The Effect of Paint Type on the Development of Latent Fingermarks on Walls

Abstract

Despite recent advances in DNA technology, fingermark evidence remains a fundamental method of ascertaining an individual’s identity. Latent fingermarks are the commonest type of fingermark encountered at crime scenes. The Fingermark Visualisation Manual provides crime scene practitioner’s with sequential information regarding which enhancement processes are best suited for a range of deposition surfaces (Bandey et al., 2014) [1]. However, there are still many surfaces, such as painted walls where more knowledge is required regarding which development techniques provide optimum results. In this study, four paint types were tested (matt, silk, bathroom and eggshell). Fingermarks were deposited on painted simulated walls and aged for 1 day, 1 week and 1 month. Fingermarks were developed by three processes highlighted as the most frequently used by practitioners (magnetic granular powder, magneta flake powder and ninhydrin. The results showed that overall black magnetic granular powder outperformed both magneta flake powder and ninhydrin on all paint types. This contradicts current UK guidelines for enhancement of fingermarks on matt painted walls, as black magnetic granular powder is not a recommended process at present. SEM and SEM-EDX analysis showed distinct differences between matt paint and the three non-matt paints tested, which provides an explanation for the results obtained.

1.0. Introduction

Despite recent advances in DNA technology, fingermark evidence remains a fundamental method of ascertaining an individual’s identity [2]. Fingermarks originate when residue from the skin on the fingertips transfers to a surface following contact [3]. Latent fingermarks are the most common type of fingermark encountered at crime scenes. They are predominantly composed of the secretions from the eccrine and sebaceous glands and often require development in order to be visualised [4]. The Fingermark Visualisation Manual provides crime scene practitioner’s with sequential information regarding which enhancement processes are best suited for a range of surfaces [1]. However, there are still many surfaces, such as painted walls where more knowledge is required regarding which development techniques provide optimum results.

Paints are defined as pigmented coatings that are combined with binders and solvents [5]. Pigments provide colour and opacity to the paint. Binders ensure that the pigments remain within the paint and that the paint adheres to the substrate it is applied to; whereas solvents assist in the applicability of the paint to a particular surface [5].

The composition of different architectural paints is typically described by the pigment volume concentration (PVC). The higher the PVC, the lower the proportion of binder within the paint and the higher the ratio of pigment particles [6]. PVC primarily determines properties such as gloss, durability and hiding power etc. [7]. Matt paints typically have PVC levels above the critical pigment volume concentration (CPVC). The CPVC is the point when there is only enough binder present to fill all of the fissures between the packed pigment particles [8]. Typically, matt paints have PVCs between 38 – 80%, paints like silk, satin and eggshell have PVCs between 25 – 45% and gloss paints have PVCs of 15% [9].

Previously, the majority of paints purchased by home owners were solvent based paints. However, due to the European Union (EU) Directive 2004/42/EC, which was subsequently revised in 2010, these paints have now been superseded by aqueous based paints as a measure to limit the levels of volatile organic compounds (VOC) in paint [10].

According to Wickes [11], the most popular paint purchased by domestic customers in the United Kingdom (UK) is white matt paint, which dries to form a porous surface [12]. Other paint types that are typically used on interior walls, such as silk and bathroom have a lower PVC and therefore dry to create a semi-porous finish [9].

Previous research from this group has highlighted the fact that some forensic practitioners do not consider the type of paint on interior walls before attempting to develop any fingermarks that may be present [13]. The authors also highlighted the three fingermark development processes most commonly used by practitioners to develop fingermarks on painted walls at crime scenes are magnetic granular powder, magneta flake powder and ninhydrin. This therefore indicates that practitioners are not consulting the recommended guidelines.

Magnetic granular powder and magneta flake powder are physical techniques that are typically used to develop fingermarks on non-porous surfaces [1]. The powders adhere to the aqueous and lipid constituents present in latent marks. The aqueous constituents generally dissipate first, which can adversely impact the effectiveness of powders on older fingermarks [1, 14]. Therefore, one should consider this when deciding to use powders over other enhancement techniques. Flake formulations are considered more sensitive than other powder types due to their larger surface area [15]. Black magnetic powders are currently recommended for enhancement of fingermarks on walls painted with silk or satin paint, which dry to give a subtle shiny finish [1].

Ninhydrin is a chemical enhancement technique that can be used to develop older marks. Ninhydrin is used to develop fingermarks on both semi-porous and porous surfaces such as paper as it reacts with the amino acids present in latent fingermarks to produce a coloured mark known as Ruhemann’s purple [16]. Fingermarks treated with ninhydrin may continue to develop some time after the initial treatment. Furthermore, ninhydrin treated marks can also fade over time. Therefore, at present there is no optimum time frame suggested when ninhydrin developed fingermarks should be visualised. Ninhydrin is currently one of the recommended techniques for the development of fingermarks on matt painted surfaces [1].

Whether a painted surface is considered porous or non-porous is determined by the type of paint applied to the wall. Our preliminary results showed that the wall finish (plaster, plasterboard or sealed plasterboard) did not significantly affect the number of fingermarks developed using the three techniques and therefore does not need to be considered by practitioners when establishing the optimum processes to use on a specific paint type [17].

Therefore, the overall aims of this research was to determine whether the type of paint had an influence on the efficacy of the three development processes on latent fingermarks deposited on painted simulated walls over time, and if so, provide an explanation for any differences highlighted using scanning electron microscopy (SEM) and scanning electron microscopy energy dispersive x-ray (SEM-EDX) analysis.

2.0. Materials and methods

2.1. Materials

Knauf plasterboard, medium-pile mini rollers, Wickes Trade Flat Matt, Wickes Trade Vinyl Silk, Wickes ‘Colour at Home’ Bathroom, Wickes Trade Eggshell were purchased from Wickes, UK. Homebase gloss was purchased from Homebase, UK. Impega white A4 (210 x 297 mm) paper (093-057-621) was purchased from Impega (now Lyreco), France. 12 mm spectro tabs (G3358) and 0.5” aluminium pin stubs 6 mm lengths (G301F) were purchased from Agar Scientific, UK. Ninhydrin ACS reagent (CAS-485-47-2), HPLC grade acetic acid (CAS-64-19-7), HPLC grade ethanol (CAS-64-17-5) and HPLC grade ethyl acetate (CAS-141-78-6) were purchased from Fisher Scientific, UK. 1-methoxynonaffliuorobutane (HFE7100) was purchased from 3M Novec, USA. Magneta flake powder (96567) was purchased from Crime Scene Investigation equipment, UK. Black magnetic granular powder (TFP0105) was purchased from Tetra Scenes of Crime Ltd, UK. Squirrel hair brush (92-15), Magnetic wand (PW/259) and a linen glass were purchased from WA Products, UK.

2.2. Methods

2.2.1. Preparation of samples for paint type study

Simulated walls were prepared by initially cutting sheets of Knauf plasterboard (1200 x 900 mm) into 72 smaller boards (200 x 300 mm). For each paint type (Table 1), 18 boards were painted with the respective paint using a medium pile mini roller. Each board was coated with 3 layers of paint, with each layer drying for 24 hours before the next layer was applied.

|  |  |
| --- | --- |
| **Paint Type** | **Paint Brand (all white)** |
| Matt | Wickes Trade Flat Matt |
| Silk | Wickes Trade Vinyl Silk |
| Bathroom | Wickes ‘Colour at Home’ Bathroom |
| Eggshell | Wickes Trade Eggshell |

Table 1: The four paint types used in the paint type study

2.2.2. Deposition and development of fingermarks for paint type study

After 1 week, each of the 72 boards was divided into 30 sections and 30 donors each deposited one natural fingermark onto a specific section of each board using the fingers and thumbs of both hands. Donors were not given any pre-donation instructions to ensure the donated fingermark were entirely natural. After the first ten fingermarks were deposited, the hands were rubbed together. This process was repeated every 10 fingermark depositions until donors had deposited fingermarks on all 72 boards. Each donor started the deposition process on a different board to ensure a range of residue levels per board. All of the fingermarks deposited on the 72 boards were aged in general room conditions. For each paint type, the fingermarks deposited on the 18 boards were aged for 1 day (n=6), 1 week (n=6) or 1 month (n=6). After the designated ageing period, each board was developed by one of the three development methods (magnetic granular powder, magneta flake powder and ninhydrin).

2.2.3. Magnetic granular powder and magneta flake powder

Black magnetic granular powder and magneta flake powder were applied to different sets of fingermarks deposited on the substrates tested (as described in section 2.2.2) using a magnetic wand.

2.2.4. Ninhydrin

25 g of ninhydrin was dissolved in 25 mL of acetic acid, 225 mL of ethanol and 10 mL of ethyl acetate. 52 mL of this solution was then combined with 1 litre of HFE7100. The final working solution was stored at room temperature. The ninhydrin solution was applied to fingermarks deposited on each of the substrates tested using a squirrel hair brush in order to control the application. Treated fingermarks were developed under standard room conditions (approximately 180C and 45% RH) in order to simulate scene conditions. Fingermarks were examined over a 14 day period using the grading system presented in Table 2 to ensure the best marks were recorded.

2.2.5. Grading system

All of the boards were photographed using a Nikon D90 camera. All of the developed fingermarks were individually viewed using a magnifying linen glass and graded using an adapted version of the Home Office grading scale (Table 2) as described in [18, 19].

|  |  |  |
| --- | --- | --- |
| **Grade** | **Description** | **Likelihood of identification** |
| 0 | Nothing visible | None |
| 1 | Partial fingermark visible but < 1/3 ridge detail present | None |
| 2 | 1/3 - 2/3 of the fingermark visible with ridge detail | Limited |
| 3 | >2/3 of the fingermark visible with ridge detail but not a perfect mark | Moderately strong |
| 4 | Full fingermark with ridge detail | Very strong |

Table 2: Fingermark grading system (adapted from [18 - 20]).

2.2.6. Statistical analysis

Statistical analysis (Kruskal-Wallis test) was performed on the collated fingermark grades using IBM SPSS Statistics version 24.

2.2.7. Scanning electron microscopy and scanning electron microscopy energy dispersive x-ray analysis of paint samples

Each of the four paints (noted in Table 1), as well as gloss paint, were applied to separate sheets of Impega A4 paper using a medium pile mini roller. Each piece of paper was coated with a total of 3 layers of paint, with each layer drying for 24 hours before the next layer was applied.

A 10 x 10 mm section of paint was removed from each of the painted papers and attached to the SEM pin stubs using spectro tabs. Each sample was gold coated to a thickness of 5 nm using a Quorum Q150R S Rotatory Pumped Coater (Quorum Technologies). Each paint sample was analysed using a Carl Zeiss EVO LS15 Scanning Electron Microscopy (SEM) instrument equipped with a X-Max 80mm2 Energy Dispersive X-ray (EDX) detector (Oxford Instruments, UK). Images were acquired using an accelerating voltage of 15 KV, a working distance of 8 mm and an I probe of 250 pA. Images were acquired of each paint sample at 5000x and 25000x magnifications.

3.0. Results and discussion

The aim of this research was to determine whether the development of latent fingermarks on painted walls using the three most commonly used techniques previously highlighted by practitioners (magnetic granular powder, magneta flake powder and ninhydrin) [13] was affected by the type of paint applied to the walls. The developed fingermarks were graded according to Table 2 and the data was collated as shown in Table 3.

|  |  |  |
| --- | --- | --- |
| **Paint type**  **(n=540)** | **Number of fingermarks developed**  **(grade 1 to 4)** | **Number of quality fingermarks developed (grade 3 or 4)** |
| Matt | 88 (16.3%) | 15 (2.7%) |
| Silk | 280 (51.9%) | 47 (8.7%) |
| Bathroom | 267 (49.4%) | 61 (11.3%) |
| Eggshell | 305 (56.5%) | 85 (15.7%) |

Table 3: Total number of fingermarks developed according to paint type (matt, silk, bathroom, eggshell) (N=2160)

As seen in Table 3, only 88 of the 540 fingermarks deposited were developed on the matt painted substrate (16.3%). In addition, the number of good quality fingermarks developed (grades 3 and 4) was only 15 out of the 540 fingermarks deposited (2.7%), which is concerning as matt paint is the most frequently purchased paint in the UK [11].

This was followed by bathroom paint, with 267 of the 540 fingermarks deposited being developed (49.4%) with 61 out of the 540 fingermarks deposited being grade 3 and 4 (11.3%).

Silk paint had 280 of the 540 fingermarks deposited being developed (51.9%) with 47 out of the 540 fingermarks deposited being grade 3 and 4 (8.7%).

Eggshell paint gave the best results, with 305 of the 540 fingermarks deposited being developed (56.5%). In addition, the number of grade 3 and 4 fingermarks developed was 85 out of the 540 fingermarks deposited (15.7%).

The overall results were analysed using the Kruskal-Wallis test which returned a *p* value of <0.05, showing that the difference between the paint types was significant at 95% confidence level. Therefore highlighting the fact that the type of paint applied to walls should be considered by practitioners when developing fingermark recovery strategies.

3.1. The effectiveness of the development processes on each paint type

The relationship between the porosity of paint and the effectiveness of development techniques is well documented and will affect the quantity and quality of fingermarks recovered [1, 15, 16]. Out of the three development techniques tested, magnetic granular powder outperformed both magneta flake powder and ninhydrin on all 4 paint types with respect to the number of fingermarks developed (Table 4) and the mean grade obtained (Figure 1).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Paint type** | **Development process** | | | **Total** |
| **Magneta Flake** | **Magnetic Granular** | **Ninhydrin** |
| **Matt** | 0 | 60 | 28 | 88 |
| **Silk** | 32 | 142 | 106 | 280 |
| **Bathroom** | 63 | 168 | 36 | 267 |
| **Eggshell** | 130 | 171 | 4 | 305 |
| **Total** | 225 | 541 | 174 | 940 |

Table 4: Total number of marks developed (grades 1 - 4) according to paint type (matt, silk, bathroom and eggshell) and development process (magneta flake powder, black magnetic granular powder and ninhydrin)

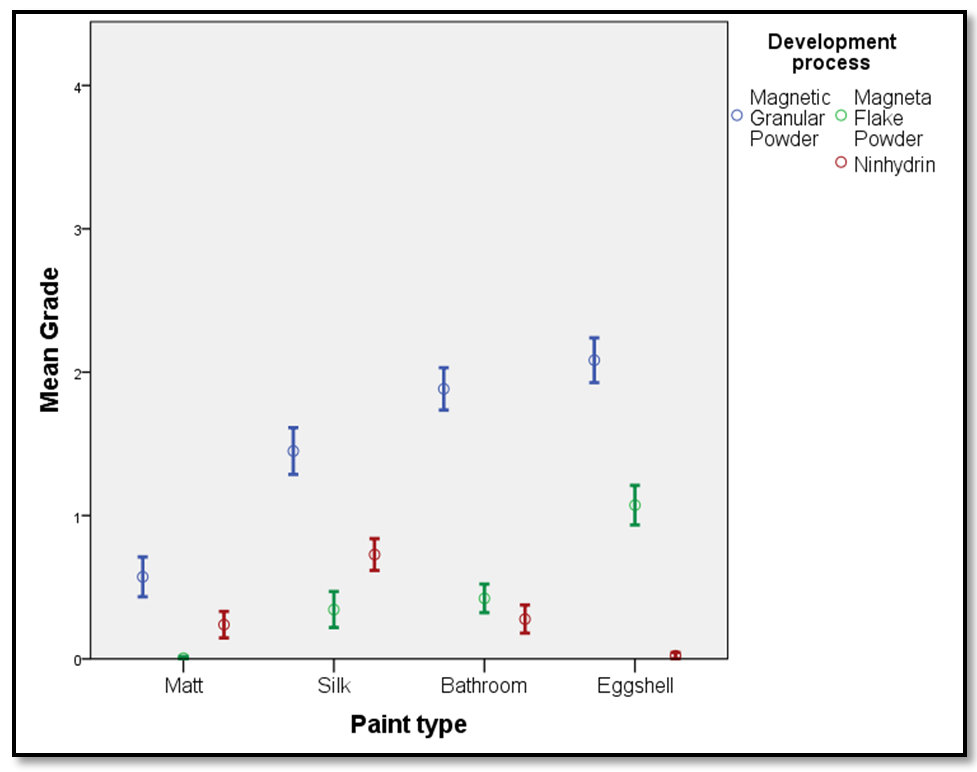


Figure 1: Chart comparing effect of development process used (magnetic granular, magneta flake and ninhydrin) on paint type (matt, silk, bathroom and eggshell) applied to plain plasterboard.

For the non-matt paints (silk, eggshell and bathroom paints), powders were expected to be the most effective development process, as these paints are considered to give a semi-porous or non-porous finish; and current guidelines recommend using black magnetic powders as part of a sequential workflow on these surfaces [1]. Previous research showed that magneta flake powder was the most frequently used development process used by Crime Scene Examiners (CSEs) and Crime Scene Managers (CSMs) when developing latent fingermarks on painted walls [13]. However, the results presented in this study highlight the disparity between the effectiveness of the two powders for enhancement of marks on painted walls. Therefore, practitioners should only use black magnetic granular powder on painted walls and not magneta flake powder. Furthermore, it is prudent to focus application of the powder to specific areas of painted walls due to the practical difficulty of applying powder to a vertical wall using a magnetic wand.

Magnetic granular powder developed the most fingermarks on matt paint, which contradicts current guidelines as matt paint is considered a porous surface and magnetic granular powder is not recommended for developing fingermarks on matt painted walls at present [1]. Ninhydrin however, is currently recommended as part of a sequential workflow for development of fingermarks on matt painted walls [1], and it was expected to give the best results in terms of the quantity and quality of the marks developed. However, the results presented in Table 4 and Figure 1 show that overall ninhydrin developed less fingermarks than magnetic granular powder on all four paint types and the fingermarks obtained were of a lower quality. Therefore, these results show that the Fingermark Visualisation Manual needs updating.

The low number of marks developed overall using ninhydrin could be due to environmental conditions. If the substrate is too cold or dry, the amino acids present in the fingermark residue do not sufficiently react with the ninhydrin reagent resulting in partially developed fingermarks [21]. This is often circumvented by using a ninhydrin oven to regulate temperature and humidity [1]. However, a ninhydrin oven was not used in this research in order to simulate scene conditions. In addition, the poor performance of ninhydrin on matt paint could be due to the lack of cellulose within the paint, which is known to affect the development of latent marks [15, 22, 23]. Fingermarks that are absorbed into cellulose materials are considered more stable, and therefore marks can be developed more effectively with chemical reagents such as ninhydrin [24 - 26].

3.2. The effectiveness of the development processes on each paint type over time

Table 5 shows the number of fingermarks developed on each paint type by each development process at the three times investigated and Figure 2 shows the mean grade obtained.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Paint Type** | **Development process and ageing period** | | | | | | | | |
| **Magneta Flake** | | | **Magnetic Granular** | | | **Ninhydrin** | | |
| 1  Day | 1 Week | 1 Month | 1  Day | 1 Week | 1 Month | 1  Day | 1 Week | 1 Month |
| **Matt** | 0 | 0 | 0 | 5 | 20 | 35 | 20 | 8 | 0 |
| **Silk** | 24 | 4 | 4 | 52 | 38 | 52 | 38 | 35 | 33 |
| **Bathroom** | 24 | 19 | 20 | 53 | 58 | 57 | 16 | 10 | 10 |
| **Eggshell** | 51 | 44 | 35 | 57 | 56 | 58 | 0 | 4 | 0 |

Table 5: Number of fingermarks developed on each paint type (matt, silk, bathroom, and eggshell) by three development processes (magneta flake powder, black magnetic granular powder and ninhydrin) over time.

Figure 2: Chart comparing effectiveness of paint type (bathroom, eggshell, matt and silk) and development process (magneta flake powder, black magnetic granular powder and ninhydrin) over time.

For matt paint, magneta flake powder did not develop any fingermarks at any of the time points investigated (Table 5). Ninhydrin developed more fingermarks that were of a higher quality than magnetic granular powder on matt paint after fingermarks were aged for 1 day, which was expected as ninhydrin is a porous process. Conversely, magnetic granular powder developed more fingermarks than ninhydrin on matt paint after fingermarks were aged for 1 week. Unexpectedly, the greatest disparity was observed with fingermarks aged for 1 month, where magnetic granular powder was the only enhancement process to develop any fingermarks on matt paint.

For the three non-matt paints (bathroom, silk and eggshell), magnetic granular powder developed more fingermarks that were of a higher quality than both magneta flake powder and ninhydrin at all three time points as highlighted in Table 5 and Figure 2.

For bathroom paint, magneta flake powder and ninhydrin saw a decrease in the quantity and the quality of the fingermarks developed after 1 weeks ageing. After one month, the number of fingermarks developed with ninhydrin remained constant, however there was a slight decrease in the mean grade of the marks obtained. For magneta flake powder, there was a slight increase in the quantity of fingermarks developed and for magnetic granular powder there was a slight decrease after one month’s ageing. However, the quality of the fingermarks obtained by magnetic granular powder increased (Figure 2).

For silk paint, all three development techniques saw a decrease in the quantity and the quality of the fingermarks developed after 1 weeks ageing. This trend continued after 1 months ageing for fingermarks developed ninhydrin. Magneta flake powder developed the same number of fingermarks after ageing for one month, although there was a slight decrease in the quality of the marks obtained. For magnetic granular powder, there was an increase in the quantity and quality of fingermarks developed after ageing for 1 month (Table 5 and Figure 2).

For eggshell paint, ninhydrin failed to develop any marks after ageing for 1 day and 1 month. However, there were four fingermarks visualised after developing with ninhydrin at 1 week. Magneta flake powder saw a decrease in the quantity and the quality of the fingermarks developed over the three time points investigated. The number of fingermarks developed with magnetic granular powder remained relatively constant over the three time points. However, the quality of the marks obtained increased after one month’s ageing (Table 5 and Figure 2).

From the results presented, it is evident that magnetic granular powder out-performed both magneta flake powder and ninhydrin on fingermarks aged for 1 week and 1 month. This result was unexpected as the aqueous constituents present in latent fingermarks are known to evaporate first, which can inadvertently affect the efficacy of powders on aged fingermarks on some substrates [1, 14].

The efficacy of black magnetic granular powder on matt, silk, bathroom and eggshell paint highlights the need to update current guidelines. At present black magnetic granular powder is not recommended for use on matt painted walls, despite it being significantly more effective than ninhydrin, which is currently recommended.

3.3. Scanning electron microscopy (SEM) of different paint types

In order to establish why more fingermarks were developed on some paint types than on others, each of the four paint types was examined using scanning electron microscopy (SEM). Gloss paint was also examined for comparative purposes as gloss paints typically have PVCs below 20%, providing a smooth, homogenous finish due to the low PVC [6].

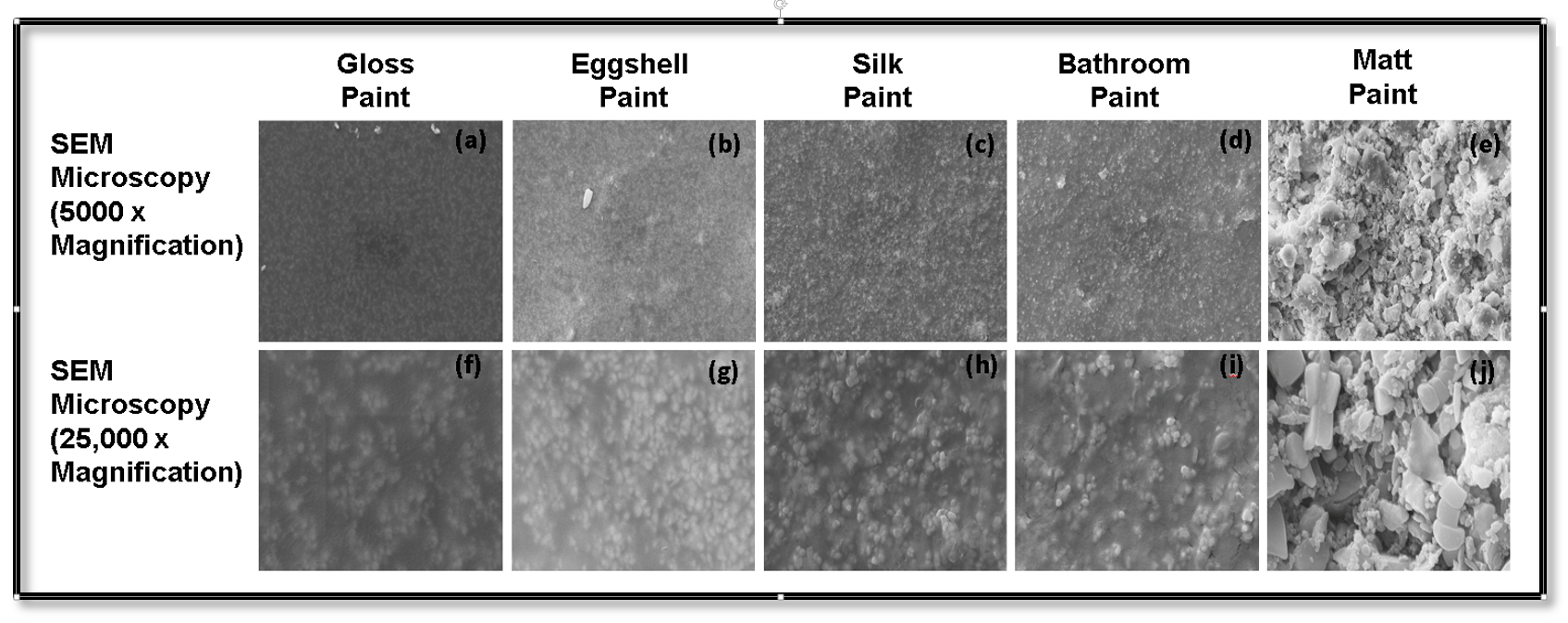


Figure 3: SEM images of gloss, eggshell, silk, bathroom and matt paint types at both 5000 x and 25,000 x magnification.

Figure 3 shows the SEM images obtained on each of the paint types tested at 5000 x and 25,000 x magnification. In the SEM images of gloss paint (Figures 3a and 3f) the pigment particles are contained within the binder layer with no protrusion of particles through the surface. The particles are of a uniform size, with no overlap between adjacent particles. This ensures optimum specular reflection of light, resulting in a shiny gloss finish [27].

From the 5000 x SEM images, it is clear that the pigment particles in bathroom, silk and eggshell paint are visible within the binder layer. The topography of the eggshell paint (Figure 3b) looks similar to the gloss paint (Figure 3a). However, for the silk and bathroom paints (Figures 3c and 3d), the surface looks more irregular, with some particles protruding through the surface. Nonetheless, the particles in all 4 paint types look homogenously dispersed throughout the samples (Figure 3a-3d). However, at 25000 x magnification, the pigments in the bathroom and silk paints (Figure 3h and 3i), extend above the binder layer; whereas in the eggshell and gloss paints the pigments are constrained (Figure 3f and 3g).

In contrast to the other paint types, the topography of the matt painted substrate at 5000 x and 25000 x magnification looks distinctly different (Figure 3e and 3j). The pigment particles are clearly protruding through the binder layer due to the high PVC of matt paints. The pigments also appear to be present in layers and are unevenly distributed throughout the paint sample resulting in an irregular, coarse, textured surface. This is in agreement with the findings of previous studies, who also reported the protrusion of pigment particles above the binder in high PVC paints, such as matt [28, 29].

The size and shape of the pigment particles present in matt paint also look markedly different from the particles present in the non-matt paints as they look more irregular (Figures 3e and 3j). Conversely, the pigment particles present in the other four paint types (Figure 3a–3d and 3f-3i) look similar as the pigments all look a comparable size and shape.

According to Gueli and co-workers [30], pigment particles can be categorised into fine (diameter < 1 µm), medium (diameter between 1 – 10 µm) and course (diameter > 10 µm). Together with the refractive index of the binder and pigments, the size of the pigment has an effect on the hiding power of the paint [30].

In this study, the impact of particle size was investigated in order to determine whether the size of the pigments present contributed to the differences observed with regards to the number of fingermarks developed on each paint type.

For each paint type, measurements (length and width) were taken of 10 randomly selected particles present in the 25,000 x magnification SEM images and the results are presented in Table 6.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Paint Type** | **Mean Particle Length (μm) (± STD)** | **Range of Particle Lengths (μm)** | **Mean Particle Width (μm)**  **(±STD)** | **Range of Particle Widths (μm)** |
| **Matt** | 0.87 (± 0.61) | 0.21 – 2.09 | 0.78 (± 0.60) | 0.18 – 2.09 |
| **Silk** | 0.29 (± 0.05) | 0.22 – 0.37 | 0.28 (± 0.06) | 0.21 – 0.38 |
| **Bathroom** | 0.32 (± 0.09) | 0.18 – 0.45 | 0.32 (± 0.08) | 0.19 – 0.45 |
| **Eggshell** | 0.28 (± 0.05) | 0.21 – 0.36 | 0.28 (± 0.04) | 0.21 – 0.33 |
| **Gloss** | 0.28 (± 0.02) | 0.23 – 0.32 | 0.28 (± 0.04) | 0.22 – 0.34 |

Table 6: Analysis of mean particle sizes (± standard deviation) and range of particle sizes (N=10) of different paint types (matt, silk, bathroom, eggshell and gloss)

The mean particle size (length and width) in all paint types was less than 1 µm, classifying the particles as fine [30]. However, when considering the range of particle sizes observed in the SEM images of matt paint, some of the pigments present were larger than 1 µm, with the biggest being 2.09 µm, classifying some of the particles as medium according to [30]. This therefore has an overall effect on the topography of the paint finish and subsequently affects the quantity and quality of fingermarks developed and recovered on matt painted walls.

For bathroom, silk, eggshell and gloss paints, the range in size of the 10 pigment particles measured per paint type was consistent, with none of the pigments having a length or width greater than 1 µm. The measurements also show that the particles are spherical in shape and relatively uniform (Table 6).

For paints with a high sheen such as gloss and eggshell, a consistent small particle size is important (ideally < 0.5 µm) as larger particles decrease the lustre of the paint [31]. All the non-matt paints tested in this study had particle sizes below 0.5 µm, resulting in finishes that are smoother and more homogenous than matt painted surfaces.

The results of the particle size study were subjected to the Kruskal-Wallis statistical test in order to determine whether the results were statistically significant. The results showed that there was a significant difference between all of the five paint types tested as a p value of <0.05 was obtained at a 95% confidence level. However, when the Kruskal-Wallis test was performed on the four non-matt paints, a p value of 0.85 was obtained. This shows that the particle sizes present in these paints were not significantly different from each other at a 95% confidence level. The statistical analysis highlights that matt paint contains significantly different particle sizes to non-matt paints, producing a rough and textured surface when dry. This will affect the deposition and subsequent development of latent fingermarks, and therefore practitioners need to consider this issue when devising fingermark recovery strategies.

3.4. Scanning electron microscopy energy dispersive x-ray (SEM-EDX) analysis

Each of the five paint types tested were analysed by SEM-EDX in order to ascertain the elemental composition of the paints. The results of the analysis are shown in Table 7.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Average weight %** | | | | | | | | |
| **Paint** | **C** | **O** | **Na** | **Mg** | **Al** | **Si** | **Ca** | **Ti** | **Fe** |
| **Matt** | 22.35 | 38.63 | 0.32 | 0.39 | - | 0.27 | 23.46 | 6.29 | 8.29 |
| **Silk** | 37.52 | 32.80 | 0.39 | - | 1.72 | 1.99 | 0.35 | 20.00 | 5.22 |
| **Bathroom** | 34.67 | 31.96 | - | - | 3.38 | 4.53 | - | 25.45 | - |
| **Eggshell** | 34.56 | 33.31 | - | - | 0.86 | 1.02 | 1.37 | 28.88 | - |
| **Gloss** | 44.82 | 27.85 | - | - | 0.66 | 0.52 | 0.32 | 23.01 | 2.82 |

Table 7: Elemental composition of paint types (N=3) (C=Carbon, O=Oxygen, Na=Sodium, Mg=Magnesium, Al=Aluminium, Si=Silicon, Ca=Calcium, Ti=Titanium, Fe=Iron) (- not detected)

All the paint types tested contained both carbon and oxygen in varying amounts. Matt paint contained the lowest percentage of carbon (22.35%) and the highest percentage of oxygen (38.63%). Matt paint was the only paint to contain magnesium (0.39%) and the only paint type not to contain aluminium. Matt and silk paint were the only paints to include sodium at 0.32% and 0.39% respectively.

All of the paints tested contained titanium as expected, as titanium dioxide is one of the most commonly used pigments in white paint due to its high refractive index, which increases its opacity [6]. However, the percentage of titanium present in matt paint (6.29%) was significantly lower than the four non-matt paints, (20.00 - 28.88%). This is due to the fact that paint manufacturers often supplement matt paints with less expensive extenders and additives such as calcium carbonate, which accounts for the high amount of calcium present in matt paints (23.46%) compared to the other four paint types (0 - 1.37%). The addition of fillers such as calcium carbonate to matt paints increases the PVC of the paint, thereby increasing the hiding power and surface roughness of the paint [6]. This offers an explanation for why the pigment particles visualised in the SEM images of matt paint look larger and more irregular than the pigments visible in the SEM images of the four non-matt paints, which contain higher proportions of titanium dioxide.

Although the SEM-EDX results do provide some explanation for why matt paint looks distinctly different from the non-matt paints tested, the evidence denotes that the elemental composition of the paints should not have any significant impact on the deposition and development of fingermarks. As shown in the SEM images, it is the overall topography of the painted surface that is likely to be the most significant contributing factor to the successful development of fingermarks on painted walls.

4.0. Conclusion

It is evident that there is a significant difference in the topography of matt and non-matt painted walls. The SEM results show that the particles contained within matt paint vary significantly in size and shape, compared to non-matt paints which contain small particles of uniform shape and size. The SEM-EDX results also show elemental differences between matt and non-matt paints, highlighting the use of extenders and fillers in matt paint, accounting for the variations in particle size and shape. Nevertheless, the evidence indicates that the surface texture of the painted walls is likely to have the greatest effect on the development of latent fingermarks.

At present, ninhydrin is one of the techniques recommended in the UK fingermark visualisation guidelines to develop latent fingermarks on matt painted walls. However, the results of this study show that this process is no longer effective on matt paint. Magneta flake powder, which is the most common process used by practitioners *‘in situ’*, was also ineffective and should not be used on painted walls at crime scenes. The most effective development process tested on all paint types was black magnetic granular powder, which is currently only recommended for use on silk painted walls.

The research conducted in this study complies with Technology Readiness Level (TRL) 5 in accordance with the IFRG and Centre for Applied Science and Technology (CAST) guidelines. The results presented show that the fingermark visualisation guidelines should be updated to include black magnetic granular powder for use on matt painted walls, in addition to other non-matt paints, such as bathroom and eggshell. Future work will involve investigating different brands of the four paint types tested in this study in order to determine whether the brand of paint has a significant impact on the development of latent fingermarks. In addition, subsequent work will focus on ascertaining whether any of the other available techniques are more effective for developing quality fingermarks on painted walls.

References

[1] Bandey, H.L., Bleay, S.M., Bowman, V.J., Downham, R.P., Sears, V.G., 2014. *Fingermark visualisation manual*. St Albans: Home Office - Centre for Applied Science and Technology.

[2] Hamilton, I., 2013 Fingerprints. In: Houck, M.M., (ed), 2016, *Forensic fingerprints*, London: Academic Press. Ch 1.

[3] Ferguson, L., Bradshaw, R., Wolstenholme, R., Clench, M., and Francese, S., 2011, Two-step matrix application for the enhancement and imaging of latent fingermarks. *Analytical Chemistry,* 83*, 5585 – 5591.*

[4] Francese, S., Bradshaw, R., Ferguson, L.S., Wolstenholme, R., Clench, M.R. and Bleay, S. 2013. Beyond the ridge pattern: Multi-informative analysis of latent fingermarks by MALDI mass spectrometry. *Analyst,* 138(15), 4215-4228

[5] Bentley, J., 2001, Composition, manufacture and use of paint. In: Caddy, B., (ed) 2001, *Forensic analysis of glass and paint – analysis and interpretation*. London: Taylor and Francis. Ch 7.

[6] Tiarks, F., Frechen, T., Kirsch, S., Leuninger, J., Melan, M., Pfau, A., Richter, F., Schuler, B., and Zhao, C.L., 2002, Formulation effects on the distribution of pigment particles in paint. *Progress in Organic Coatings, 48, 140-152.*

[7] Resene, 2003, *Volume Solids, PVC and Hiding Power* [online]. Available at http://www.resene.co.nz/archspec/cpd\_earn\_points/pdfs/CPD\_volumesolidspvchiding\_oct2003.pdf (accessed on 17/06/15).

[8] Farrakhpay, S., Gayle, M. E. and Fornasiero, D. 2006. Titania Pigment Particles Dispersion in Water Based Paint Films. *JCT Research*, 3 (4), 275 - 283

[9] Paint Quality Institute, 2004. *The ingredients of paint and their impact on paint properties* [online] Available at http://www.industrialpaintquality.com/pdfs/ ingredientsofpaint.pdf (accessed on 17/06/15).

[10] Learner, T.J.S., 2004. *Analysis of modern paints*. Los Angeles: Getty Publications.

[11] Wickes, 2015, *Sales data for 2013-14* (Personal Communication 24th February 2015)

[12] Strauch, D., 2001, Surface Coatings, In: Tegethoff, F.W., 2001, *Calcium carbonate: from the cretaceous period into the 21st century*. Basel, Birkhauser Verlag. Ch. 3.

[13] Dawkins, J. Gautam, L. Bandey, H. and Ferguson, L. 2019. *The problem of developing latent fingermarks on painted walls – a practitioner’s viewpoint* [online] CSEye, August 2019. Available at <https://www.csofs.org/CSEye>

[14] Bowman, V. (ed.) (2005).*Home office fingerprint development handbook.* 2nd ed., Derbyshire, UK, Home Office, London, UK.

[15] Bleay, S.M., Sears, V.G., Downham, R., Bandey, H.L., Gibson, A.P., Bowman, V.J., Fitzgerald, L., Ciuksza, T., Ramadani, J., Selway, C., 2017, *Fingerprint source book – version 2*. St Albans: Home Office - Centre for Applied Science and Technology.

[16] Ramotowski, R.S., 2013a, Amino Acid Reagents. In: Ramotowski, R.S., (ed), 2013, *Lee and Gaensslen’s Advances in Fingerprint Technology*. 3rd ed. Boca Raton: CRC Press. Ch. 2.

[17] Dawkins, J., 2019, (Unpublished results). The Development of latent fingermarks on painted walls. PhD Thesis

[18] Sears, V.G., Bleay, S.M., Bandey, H.L., and Bowman, V.J., 2012, A methodology for fingermark research. *Science and Justice 52, 145-160.*

[19] International Fingerprint Research Group (IFRG), 2014, *Guidelines for the assessment of fingermark detection techniques*[online]. Available at https://ips-labs.unil.ch/ifrg/wp-content/uploads/2014/06/IFRG-Research-Guidelines-v1-Jan-2014.pdf (accessed on 21/11/19).

[20] Bandey, H. L. and Gibson A. P. 2006, The Powders Process, Study 2. Evaluation of Fingerprint Powders on Smooth Surfaces. Home Office Science and Development Branch Fingerprint Development and Imaging Newsletter. Publication No 08/06.

[21] Ramminger, U., Nickel, U., and Geide, B., 2001, Enhancement of insufficient dye-formation in the ninhydrin reaction by a suitable post treatment process. *Journal of Forensic Sciences, 46 (2), 288-293.*[*See comment in PubMed Commons below*](http://www.ncbi.nlm.nih.gov/pubmed/11305430#comments)

[22] Spindler, X., Shimmon, R., Roux, C., Lennard, C., 2011, The effect of zinc chloride, humidity and the substrate on the reaction of 1,2-Indanedione-zinc with amino acids in latent fingermark secretions. *Forensic Science International, 212, 150-157.*

[23] Nicolasora, N., Downham, R., Dyer, R.M., Hussey, L., Luscombe, A., Sears, V., 2018, A validation study of the 1, 2-indandione reagent for operational use in the UK: Part 2 - Optimization of processing conditions. [*Forensic Science International*](https://www.ncbi.nlm.nih.gov/pubmed/29793193)*, 288, 266-277.*

[24] Champod, C., Lennard, C., Margot, P., Stoilovic, M., 2004, *Fingerprints and other ridge skin impressions.* Boca Raton: CRC Press.

[25] Hansen, D.B. and Joullié, M.M., 2005, The development of novel ninhydrin analogues*. Chemical Society Reviews, 34 (5), 408-17.*

[26] Daluz, H.M., 2015, *Fundamentals of fingerprint analysis*. Boca Raton: CRC Press.

[27] Braun, J.H., 1995, White pigments. In: Koleske, J.V. (ed), 1995, *Paint and coating testing manual. 14th ed.*Philadelphia: American Society for Testing & Materials. Ch 19.

[28] Ryland, S.G., and Suzuki, E.M., 2012, Analysis of paint evidence. In: Kobilinsky, L., (ed), 2012, *Forensic chemistry handbook*. Hoboken, John Wiley and Sons. Ch. 5.

[29] Bender, L., 2013, Architectural paint (Volume 2): In Siegel, J.A., and Saukko, P.J., (eds), 2013, *Encyclopaedia of forensic sciences.* 2nd ed. London: Elsevier Ltd.

[30] Gueli, A.M., Bonfiglio, G., Pasquale, S., Troja, S.O., 2017, Effect of particle size on pigments colour. *Color Research and Application, 42 (2), 236–243.*

[31] Braun, J.H. and Fields, D.P., 1994 Effects of pigment size. *The Journal of Coatings Technology, 66 (828), 93-98.*