were deposited by 5 donors onto kitchen knives (120 prints on the blades, 96 prints on the handles) and then washed in the dishwasher, either with or without dishwashing detergent tablets, and then left to dry.
Once the knives were dry and removed from the dishwasher, the prints were first viewed using a white light source and evaluated using the grading scheme. An enhancement technique; either fingerprint powder, powder suspension, small particle reagent, or superglue, was applied, at which point the prints were re-evaluated using the same grading scheme. Based on the grading scale it is recognised that prints of grade 3 or 4 are of high enough quality to make an identification. Results for this white light source and enhancement technique paired evaluation process for the normal, eccrine and sebaceous prints; deposited onto blades washed without detergent, deposited onto handles washed without detergent, deposited onto blades washed with detergent, and deposited onto handles washed with detergent, can be seen in tables 2-5 (appendix) respectively. Figures 3 and 4 are of results extracted from the tables 2-5.

![Figure 8](image_url)  
*Figure 8: Percentage of prints of each grade level, observed by WLS optical enhancement*
Wetting and Wash Cycle Effect on Fingerprint Quality

Both washing regimes (30 min wash, with and without detergent) produced a decrease in print quality, with prints washed with detergent, on average, resulting in poorer quality and lower graded prints.

Prints washed only using water (no detergent), evaluated using a WLS, prior to powder or reagent enhancement, produced a decline in print quality for both prints deposited onto blades and handles. Figure 3A shows that prints deposited onto blades washed without detergent, graded using WLS prior to physical and chemical enhancement, produced 0 prints of quality 4 and only a limited number of prints of quality 3 compared to prints of quality of 2, 1, and 0, with 6 out of 60 (10%) of prints recorded as level 3, and print qualities of 2, 1, and 0 recorded at 15 out of 60 (25%), 15 out of 60 (25%), and 24 out of 60 (40%)
respectively. Prints deposited onto handles washed without detergent (Figure 3B), graded using WLS prior to physical enhancement, produced 0 prints of quality 4 and 3, compared to the limited number of prints of quality 2 and 1, with 2 out of 48 (4.16%), and 7 out of 48 (14.98%) prints recorded respectively, and a large number of prints of grade 0, at 39 out of 48 prints (81.25%). These results, whereby low numbers of grade 3 and 4 prints and a higher number of grade 2, 1, and 0 prints were observed after washing in the dishwasher with just water are contradictory to other results observed in the literature were prints were exposed to water environments. Numerous other studies have looked at the effect of water environments on the recoverability of fingerprints (12, 18, 19, 21-24). In these studies, prints are submerged in different types of water, with no agitation, and after certain lengths of time removed, and prints attempted to be enhanced. In these studies, prints are generally observed to be of high enough quality for fingerprint donor identification, with fingerprint grades recorded at of 3 or 4. The differing results observed in this study is most likely due to the force the dishwasher uses to expel the water from its spray arms and the agitation caused when the water interacts with the items in the dishwasher, coupled with the 60°C water temperature used. It stands to reason that these conditions were enough to at the very least, remove some the ridge detail of the fingerprint, if not the entire print and hence the difference between results from studies were prints are just submerged in water.

Prints deposited onto the blades and handles and washed with detergent (figure 3C-D), produced a decline in print quality after being washed, and assessed using a WLS. No prints washed with detergent were recorded at a quality of 3 or 4, and minimal prints recorded
at a quality of grade 2, with only 3 out of 60 (5%) of prints deposited onto the blade recorded as grade 2 (figure 3C). Most of the prints washed with detergent on the blades and handles were of grade 0, with 9 out 60 (15%), and 48 out of 60 (80%) graded as a 1 and 0 for prints deposited on blades (figure 3C), respectively, and 13 out of 48 (27.08%), and 35 out of 48 (72.91%) graded as a 1 and 0 for prints deposited on handles (figure 3D), respectively. The absence of grade 4 and 3 prints, then minimal grade 2 prints and majority grade 0 prints was expected due to the presence and function of the dishwashing detergent tablet. Fingerprint deposits are made up of hydrophilic, water-soluble eccrine sweat and hydrophobic, water-insoluble, sebaceous sweat (7). Detergents contain surfactant molecules that consist of a hydrophilic head and a hydrophobic tail. When mixed with water the surfactant molecules associate into a sphere with the hydrophilic heads on the outside and hydrophilic tails on the inside, known as a micelle. These micelles then interact with hydrophobic molecules, such as the sebaceous constituents of a fingerprint deposit, and allow for them to be removed or dissolved (30).

Although the decline in print quality by the washing effect of the dishwasher was expected, more interestingly was that there was still evidence of prints, albeit low quality, after washing with detergent at all, with some grade 2 and 1 prints recorded by WLS (figure 3C-D, Tables 4-5), as it was expected that all traces of prints would be removed by the detergent-dishwasher wash. The results obtained are contradictory to results obtained by Paterson et, al. (31). In this study sebaceous groomed prints were deposited onto disks of brass using light pressure, and submerged in warm (30-40°C) soapy water and rubbed vigorously with a wet tissue for 30 seconds, resulting in no prints present after the treatment. This difference in results and the unexpected remaining low-quality prints in this study could be due to the difference in pressure applied in print deposition between
the studies and difference between the vigorousness of the washing in the study by Paterson et, al. and the “30-minute” wash cycle of the dishwasher. In applying a print with medium to high pressure, as was done in this study, compared to the light pressure applied in the study by Paterson et, al. it stands to reason that a heavier concentration of sweat was deposited, therefore more difficult to be removed by washing. This coupled with a possible difference in the cleaning power by vigorously rubbing compared to the force used by the dishwasher on the “30-minute” wash setting, could stand as a reasonable explanation to the difference in results. Continuingly, the dishwasher used for the study, was not new and is used on a daily basis, for general dish cleaning, and the spray arms and filter were not cleaned before use in this study. This was intentionally done in an attempt to replicate best a real-world scenario, where if a knife was used as a murder weapon and dishwasher was used to clean the knife; the perpetrator would be in urgency to clean the knife and not think to clean the dishwasher first. The dishwasher user information manual, states that if the filter and/or spray arms have not been cleaned, then this can affect wash results. Therefore, this too could have had an impact on the cleaning ability of the dishwasher and the results observed

Comparing the results of the two-different wash trials (without or with detergent) it would be expected that results obtained from the no detergent wash trials (figure 3A-B), would produce less degraded prints then the results obtained from the detergent wash trials (figure 3C-D), due to the presence of the detergent. This is indeed observed when comparing the results for the prints deposited on to blades washed without detergent (Figure 3A) and with detergent (Figure 3C), observed with WLS. Prints deposited onto blades washed without detergent returned a greater number of higher quality prints, with
6 out of 60 (10%) prints, 15 out of 60 (25%) prints, and 15 out of 60 (25%) prints, recorded for print quality 3, 2, and 1 respectively, compared to 3 out of 60 (5%) prints, and 9 out of 60 (15%) prints, recorded for grades 2, and 1, with no grade 3 prints for prints deposited onto blades and washed with detergent. However, this expected result was not observed when comparing the results of the prints deposited onto blades and washed without detergent (Figure 3B) and washed with detergent (Figure 3D), observed using WLS. Prints washed without detergent returned 0 prints of quality 3, 2 out of 48 (4.16%) prints of quality 2, 7 out of 48 (14.58%) prints of quality 1, and 39 out of 48 (81.25%) of quality 0. Prints washed with detergent returned 0 prints of quality 3 and 2, 13 out of 48 (27.08%) prints of quality 1, and 35 out of 48 (72.91%) prints of quality 0. In comparing the results both wash trials for the handles produced 0 quality 3 prints, and although the without detergent wash resulted in 2 prints of quality 2, were the detergent wash resulted in none, the without detergent wash produced more prints of quality 0 than that of the detergent wash. Based on the cleaning properties of detergent as mentioned above, this result for the handle prints washed without detergent seems questionable. A reason for this questionable result could be that the handle-no detergent wash trials were the last trials completed of the 4 trials, and as after each trial and enhancement technique application, the knives were thoroughly washed with soapy water and dried before the next application of prints and washing regime. Due to this, the quality of the knife handles may have decreased, which may have had an impact on the ability of the knife to retain prints and hence possibly why a greater amount of grade 0 prints were recorded for the no detergent knives.
Substrate Effect (Stainless-steel blade vs Polymer handle)

In comparing the results obtained from the two different washing trials (no detergent and detergent) on the effect of the prints deposited onto the blades or handles (figure 3), inferences can be made as to whether the different substrates influenced print retention in the dishwasher. Prints deposited onto the blades washed without detergent (figure 3A) retained a greater percentage of higher quality prints than prints deposited onto the handles and washed without detergent (Figure 3B), by optical enhancement using WLS. Blade-no detergent print grade percentage were at 10%, 25%, 25%, and 40%, for print grades, 3, 2, 1, and 0 respectively, compared to the handle-no detergent print grade percentages at 0%, 4.16%, 14.58%, and 81.25% for print grades of 3, 2, 1, and 0, respectively. This suggests that a difference in the surface chemistry or characteristic between the non-porous stainless-steel blade and the polymer handle substrates could be influencing the retention of the deposited prints by the interaction between the substrate and the prints, and allowing for the stainless-steel blade to retain more prints. However, as mentioned above, it is possible that the without detergent printed handle wash results could have been affected due to a possible decline in the handle quality for that wash trial. Comparing the results for the prints deposited onto the blades and handles washed with detergent (figure 3C-D), by optical enhancement using WLS, the different substrates on average produced similar results. The percentages of the prints graded as a grade of 2, 1, and 0 for the blade-detergent wash were 5%, 15%, and 80% respectively, compared to the percentages of the prints graded as a grade 2, 1, and 0, for the handle-detergent wash of 0%, 27.08%, 72.91%, with no prints of grade 3, or 4 observed for either wash. Based on these results, it is too difficult to declare that one substrate retained a greater percentage
of higher qualities prints. Although the blade-detergent washed prints had a 5% retention of level 2 prints, while the handle-detergent prints retained 0 grade 2 prints, the handle-detergent prints retained a greater percentage of grade 1 prints, and a lower percentage of grade 0 prints, compared to the blade-detergent prints. It seems more likely to hypothesise that the regardless of the substrate, that the cleaning/washing effect of the detergent was greater than and the possible capability of one substrate to retain prints more efficiently than the other, as on average the two substrates performed similarly. Considering the results of all the wash trials described above (blade-no detergent, handle-no detergent, blade-detergent, handle-detergent), caution should be taken when suggesting one substrate performed better than the other, based on the results acquired.

*Enhancement Technique Evaluation*

In evaluating the quality of the prints deposited onto the blades and handles, after application of the physical and chemical enhancement techniques (fingerprint powder, small particle reagent, powder suspension, cyanoacrylate), for the two washing trials, it was observed that none of the techniques consistently enhanced the prints, regardless if they were washed with or without detergent (appendix tables 2-5). In fact, in most instances, the enhancement technique lowered the quality of the present print, either by removing the print that was there or masking it, as can be seen by comparing the results displayed in figures 3 and 4. Relative example images of the prints before and after enhancement with fingerprint powder, small particle reagent, and cyanoacrylate, can be seen in figures (5-7), respectively. This is inconstant with other studies where prints were deposited onto items and submerged in water (12, 18, 19, 21-24) and the study by Beresford et al. (20), where prints were washed with warm soapy water, whereby prints
were successfully enhanced to some degree, with varying enhancement techniques. This inconsistency is most likely due to the harsher wetting and washing environment the knives and prints were exposed to in this study. For the studies where prints were simply submerged in water and for the study by Beresford, maximum water temperature that was used was 40°C, where the water temperature used in this experiment was 60°C. Furthermore, as mentioned earlier, the studies where the prints were just submerged in water, there was no agitation of the water on the prints, as opposed to the agitation and wetting of the water on the prints in the dishwasher in this study. It stands to reason that although some prints could be visualised using a white light after washing, the wetting and washing imposed on the prints in the dishwasher, greatly reduced the amount of fingerprint residue and constituents available for the enhancement techniques to adhere to or react with, to a level lower than that of the sensitivity of all the enhancement techniques.

Figure 10: Control print enhanced with black granular powder (left), Sebaceous print washed with detergent, visualised with white light (middle), the same print with black granular powder applied (right).
Conclusion

Knifes are recorded in Australia as the most common weapon used to commit murder with, and therefore, there washing in a dishwasher to remove incriminating identification evidence is a highly plausible scenario. Based on the results obtained from this study, it is shown that for the majority of prints washed in a dishwasher without detergent, and for all prints washed with detergent, no prints were recovered that were of a quality to identify the print donor, or no prints were recovered at all. Furthermore, the enhancement
techniques applied were unsuccessful in enhancing and more likely to further decrease quality of any of the prints. Based off these results, it is suggested that if a knife is recovered in this manner at a crime scene, the knife be inspected for prints using a light source, and if prints are identified, they are photographed, and then swabbed for the collection of DNA, over attempting to enhance the prints with the techniques used in this study. Further studies could investigate the recoverability of fingerprints deposited in or with blood, on a knife, washed in a dishwasher as given the close proximity to blood of a knife wielders hands during a stabbing event, this stands a plausible fingerprint deposition medium. Furthermore, more studies can be done using normal fingerprints washed in a dishwasher as done in this experiment, but using different enhancement techniques. The study by Beresford et, al.(19) recorded good enhancement of prints washed with warm soapy water on stainless steel substrates, using a technique called electrochromic enhancement, which could be used on the blades of knives.
References

27. AEG-Electrolux. FAVORIT 60850 ViM: User Information.
29. SIRCHIE. Technical Information: Small Particle Reagent (SPR) Kit 2016 [Available from: http://d1zh4ok0q8k7dm.cloudfront.net/media/resourcecenter/item/s/p/spr300_tio3-238eng-rev4e.pdf.
### Appendix

**Table 4: Print Grading for prints deposited on to the blades of knives washed without detergent**

Prints were graded twice, white light source prior to use of enhancement technique and after use (prior/after)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Print Type</th>
<th>Grade</th>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Powder</td>
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<td>4/4</td>
<td>0/1</td>
<td>1/1</td>
<td>0/0</td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Eccrine</td>
<td></td>
<td>5/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Sebaceous</td>
<td></td>
<td>0/2</td>
<td>2/2</td>
<td>2/1</td>
<td>1/0</td>
<td></td>
<td>5/5</td>
</tr>
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<td>3/1</td>
<td>1/0</td>
<td></td>
<td>15/15</td>
</tr>
<tr>
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<td>Normal</td>
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<td>1/0</td>
<td>0/0</td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Eccrine</td>
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<td>5/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Sebaceous</td>
<td></td>
<td>1/3</td>
<td>2/1</td>
<td>1/0</td>
<td>1/1</td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
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<td>4/1</td>
<td>2/0</td>
<td>1/1</td>
<td></td>
<td>15/15</td>
</tr>
<tr>
<td>Small Particle Reagent - Black</td>
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<td>1/4</td>
<td>3/1</td>
<td>1/1</td>
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<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Eccrine</td>
<td></td>
<td>3/5</td>
<td>1/3</td>
<td>1/0</td>
<td></td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Sebaceous</td>
<td></td>
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<td>1/3</td>
<td>3/2</td>
<td>1/0</td>
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<td></td>
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<td>3/10</td>
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</tr>
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<td>1/4</td>
<td>4/0</td>
<td>0/1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Eccrine</td>
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<td>3/5</td>
<td>1/0</td>
<td>1/0</td>
<td></td>
<td></td>
<td>5/5</td>
</tr>
<tr>
<td></td>
<td>Sebaceous</td>
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<td>0/1</td>
<td>1/1</td>
<td>2/2</td>
<td>2/1</td>
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<td>2/1</td>
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<td>Overall Total</td>
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</tr>
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<td>Percentage Total</td>
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<td>10/3.33</td>
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</table>

**Table 5: Print Grading for prints deposited on to the handles of knives washed without detergent**

Prints were graded twice, white light source prior to use of enhancement technique and after use (prior/after)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Print Type</th>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
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<td>1/0</td>
<td>1/0</td>
<td></td>
<td></td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td>Eccrine</td>
<td></td>
<td>4/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td>Sebaceous</td>
<td></td>
<td>3/3</td>
<td>0/1</td>
<td>1/0</td>
<td></td>
<td></td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
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<td>1/2</td>
<td>2/0</td>
<td></td>
<td></td>
<td>12/12</td>
</tr>
<tr>
<td>Powder Suspension - White</td>
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<td>3/4</td>
<td>1/0</td>
<td></td>
<td></td>
<td></td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td>Eccrine</td>
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<td>4/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4/4</td>
</tr>
<tr>
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<td>Sebaceous</td>
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<td>4/4</td>
</tr>
<tr>
<td></td>
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<td>11/12</td>
<td>1/0</td>
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<td></td>
<td>12/12</td>
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<td>Small Particle Reagent - White</td>
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<td>3/4</td>
<td>1/4</td>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>Cyanoacrylate</td>
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<tr>
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<td>2/0</td>
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<tr>
<td></td>
<td>Sebaceous</td>
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<td></td>
<td></td>
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<td>4/4</td>
</tr>
<tr>
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Table 7: Print Grading for prints deposited on to the blades of knives washed with detergent
Prints were graded twice, white light source prior to use of enhancement technique and after use (prior/after)

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<th>Technique</th>
<th>Print Type</th>
<th>Grade</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Powder</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>3/3</td>
<td>1/2</td>
<td>1/0</td>
</tr>
<tr>
<td>Eccrine</td>
<td>5/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sebaceous</td>
<td>2/2</td>
<td>2/3</td>
<td>1/0</td>
</tr>
<tr>
<td>Total</td>
<td>10/10</td>
<td>3/5</td>
<td>2/0</td>
</tr>
<tr>
<td>Powder Suspension - Black</td>
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<td></td>
</tr>
<tr>
<td>Normal</td>
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<td>1/0</td>
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</tr>
<tr>
<td>Eccrine</td>
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</tr>
<tr>
<td>Sebaceous</td>
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</tr>
<tr>
<td>Total</td>
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<td>1/0</td>
</tr>
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</tr>
<tr>
<td>Total</td>
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<td>Cyanoacrylate</td>
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<td>Sebaceous</td>
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<td>Total</td>
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<td>Percentage Total</td>
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<td>15/10</td>
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Table 6: Print Grading for prints deposited on to the handles of knives washed with detergent
Prints were graded twice, white light source prior to use of enhancement technique and after use (prior/after)

<table>
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<tr>
<th>Technique</th>
<th>Print Type</th>
<th>Grade</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-Chromatic Powder</td>
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<tr>
<td>Normal</td>
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<td>2/0</td>
<td>4/4</td>
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<tr>
<td>Eccrine</td>
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<td>4/4</td>
</tr>
<tr>
<td>Sebaceous</td>
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<td>1/1</td>
<td>4/4</td>
</tr>
<tr>
<td>Total</td>
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<td>12/12</td>
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<td>Powder Suspension - White</td>
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<tr>
<td>Normal</td>
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<td>1/0</td>
<td>4/4</td>
</tr>
<tr>
<td>Eccrine</td>
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<td>4/4</td>
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<tr>
<td>Sebaceous</td>
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<td>2/0</td>
<td>4/4</td>
</tr>
<tr>
<td>Total</td>
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<td>12/12</td>
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<td>4/4</td>
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<td>Total</td>
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<td>12/12</td>
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<td>4/4</td>
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<tr>
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<td>0/1</td>
<td>4/4</td>
</tr>
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</tr>
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</tr>
<tr>
<td>Overall Total</td>
<td>35/43</td>
<td>13/4</td>
<td>0/1</td>
</tr>
<tr>
<td>Percentage Total</td>
<td>72.91/89.58</td>
<td>27.08/8.33</td>
<td>0/2.08</td>
</tr>
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