Application of fingermark enhancement techniques on Clydesdale Bank and Royal Bank of Scotland £10 and £5 polymer banknotes in a pseudo-operational trial

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Abstract

The aim of this study was to apply the two most effective enhancement sequences for latent fingermarks on Clydesdale Bank and Royal Bank of Scotland polymer banknotes (£10 and £5), as determined in a previous study, to a pseudo-operational trial. The two enhancement sequences established as being the most effective for these types of notes were superglue fuming using PolycyanoUV followed by black magnetic powder, and black powder suspension. Both enhancement sequences included a fluorescence examination before enhancement, and after-treatment using white light, followed by Infrared light. The study conducted by Joannidis et al. was carried out in a controlled laboratory environment where all variables, i.e., the position and age of each fingermark, were known and controlled. However, these conditions do not accurately mirror those of polymer notes seized as part of a criminal investigation. The two most effective enhancement sequences were therefore tested in a pseudo-operational trial to determine whether they would be as effective when applied to banknotes that mimicked those seized in an investigation. To mimic these conditions 102 banknotes from each bank (each containing a mixture of circulated and uncirculated banknotes) were left out in the laboratory for four weeks for the laboratory staff to randomly handle. The results from this pseudo operational trial study confirmed the outcomes of the previous study. Superglue fuming (using PolyCyano UV) followed by black magnetic powder was found to be effective in enhancing fingermarks on both Clydesdale Bank and Royal Bank of Scotland polymer banknotes (£10 and £5). This was closely followed in effectiveness by powder suspension which, although it gave slightly poorer results than superglue followed by black magnetic powder, was also

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effective at enhancing ridge detail. This study also confirmed that Infrared light (730-800 nm), with the additional of a 815nm filter for notes processed using superglue and black magnetic powder - aided in the reduction of background pattern interference when photographing any ridge detail.

Introduction

In forensic science, fingermarks are a valuable source of identification [1]. A fingermark recovered from an object used in a criminal act can help identify any person(s) involved [2]. One common object involved in serious and organised crime is banknotes. Polymer banknotes – made from bi-axially oriented polypropene [3,4] – were first introduced into Australia in 1988 and are now used in over 30 countries [5]. Clydesdale Bank and the Royal Bank of Scotland released a £5 polymer banknote in 2016, followed by a £10 polymer banknote in 2017 [3,6]. This change in banknote material from the previous cotton banknote was implemented in order to increase counterfeit resilience and durability [3,4].

In 2018, researchers at the University of Strathclyde – in collaboration with the Scottish Police Authority – carried out a study to determine the most effective process for enhancing latent fingermarks on Clydesdale Bank and Royal Bank of Scotland £10 and £5 polymer banknotes [7]. This study tested five enhancement sequences, which were applied to 288 banknotes in total. These sequences, along with the individual chemical treatments were chosen during a preliminary study, as detailed in Joannidis et al. This study was conducted on the basis of an operational requirement therefore, all treatments were chosen based on their availability to all criminal justice partners within the United Kingdom (UK). Although Vacuum metal deposition (VMD) has been reported in being successful at recovering fingermarks on polymer notes produced by English, Canadian and Australian banks, this process is not available to all UK forces and the time required to process large monetary cases makes it an inefficient process for use in an operational setting. Three donors were selected for the study – one good, one medium, and one poor – and the fingermarks separated into four age categories: 7, 14, 21, and 28 days. The authors also tested a variety of light sources for each enhancement sequence to determine which source gave the best visibility of any ridge detail enhanced and simultaneously reduced background pattern interference. The best light source for the two most effective sequences were Infrared (IR) light (730-800 nm), with the addition of an 815 nm long-pass filter for sequence 1 (see below). The research concluded that the following two enhancement sequences were the most effective for enhancing and visualising latent marks on Clydesdale Bank and Royal Bank of Scotland polymer banknotes:

1. visual examination > superglue fuming (using PolyCyanoUV) > black magnetic powder > visual examination > IR fluorescence examination
2. visual examination > black iron oxide powder suspension > visualisation examination > IR fluorescence examination

Fingerprint research studies are carried out under controlled conditions as set out in guidelines for the assessment of fingermark detection techniques [8]. In the study carried out by Joannidis et al [7], all bank notes used were uncirculated and the environmental conditions in which they were tested were kept consistent throughout the study. The donors were selected, and the placement and age of each fingermark was known and controlled. Although this study was successful under those chosen conditions, it is unknown how effective the sequences would be when applied to banknotes seized in a criminal investigation, where the placement and condition of fingermarks – if any – are unknown. The aim of the current study was to test the two best sequences from the research carried out by Joannidis et al. [7] on a pseudo operational trial that better reflects the uncontrolled conditions encountered in real casework. The notes used were a mixture of circulated and uncirculated £10 and £5 notes obtained directly from Clydesdale Bank and the Royal Bank of Scotland. PolyCyano UV followed by black magnetic powder and black iron oxide powder suspension were the enhancement treatments used in this study, in order to validate the outcomes of the previous study. All banknotes were returned to the relevant bank after this trial was conducted. Permissions were not granted to destroy the banknotes therefore, split fingermarks were not used. Bank of Scotland polymer notes were not available for this study.

Methodology

Clydesdale Bank and Royal Bank of Scotland supplied a mixture of circulated and uncirculated £10 and £5 polymer banknotes for this study. A total of 102 notes were used from each bank (Table 1). All uncirculated notes were marked with a small cross (×) and the circulated notes were marked with a small dot (·). The environmental conditions that the circulated notes had been subjected to before entering the laboratory were unknown, as were the placement of fingermarks, if any, as would be the case in operational work.

Table 1. Total number of each denomination of Clydesdale Bank and Royal Bank of Scotland notes examined

Denomination	Clydesdale bank	Royal Bank of Scotland

£10	48	50
£5	54	52
Total	102	102

The mixture of circulated (165) and uncirculated (39) notes was left out in the laboratory for four weeks for the laboratory staff to randomly handle. The number of individuals who handled the notes and the frequency with which they were handled was not known or recorded, to mimic operational work. Notes were available to be handled every weekday across these four weeks. The notes were then separated into two bundles, each containing the same number of £10 and £5 notes from each bank (see Tables 2 and 3) and as close as possible to equal numbers of circulated and uncirculated notes, to be processed using the two enhancement sequences.

To keep working conditions realistic, the notes were processed within a normal working day (8am – 4pm) and appropriate breaks were taken (one 15-minute morning break and a 30-minute lunch break). One whole day was used for each enhancement sequence to determine how many notes could be processed within one day and how successful this process was in the enhancement of any latent fingermarks. All bank notes were handled using latex gloves and the surface area being handled was kept as small as possible to prevent contamination or disruption of any marks present.

Enhancement sequences were carried out following the methods described in Joannidis et al. [7]. A visual examination using white light was carried out prior to any chemical enhancement to check for visible fingermarks. The chemical enhancement methods following this summarised below:

Sequence 1: Superglue fuming > black magnetic powder

Superglue (cyanoacrylate) fuming was carried out using PolyCyano UV powder and distilled water, both of which were placed into a Foster + Freeman MVC3000 fuming chamber. The notes were suspended in the chamber using clips (Q-connect, Gent, Belgium) (Figure 1), ensuring there was a gap between each bank note. The temperature was set to 230 degrees Celsius, as this is the optimum temperature for PolyCyano UV, and the glueing cycle was set to run for 20 minutes [9]. Overall, the process took approximately 1 hour.

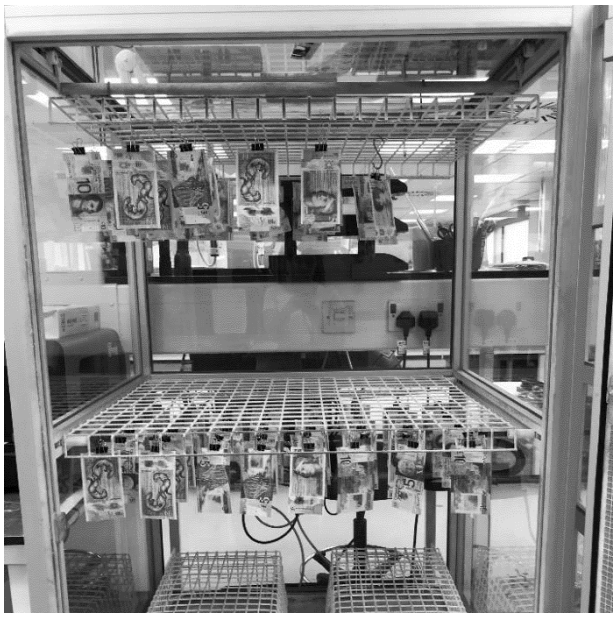

Figure 1. Photograph showing how the banknotes treated using sequence 1 were suspended in the fuming chamber.

The cyanoacrylate vapours adhered to any fingermarks present, depositing a white coating. After the process was complete, the samples were removed from the chamber and the glue left to set for 30 minutes (as determined in preliminary testing) in a secure area. Black magnetic powder was then applied to both sides of each bank note, using a magnetic applicator. All bank notes were then examined visually under white light and ultraviolet light (UV) for any fingermarks or ridges. Although PolyCyanoUV is normally visualised under ultraviolet (UV) light, preliminary testing demonstrated that the addition of black magnetic powder provided better visualisation of fingermarks due to the ultraviolet security features within the banknotes. To maximise evidence recovery all notes were then photographed under Infrared light (730-800nm with 815nm filter (Foster + Freeman Anti-Glare Schott)). Photographs were taken using a Nikon D5 camera, with an AF-S VR Micro-Nikkor 105mm lens and all settings were adjusted using the Foster and Freeman DCS®5 imaging system.

Sequence 2: Black iron oxide powder suspension

The black powder suspension powder (50 g magnetic iron (II) oxide, WhitChem, grade: precipitated (synthetic), magnetic,particle size: 200 nm–1mm) was mixed with a pre-made detergent (500 ml ethyleneglycol (Fisher Scientific, grade: >99%), 150 ml Triton X-100 (FisherScientific, grade: laboratory) and 1350 ml distilled water), and applied to bank notes

over a sink using a soft brush. The solution was left on the bank notes for approximately 20-30 seconds and then washed off using tap water. The notes were then suspended using small clips, ensuring there was a gap between each bank note. The clips were hung onto a metal rack and left to dry in a secure area for 2-3 hours at room temperature. All notes were then examined visually under white light for any fingermarks or ridges. To maximise evidence recovery all notes were then photographed under Infrared light (Crime-lite 730800 nm, Foster + Freeman) . Photographs were taken using a Nikon D5 camera, with an AF-S VR Micro-Nikkor 105mm lens and all settings were adjusted using the Foster and Freeman DCS®5 imaging system.

Data collection

After a day of processing the bank notes using the enhancement sequences as described above, the following data was collected from each sample set: the total number of notes with no ridges, the total number of notes with ridges only but no fingermarks and the total number of notes with fingermarks. 'No ridges' meant that no detail was enhanced on the bank note at all. 'Ridges only' meant that there was visible ridge detail but not enough to give a fingermark score of 2 – where more than 1/3 – 2/3 of detail was present. 'Fingermarks' meant that a large portion of a full fingermark was present, which would be given a score above 2 – where more than 2/3 of detail was present [9]. Due to this scoring method being subjective, all scoring was carried out by the same trained enhancement expert. Within each of those categories the following data was also collected:

- number of uncirculated and circulated notes
- number of £10 and £5 notes
- number of Clydesdale Bank (CB) and Royal Bank of Scotland (RBS) notes

Results and Discussion

Both enhancement sequences were applied to a total of 102 notes, containing a mixture of circulated and uncirculated notes. After processing was completed, each bank note was examined for ridge detail. Each bank note was assigned into one of three categories: no ridges, ridges only, and fingermarks. Table 2 shows the number of notes for each of these categories, along with a breakdown of note types, for sequence 1 (PolycyanoUV followed

by black magnetic powder) and Table 3 shows the values for sequence 2 (black powder suspension).

Table 2. A breakdown of the bank note types processed using sequence 1 (PolyCyanoUV – black magnetic powder)

Number of banknotes							
	Total	**uncirculated**	**circulated**	**£10 CB**	**£5 CB**	**£10 RBS**	**£5 RBS**
No ridges	16	0	16	1	4	0	11
Ridges only	50	11	39	11	15	13	11
Fingermarks	36	8	28	12	8	12	4
Total	102	19	83	24	27	25	26

Table 3. A breakdown of the bank note types processed using sequence 2 (black powder suspension)

Number of banknotes							
	Total	**uncirculated**	**circulated**	**£10 CB**	**£5 CB**	**£10 RBS**	**£5 RBS**
No ridges	22	1	21	2	9	0	11
Ridges only	53	2	51	13	11	17	12
Fingermarks	27	17	10	9	7	8	3
Total	102	20	82	24	27	25	26

All ridge detail enhanced by both sequences was visible under white light, however the use of IR light did eradicate background interference and help with visualisation (Figure 2).

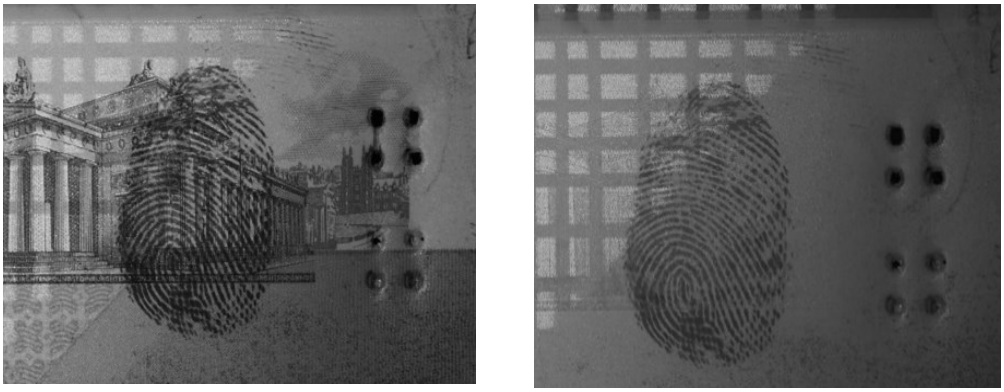

Figure 2. Photograph showing a fingermark enhanced using PolyCyanoUV and black magnetic powder, present on a polymer banknote, visualised under white light (left) and infrared light (700-830nm) (right)

Looking at the data overall, of the 204 bank notes tested in total, 166 (81%) contained either ridge detail or fingermarks, showing that the enhancement techniques are effective for recovering fingermark evidence on these bank notes. However, 38/39 (97%) of uncirculated notes contained either ridge detail or fingermarks, but only 128/165 (78%) of circulated bank notes contained either ridge detail or fingermarks. This suggests that the more complex nature of fingermark evidence on circulated bank notes has an impact on the ability to enhance this evidence. Comparing the proportion of bank notes containing ridge detail or fingermarks for the two enhancement sequences, results were very similar for uncirculated notes, with 19/19 (100%) for uncirculated bank notes enhanced using Sequence 1 and 19/20 (95%) for uncirculated bank notes enhanced using Sequence 2. However, on circulated notes, 67/83 (80%) bank notes enhanced using PolycyanoUV followed by black magnetic powder contained ridge detail or fingermarks, whereas this measure was only 61/82 (74%) for bank notes enhanced using black powder suspension. This result suggests that sequence 1 is more successful on circulated notes compared with sequence 2, however this cannot be confirmed as there was not an equal split of circulated and uncirculated notes due to the limited resource available.

Across all notes originating from the two different banks, 86/102 (84%) of Clydesdale Bank notes contained either ridge detail or fingermarks, whereas this value was 80/102 (78%) for Royal Bank of Scotland notes. This is in agreement with the findings of Joannidis et al [7], where the proportion of fingermarks given a score between 2 and 4 was significantly higher for Clydesdale Bank notes compared to Royal Bank of Scotland and is notable because the majority of bank notes received by the Scottish Police Authority laboratories

are from Clydesdale Bank. Across all £10 and £5 notes, the data shows that 95/98 (97%) £10 notes and 71/107 (67%) £5 notes were found to contain ridge detail or fingermarks. This trend also corresponds to the Joannidis et al. study [7], which found better results on £10 notes compared to the £5 notes for both enhancement sequences. Overall, the majority of Clydesdale Bank £10 notes (45/48 = 94%), Clydesdale Bank £5 notes (41/54 = 76%), and Royal Bank of Scotland £10 notes (50/50 = 100%) gave a result where ridge detail or fingermarks were visible. The Royal Bank of Scotland £5 notes, however, gave the worst results overall (30/52 = 58%), as a larger number of these notes were found to have little or no ridge detail.

Figure 4 shows a comparison between the two enhancement sequences, showing the number of bank notes in each of the three categories (no ridges, ridges only, fingermarks), for both uncirculated and circulated notes combined. Sequence 1 enhanced a larger number of full fingerprints (36/102 = 35%) compared to sequence 2 (27/102 = 27%). However, Sequence 2 had a larger number of notes with ridge detail (53/102 = 52%) compared to sequence 1 (50/102 = 49%). In forensic case work, it is not necessary to find a full fingerprint for comparison, as long as a sufficient amount of ridge detail is present then this can be analysed. This data shows that both processes are effective and can effectively enhance ridge detail on notes that are in a similar condition to those submitted as part of a criminal investigation.

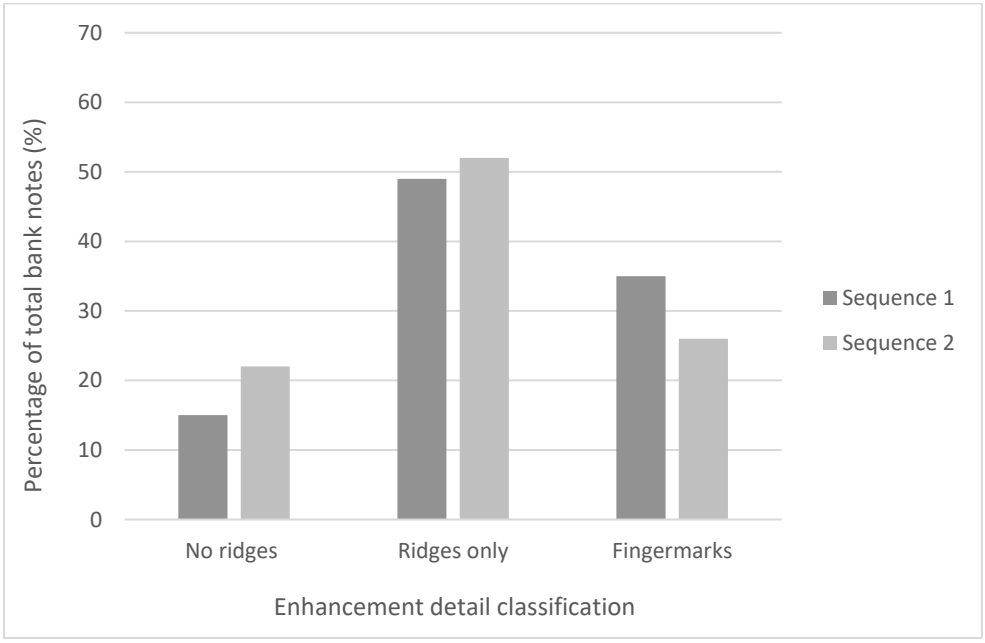

Figure 4. Total number (circulated and uncirculated) of banknotes that showed no ridges, ridges only and fingermarks for Sequence 1 and 2.

Figure 5 shows the percentage of each note within each denomination group that gave no ridges, ridges only, and fingermarks for sequence 1. A larger proportion of the notes on which usable ridge detail was enhanced were Clydesdale Bank £5 notes (15/27 = 56%) and Royal Bank of Scotland £10 notes (13/25 = 52%), in comparison to Clydesdale Bank £10 notes (11/24 = 46%) and Royal Bank of Scotland £5 notes (11/26 = 42%). However, a greater proportion of the notes containing full fingermarks were Clydesdale Bank £10 notes (12/24 = 50 %) and Royal Bank of Scotland £10 notes (12/25 = 48 %), compared to £5 notes from Clydesdale Bank (8/27 = 26%) or Royal Bank of Scotland (4/26 = 12%). This is consistent with Joannidis et al., who found that overall better results were obtained on £10 notes compared to £5 notes. It is notable that zero of the Royal Bank of Scotland £10 notes tested using sequence 1 gave a negative result, i.e., no ridges.

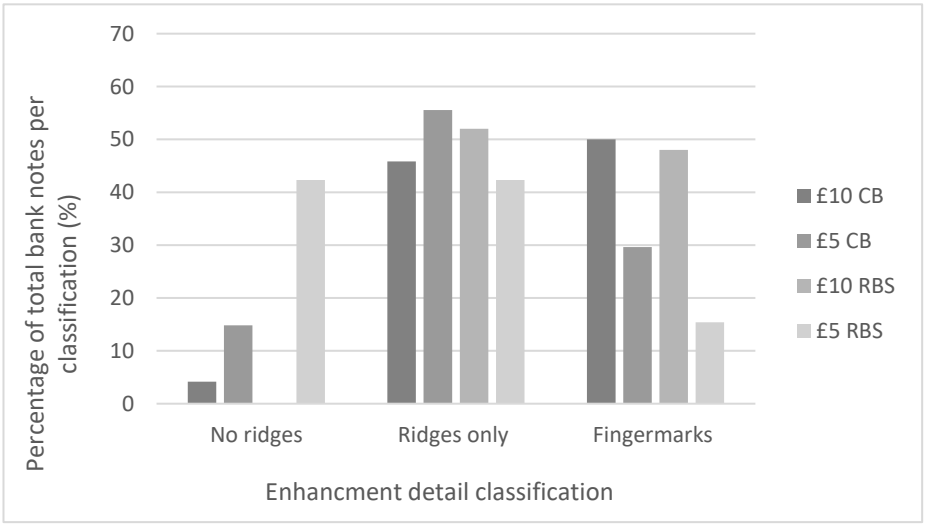

Figure 5. Percentage of bank notes with no ridges, ridges only and fingermarks for the different bank notes types treated using Sequence 1

Figure 6 shows the percentage of each note type that gave no ridges, ridges only and fingermarks for sequence 2. Dissimilar to sequence 1, sequence 2 was particularly successful in terms of enhancing usable ridge detail on Royal Bank of Scotland £10 notes (17/25 = 68%), in comparison to Clydesdale Bank £10 notes (13/24 = 54%), Royal Bank of Scotland £5 notes (12/26 = 46%), and Clydesdale Bank £5 notes (11/27 = 41%). However, sequence 2 performed similarly to sequence 1 for bank notes that were observed to contain fingermarks, where a larger proportion of the notes that showed enhanced detail were £10 notes from both banks (Clydesdale Bank 9/24 = 38% and Royal Bank of Scotland 8/25 = 32%), compared to £5 notes from Clydesdale Bank (7/27 = 26%)

and Royal Bank of Scotland (3/26 = 12%), again confirming the results from Joannidis et al. [7]. Similar to sequence 1, zero of the Royal Bank of Scotland £10 notes tested using sequence 2 gave a negative result, i.e., no ridges.

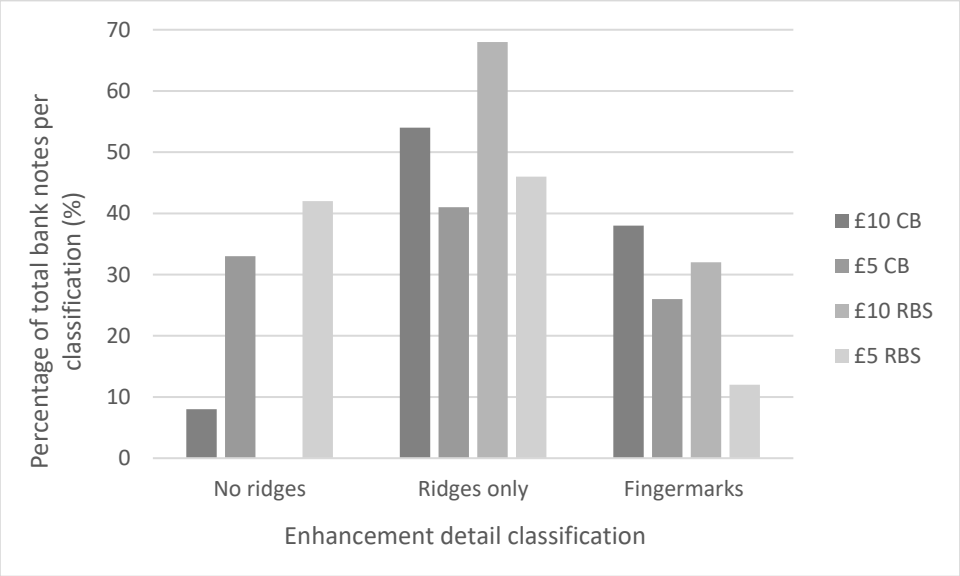

Figure 6. Percentage of bank notes with no ridges, ridges only and fingermarks for the different bank notes types treated using Sequence 2

Table 4 compares the overall results as well as the time taken to complete each sequence for the two enhancement techniques.

Table 4. Time taken to complete both sequences and a summary of the number of bank notes per sequence to give each of the three enhancement classifications.

	Poly + BP	**PS**
Time for completion (hrs)	6	5 (+ drying)
Total no. of notes	102	102
Categories		
Notes with no ridges	16 (16%)	22 (22%)

Notes with ridges only	50 (49%)	53 (52%)
Notes with fingermarks	36 (35%)	27 (26%)

Although both methods require a similar amount of time to complete, sequence 1 was the most laborious due to the application of black magnetic powder. The total processing time for sequence 2 can be up to 12 hours as the notes need a sufficient amount of time to dry, although this time can be significantly reduced using a fan. Unlike sequence 2, sequence 1 did not require any drying time, although it is recommended to wait approximately 30 minutes after the fuming process to allow the glue to set. All 102 of the bank notes treated using each of sequence 1 and 2 (with the aid of a fan) were processed fully within 1 working day.

The overall results for the number of notes containing usable ridge detail corresponded to the results produced by Joannidis et al [7]. PolyCyanoUV followed by black magnetic powder (sequence 1) and black powder suspension (sequence 2) were both effective at enhancing latent fingermarks on Clydesdale Bank and Royal Bank of Scotland polymer notes. Sequence 1 enhanced usable ridge detail on a total of 86/102 (84%) banknotes compared Sequence 2, which enhanced usable ridge detail on a total of 80/102 (78%) banknotes. It is important to note that a result of ‘no ridges’ did not necessarily mean that there were no fingermarks present but could be due to the process not working. As all notes were handled prior to processing, it is likely that fingermarks were present on all notes. It is therefore important to note that a result of ‘no ridges’ is unlikely to mean that there were no fingermarks present but is more likely to be due to fingermarks on these notes not being successfully enhanced. Alternatively, for circulated notes, a result of ‘no ridges’ could be caused by surface degradation. It has been postulated that polymers will degrade over time and as a result of handling, which could change the surface type of the bank notes from non-porous to semi-porous, thereby causing absorption of any fingermarks present or the treatments applied in this study [10]. This can be backed up by the observed higher levels of surface staining visible on the circulated bank notes compared to the uncirculated bank notes (data not shown). In operational work, notes that gave a result of this type would not be re-processed unless there was visual evidence of fingermarks being present, and so their inclusion in the 'no ridges’ category is as it would be in a real case.

In terms of application, the banknotes processed using sequence 2 were more sensitive to being handled as contact with the note disturbed where the powder suspension had adhered. Furthermore, these notes were harder to separate when being counted as they stuck together, compared to the notes processed using sequence 1. Due to the ease of disturbance when handling notes processed using sequence 2, all bank notes had to be laid out separately when storing overnight, unlike with sequence 1 where the notes could be stacked.

Conclusions

In conclusion, the two most effective sequences for enhancing fingermark evidence, as determined by Joannidis et al. [7], were very successful when used on Clydesdale Bank and Royal Bank of Scotland banknotes as part of a pseudo-operational trial, reflecting the uncontrolled conditions encountered in real casework. Both sequences were successful in enhancing ridge detail on £10 and £5 polymer banknotes from Clydesdale Bank and Royal Bank of Scotland. The application of PolycyanoUV followed by black magnetic powder (sequence 1) was slightly more laborious when compared with the application of black powder suspension (sequence 2). However, the practitioner would have to be more careful when handling banknotes treated with sequence 2 as, unlike sequence 1, this does not set in place so can be smudged. Powder suspension does have its advantages, however, as it works well on items that have been subjected to moisture, where PolyCyanoUV would be unsuccessful [11]. Overall, both PolyCyanoUV followed by black magnetic powder and black powder suspension, with the use of an IR 730 nm – 800 nm light were highly successful in recovering usable ridge detail on Clydesdale Bank and Royal Bank of Scotland £10 and £5 polymer banknotes that simulated those received into the laboratory as part of an investigation. Following the results of this trial, full operational trials were conducted before the use of these techniques were implemented for use within forensic laboratories.

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