Article

Evaluation of the RECOVER LFT System: Experiments on Metal Plates

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Abstract: The commercial RECOVER LFT is a relatively new system that develops latent prints on metal surfaces. This article presents the results of six experiments: specificity, sensitivity, effects of prewashing prior to processing with the RECOVER, recovery of aged fingermarks, recovery of fingermarks after bleach, and comparison to a standard nonporous processing sequence. These tests were performed on controlled samples consisting of eccrine or a combination of eccrine and sebaceous matrices on smooth brass and steel metal plates. This was done in order to gain a baseline understanding of how the instrument performs. Initial testing indicated that the RECOVER consistently developed fingermarks on the brass samples regardless of matrix type. Eccrine and sebaceous-based fingermarks on brass had the strongest development, followed by eccrine-based samples on brass. Results were less consistent on the steel samples, and development varied depending on the matrix type. The steel samples had weaker development than the brass samples, with the eccrine and sebaceous fingermarks on steel performing better than the eccrine-based fingermarks. The RECOVER can develop quality fingermarks on brass samples that are washed, but the washed brass samples did not consistently develop equal to or better than their unwashed counterpart. Prewashing of the steel samples proved to be detrimental to development. The RECOVER performed slightly better than the current Idaho State Police Forensic Services processing sequence. These findings are based on samples in optimal conditions. Further testing of semicontrolled and pseudo-operational samples is necessary to determine how to best utilize the RECOVER in casework.

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Introduction

Metal is a ubiquitous surface type found on a multitude of everyday items. On average, about 50 percent of the items the Idaho State Police Forensic Services (ISPFS) receives for latent print processing are metal or have metal parts (e.g., firearms, cartridges, scales, knives, crowbars, locks). Metal is a nonporous surface that is typically processed for latent prints using a sequence consisting of cyanoacrylate ester (CAE) fuming followed by dye stains and powders. This sequence is generally effective for smooth, metallic surfaces, but results can be inconsistent on challenging surfaces like cartridge cases, padlocks, and tools (e.g., curved, textured, or surfaces with repeated handling in the same areas). Under ideal laboratory testing conditions, cartridge cases have yielded good results [1–3]. The recovery rate of latent prints on live ammunition and fired cartridge cases in casework is extremely low [4–6]. Because of the low success rate in casework, some authors have suggested not processing cartridge cases unless there is a specific reason (e.g., investigator request or indication of item being touched after being fired) [6, 7]. Further research into alternative processing methods is necessary.

Latent print residue contains both organic and inorganic components [8]. It is the interaction of the inorganic constituents with metallic surfaces that has seen an uptick in research since 2008 [2, 3, 9–20]. Development techniques that use the redox corrosion reaction between metal and the ionic salts in fingerprint residue may provide a means to increase the recovery rate on the challenging surfaces mentioned above. These techniques target the reaction of the fingerprint residue with metal rather than the fingerprint residue itself. This means metallic items that have been subjected to adverse conditions (e.g., heat and friction, submerged in water for extended time) or that have rough surfaces (e.g., crowbar) may yield more ridge detail when processed with these techniques.

The S_2N_2 method has garnered recent interest within the latent print community following the validation of a prototype [16] and the launch of Foster and Freeman's RECOVER LFT because of a reported improvement regarding fingerprint recovery on metallic surfaces. Several studies have investigated the effectiveness of the RECOVER with the majority focusing on brass cartridges and cartridge cases [2, 3, 17, 18] and intentionally placed eccrine fingerprints [2, 3, 17–20]. Wilkinson et al. [2] and Lam et al. [3] both found promising results in the

development of fingerprints on cartridges and cartridge cases. Meanwhile, the recovery rate reported by Pontone et al. [18], the Defence Science and Technology Laboratory [17], and the pseudo-operational section of Lam et al. (those determined to be suitable for comparison) was much lower, however, an order of magnitude higher than what has been reported in the literature on traditional processing methods [4–6].

Early studies [2] performed prewashing (warm soapy water, acetone wash, and buffed dry) on cartridge cases prior to processing with the RECOVER in order to remove contaminants produced during the firing process. The promising results from these studies may have led to a misconception that prewashing items prior to processing with the RECOVER is necessary or ideal. Wilkinson et al. did not specify that the unfired controls were not subject to cleaning [3]. Therefore, prewashing has not been recommended for unfired cartridges [3].

Because the RECOVER is thought to react with microcorrosion on the metal object and not the fingerprint residue itself, fingerprints left on the surface for long periods of time may develop with the RECOVER. Many of the studies aged samples for various times, with the longest aging period being three months [16].

The run times for brass samples ranged from as low as 4 minutes [3] to more than 45 minutes (the exact time is not known because only a range for development time was given) [16]. For those studies using the RECOVER [2, 3] and not the prototype [16], the majority of the fuming times were less than 20 minutes. As with brass, the silver-colored metals were processed in a 45-to-90-minute range with the prototype. The only study [17] using the RECOVER to process silver-colored metal fumed kitchen knives for 2 to 3 hours.

Only two studies related to the RECOVER instrument had been published prior to the commencement of the ISPFS validation [2, 17]. Because of the limited nature of these studies and because the manufacturer's validation was performed on a prototype and not the commercially available instrument, ISPFS felt it was important to revisit some of the concepts in the initial validation. The ISPFS validation used the RECOVER on smooth, flat metal plates in order to gauge how it performed on basic, nonchallenging surfaces before moving onto more challenging surfaces (e.g., cartridges and cartridge cases) and pseudo-operational items. With the metal plates, this study examined areas that had not been addressed in previous studies (sebaceous-

based fingerprints, items exposed to bleach, an aging time period longer than three months) and areas that were addressed in the validation of the prototype but that had yet to be fully studied in the RECOVER (specificity, sensitivity, prewashing of samples, comparison of the traditional methods to the RECOVER).

ISPFS' objectives for this validation were to assess (1) whether friction ridge detail was developed from the majority of donors; (2) whether friction ridge detail developed, at minimum, on the first set of fingerprints in the depletion series; (3) whether friction ridge detail developed on the majority of aged samples; (4) whether friction ridge detail developed similar to or better than the current processing methods; and (5) whether the RECOVER results are reproducible. Should the RECOVER meet those goals, the internal validation would move on to the next phase using realistic items with purposely placed, natural fingerprints followed by pseudo-operational items.

Materials and Methods

Metal plates of brass 260 half-hard temper at .020-inch thickness and cold-finished carbon steel grade 1018 at .0239-inch thickness were purchased from Gem State Metals in Garden City, Idaho and were cut by the College of Western Idaho Welding and Metals Fabrication Program into 1x6-inch plates. The metal was further cut as needed per experiment. Upon receipt of the metal plates, they were wiped clean, using acetone applied with WypAll sheets. Prior to beginning the validation, all plates were washed with a powder dish soap and warm water, wiped dry, and cleaned with acetone. A yellow-colored oil build up was noted on the steel plates during the specificity study. It is thought that this substance was from the metal fabrication process, because it appeared to be passively leaching from some of the strips over time, on both the specificity and unused steel samples. All subsequent steel plates were re-washed with liquid dish soap, wiped dry, and cleaned with isopropyl alcohol prior to proceeding with additional experiments.

Six independent experiments were performed using the RECOVER on brass and steel samples. These experiments included specificity, sensitivity, the effect of prewash prior to processing, the recovery of aged fingermarks, the recovery of fingermarks after bleach, and the comparison to ISPFS standard nonporous processing sequence.

The RECOVER was operated according to the manufacturer's manual [21]. There are four settings that can be selected for the fuming process: R1, R2, R3, and R4. Each setting has a designated vial containing a premeasured amount of the copper bromide tetrathiatetrazocine reagent (DEVELOP, Foster and Freeman, Inc.). R1 is designated for copper-based metals in the small chamber (200 mm in height). R2 also uses the small chamber but is designated for silver-colored metals. R3 and R4 are for the large chamber (400 mm in height) and are designated for copper-based metals and silver-colored metals, respectively.

Per the RECOVER User Manual [21] there is no set fuming time. Based on preliminary internal testing and manufacturer recommendation, fingerprints on brass can develop in under 10 minutes, whereas silver-colored metals may react slower than brass, requiring a longer fuming time. Fingerprints made primarily of sebaceous material may develop with a shorter fuming time; however, eccrine-based fingerprints may develop better with a longer fuming time. This variation in development necessitated running sebaceous matrix separately from eccrine matrix on brass samples. The brass samples were processed on the R1 setting and closely monitored. Run times ranged from 5 to 45 minutes, depending on matrix composition. For the specificity experiment the steel samples were processed on the R2 setting for 2 ½ hours. In all other experiments, the steel samples were processed for approximately 15 hours following an instructional webinar hosted by Foster and Freeman. There did not appear to be any risk of overfuming with the steel samples.

The standard nonporous processing sequence consisted of cyanoacrylate ester (CAE), dye stain, and powder. The application of each of these steps followed the ISPFS Latent Print Analytical Methods [22]. The CAE step was performed in an Air Science CA30 (80% RH) and fumed for 15 minutes. Following CAE, samples were irrigated with a methanol-based rhodamine 6G (R6G, 0.1g to 1L of methanol) dye stain. Lastly, samples were powdered using a black standard powder.

After each processing technique, samples were photographed using a Canon EOS D6 camera equipped with a Canon Compact Macro EF 50 mm lens on a copy stand. The camera was set to aperture priority f/11 with ISO 160. Samples were photographed using an Arrowhead Forensics Coaxial Light Guide and Illuminator. R6G images were taken using a Polilight PL400 at 505 nm with an orange filter. Images were converted to grayscale, levels were adjusted, and the images were downsampled to 1000 ppi.

One analyst evaluated all of the fingerprints developed from the various studies listed below. The grading followed the Home Office criteria [23] (Table 1). The grades were tabulated and used during the evaluation portion of this study. Figure 1 consists of examples of grades given to samples.

Score	Level of detail
0	No evidence of contact
1	Evidence of contact but no ridge detail
2	Limited development, less than 1/3 of fingerprint is clear, but probably not suitable for comparison
3	Strong development, between 1/3 and 2/3 of fingerprint is clear, suitable for comparison
4	Very strong development, clear ridge detail throughout entire fingerprint, suitable for comparison

Table 1

Grading criteria used to evaluate fingerprints.

(a)

(b)

(c)

(d)

(e)
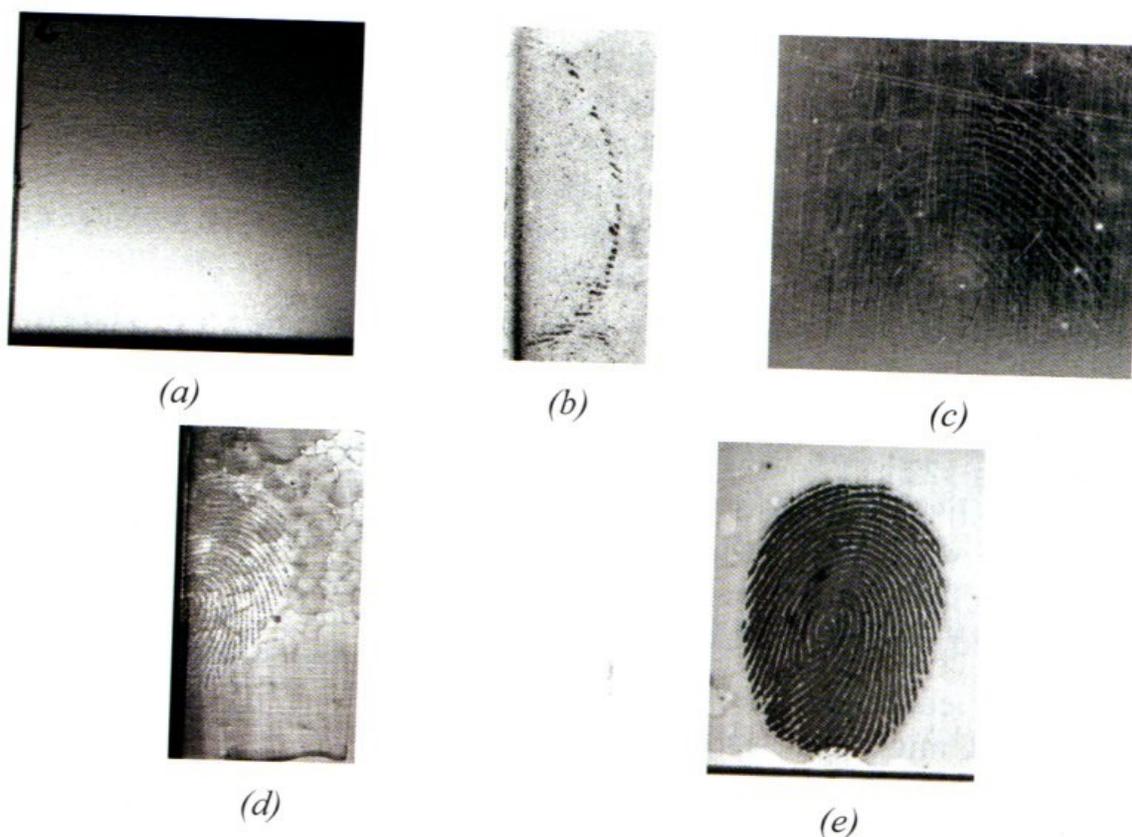
Figure 1

Examples of the grading criteria as defined in Table 1: (a) grade 0, (b) grade 1, (c) grade 2, (d) grade 3, and (e) grade 4.

Specificity

This multiple donor[1] study was conducted, using 37 donors (19 females and 18 males). Donors washed their hands with soap and water and donned a set of nitrile gloves, which they wore for 30 minutes while going about their normal activities. Donors then removed their gloves and rubbed their hands together to evenly distribute the matrix. They then deposited one eccrine print onto each of the two metal types, using two different fingers from the right hand. Donors then charged their left hand by rubbing the back of their neck or behind their ears to create a combination eccrine and sebaceous matrix and deposited these impressions onto a second area of each metal type. Specific instructions regarding pressure of deposition were not provided. The variation in pressure between donors is unknown and was not measured. Donors were instructed to briefly contact the surface and then remove the finger; no extended contact was made. Little fingers were not used because of size. Samples were aged for 1 week and stored under ambient laboratory conditions prior to processing with the RECOVER and resulted in 168 samples.

Sensitivity

The sensitivity of the RECOVER was investigated, using a depletion series from five donors (three females and two males). Donors were selected based on results from the prior specificity study by adding the grades from each of the four metal and matrix combinations together for a composite score. The five donors were selected to encompass a medium to high composite score range (6–9). In addition to the composite score, the donors were selected for their ease of access to provide samples. These five donors provided samples for the remaining experiments. Donors washed their hands with soap and water and donned a pair of nitrile gloves, which they wore for 30 minutes while going about their normal activities. Donors then removed their gloves and rubbed their hands together to evenly distribute the matrix. They then deposited a depletion series of six impressions onto each of the two metal types using two different fingers from the right hand. Donors used their left hand to rub the back of their neck or behind their ears to create a combination eccrine and sebaceous matrix and deposited a second depletion series onto each of the two metal types using the corresponding fingers from the left hand. Samples were aged for 1 week and stored under ambient laboratory conditions prior to processing with the RECOVER and resulted in 120 samples.

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[1] All donors from each experiment signed an informed consent approved by the legal department at the Idaho State Police and ISPFS management.

Effect of Prewash Prior to Processing

This experiment used the same five donors who prepared their hands as outlined in the sensitivity experiment. The donors deposited an impression onto a split sample of each of the two metal types, using different fingers from the right hand for each metal type. Donors used their left hand to rub the back of their neck or behind their ears to create a combination eccrine and sebaceous matrix and repeated the deposition onto the two metal types, using the corresponding fingers from the left hand. Samples were aged for 1 week and stored under ambient laboratory conditions. At the conclusion of the aging period, one half of the split sample was washed with warm soapy water (1 to 3 grams of mild dish detergent in 1 to 2 L of water), rubbed with acetone, and buffed with a paper towel for approximately 30 seconds [5]. The other half of the split sample was not cleaned prior to processing. All samples were processed with the RECOVER and resulted in 40 samples.

Recovery of Aged Fingermarks

This experiment used the same five donors who prepared their hands as outlined in the sensitivity experiment. The donors deposited the first and fifth mark of a depletion series onto each of the two metal types, using different fingers from the right hand for each metal type. The second through fourth impressions in the series were placed onto a piece of paper. Donors used their left hand to rub the back of their neck or behind their ears to create a combination eccrine and sebaceous matrix and repeated the deposition of the first and fifth marks onto the two metal types using different fingers. This was repeated for five sets of samples. Samples were aged for 1 day, 1 week, 1 month, 3 months, or 6 months and were stored under ambient laboratory conditions prior to processing with the RECOVER and resulted in 200 samples.

Recovery of Fingermarks after Bleach

This experiment used the same five donors who prepared their hands as outlined in the sensitivity experiment. The donors deposited the first and fifth mark of a depletion series onto each of the two metal types using different fingers for each metal type. The second through fourth impressions in the series were placed onto a piece of paper. Donors used their left hand to rub the back of their neck or behind their ears to create a combination eccrine and sebaceous print and repeated the deposition of the first and fifth marks onto the two metal types, using two

different fingers. This was repeated for four sets of samples. Samples were aged for 10 minutes, 1 hour, 2 days, and 1 week and were stored under ambient laboratory conditions. At the conclusion of the aging period, the samples were dipped in undiluted household bleach, rinsed with Nanopure water, dabbed with a paper towel, and air dried prior to processing with the RECOVER. This test resulted in 160 samples.

Comparison to Current Nonporous Sequential Processing Sequence

Part 1

This experiment used the same five donors who prepared their hands as outlined in the sensitivity experiment. The donors deposited an impression onto a split sample of each of the two metal types, using different fingers from the right hand for each metal type. Donors used their left hand to rub the back of their neck or behind their ears to create a combination eccrine and sebaceous matrix and repeated the deposition onto the two metal types using the corresponding fingers from the left hand. This was repeated for five sets of samples. Samples were aged for 1 day, 1 week, 1 month, 3 months, and 6 months and were stored under ambient laboratory conditions. At the conclusion of the aging period, the left half of the split sample was processed with the RECOVER; the right half was processed with the standard processing sequence for nonporous items [CAE, dye stain (R6G), powder], resulting in 200 samples.

Part 2

Using the samples from Part 1, the samples that were processed with the RECOVER were then processed with the standard processing sequence for nonporous items (CAE, dye stain, powder). The samples from Part 1 that were processed with the standard processing sequence for nonporous items (CAE, dye stain, powder) were washed with warm soapy water (1 to 3 grams of mild dish detergent in 1 to 2 L of water), rubbed with acetone, buffed with a paper towel for approximately 30 seconds, and air dried [5] prior to processing with the RECOVER. Part 2 resulted in an additional 200 samples.

Results

Specificity

Figure 2 is a bar chart with the breakdown of the specificity grades per metal and matrix type. Appendix A has the raw grades from the 37 participants. Some degree of development (grade 1 or higher) was seen for 81% of donors on brass plates with an eccrine matrix (EccBr); 11% of donors on steel plates with an eccrine matrix (EccSt); 100% of donors on brass plates with a sebaceous matrix (SebBr); and 57% of donors on steel plates with a sebaceous matrix (SebSt). Overall, 62% of samples had some degree of latent print development. Of these, approximately 46% were graded as a 2 (limited development). Because of the marginal nature of these prints, the samples would warrant further analysis to determine value for comparison. Approximately 34% were graded as a 3 or a 4 (strong development, or very strong development) and would be of value for comparison. There was only one donor (Donor 21) who was graded higher than 0 for all for metal and matrix combinations. Meanwhile, one donor (Donor 3) had three grades of 0. Seven donors (Donors 3, 5, 8, 10–13) did not produce any sign of contact with their eccrine samples (EccBr or EccSt). For sebaceous-based prints, no donor had a grade of 0 for both of the two metal types due to how well SebBr performed. Even if a donor received a grade of 4 for SebBr, it did not mean that the same donor had development for SebSt (Donors 3, 15, 16, 29, and 36).

Sensitivity

Figure 3 is a bar chart with the breakdown of the sensitivity grades per metal and matrix type. Appendix B has the raw grades from this experiment. Some degree of development was seen on 50% of the EccBr samples, 3% of the EccSt samples, 100% of the SebBr samples, and 100% of the SebSt samples. In total, 63% of the samples had some level of development. For the first touch in the depletion series, 35% were grade 2 (limited development) and 25% were grade 4 (very strong development). For the second touch in the series, 30% were grade 2 and 25% were grades 3 and 4. For the third touch, 25% were grade 2 and 20% were grades 3 and 4. The fourth touch revealed that 30% were grade 2 and 15% were grade 4. On the fifth touch, 45% were grade 2 and 15% were grades 3 and 4, and then on the sixth touch, 30% were grade 2 and 10% were grades 3 and 4. As might be expected, there is a general downward trend in the grades from the first touch to the last touch. There were a few instances where the prior touch was graded lower than subsequent touches, which differed from the general trend (Donor 5).
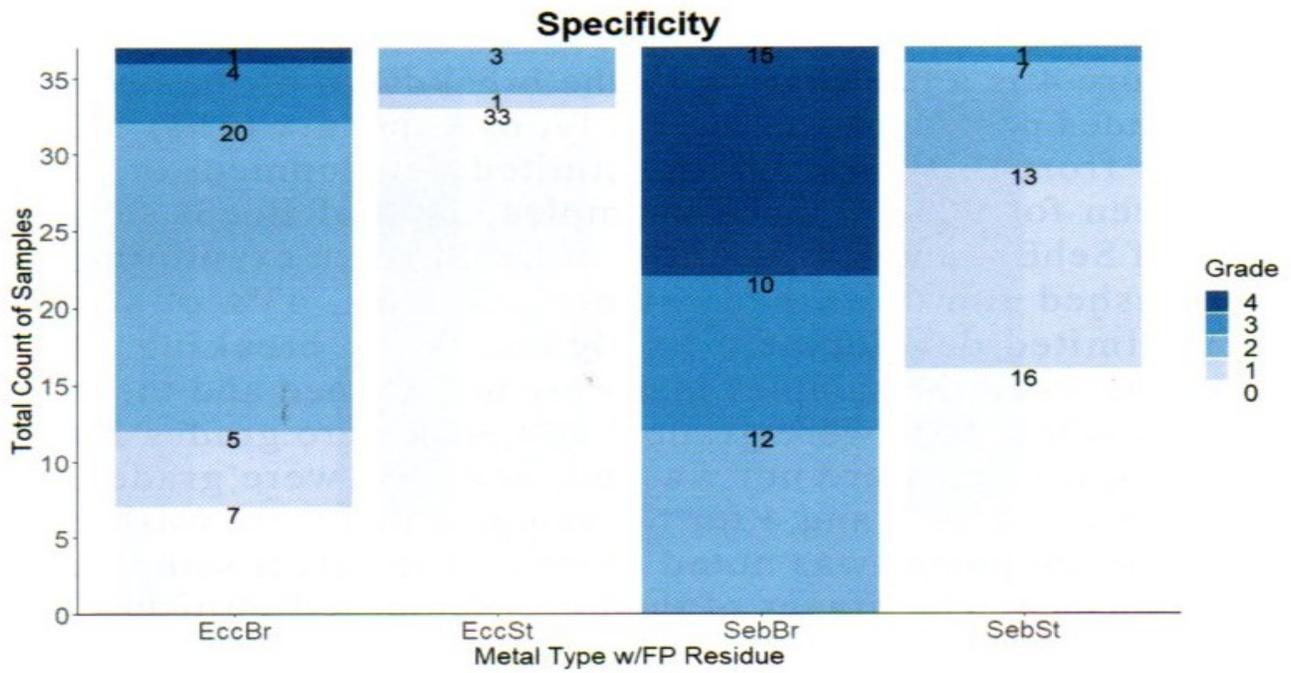
Figure 2

Counts per grade category for each of the four metal and matrix combinations.
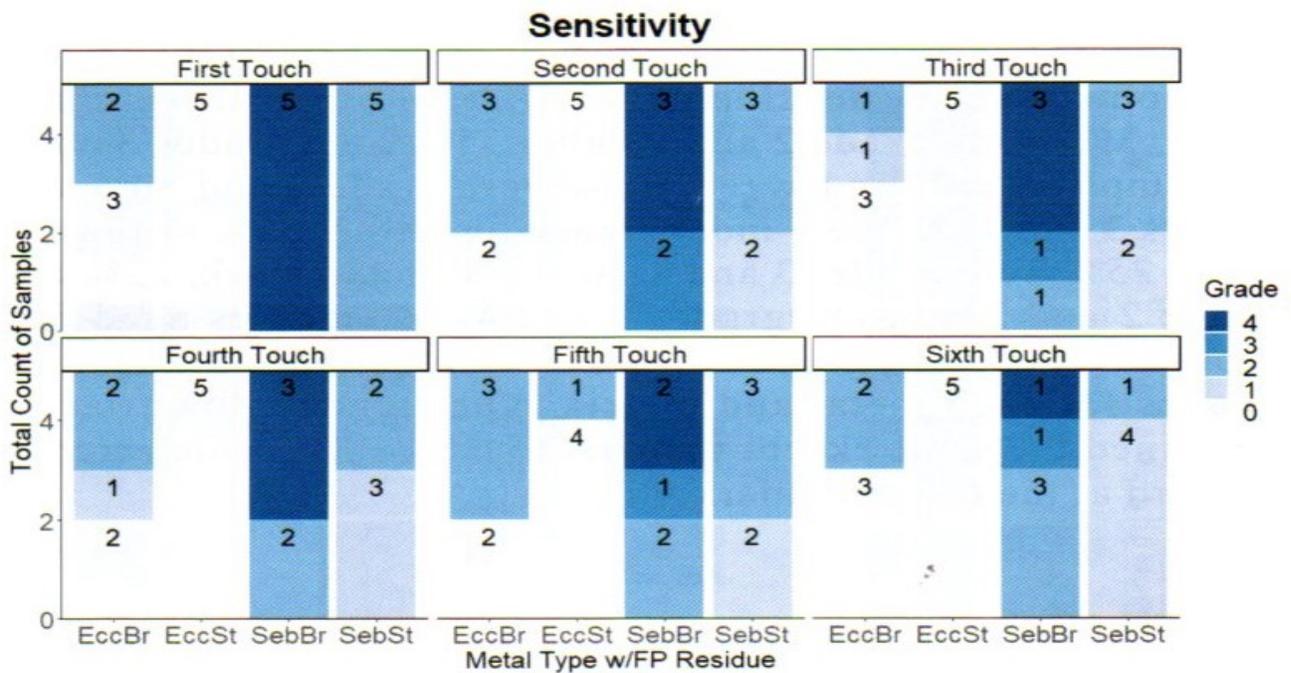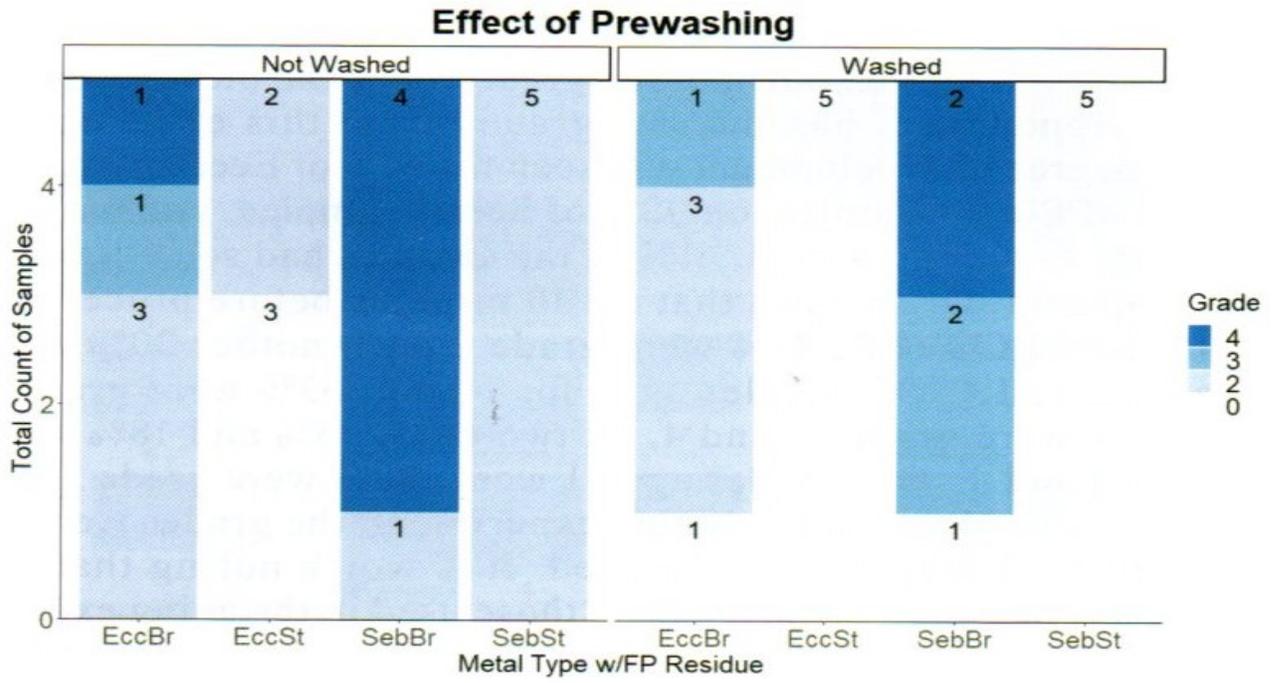

Figure 3

Counts per grade category by metal, matrix combination, and depletion.

Effect of Prewash Prior to Processing

Figure 4 is a bar chart with the breakdown of the prewashing grades per metal and matrix type. Appendix C has the raw grades from this experiment. Limited development or higher was seen for 90% of EccBr samples, 20% of EccSt samples, 90% of SebBr samples, and 50% of SebSt when examining both the washed and unwashed samples. Overall, 63% of samples were limited development or higher. When breaking results down between the samples that were not washed and those that were washed, 55% were grade 2 and 30% were grades 3 and 4 for samples that were not washed, and 15% were grade 2 and 25% were grades 3 and 4 for the samples that were washed. No ridge development was noted on any of the steel samples that were washed. The grades of the brass samples diminished after washing. Most of the results were consistent across donors, with the exception of Donor 2 who showed no signs of development after being washed.
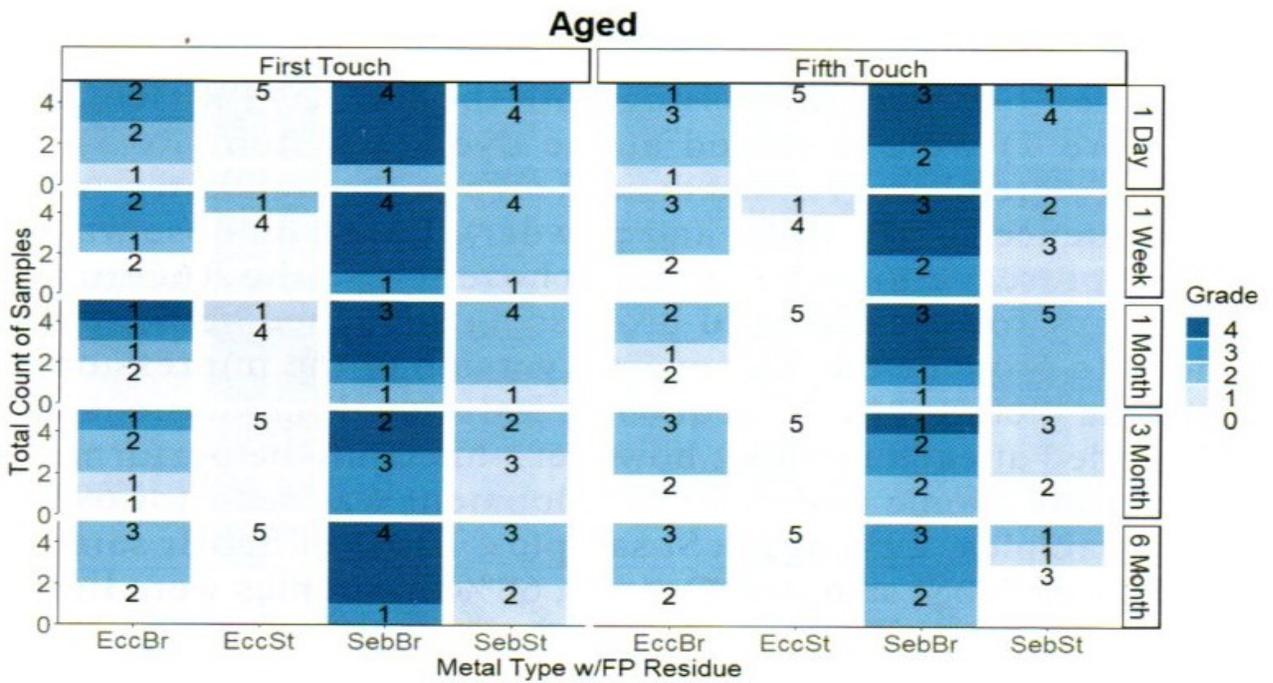
Recovery of Aged Fingermarks

Figure 5 is a breakdown of the grades from the aging experiment. Appendix D has the raw grades from this experiment. Some degree of development (grade 1 or higher) was seen for 70% of EccBr samples, 6% of EccSt samples, 100% of SebBr samples, and 90% of SebSt samples. In total, 67% of the samples had some level of development. Of samples that were aged 1 day, 35% were grade 2 and another 35% were grades 3 and 4. Of samples aged for 1 week, 28% were grade 2 and 30% were grades 3 and 4. At the 1-month mark for aging, 35% were grade 2 and 25% were grades 3 and 4. At the 3-month mark, 23% were grade 2 and 23% were grades 3 and 4. Of samples aged for 6 months, 30% were grade 2 and 20% were grades 3 and 4. All grades for each metal and matrix type trended downward or remained the same except the first touch SebBr, which trended upward at the 6-month mark.

Figure 4

Counts per grade category by metal and matrix combination and washing.

Figure 5

Counts per grade category by metal and matrix combination and aging.

Recovery of Fingermarks after Bleach

Figure 6 is a breakdown of the grades from the bleach experiment. Appendix E has the raw grades from this experiment. Some degree of development was seen for 73% of EccBr samples, on 3% of EccSt samples, on 98% of SebBr samples, and on 73% of SebSt samples. In total, 61% of the samples had some level of development. Of samples that sat 10 minutes before processing with the RECOVER, 43% were grade 2 and another 20% were grades 3 and 4. Of samples aged for 1 hour, 33% were grade 2 and 15% were grades 3 and 4. At two days, 35% and 18% were grades 3 and 4. Of samples aged 1 week, 28% were grade 2 and 28% were grades 3 and 4. In this experiment, the grades trended upward the longer they were aged. It is worth noting that the aging periods were different from those used in the aging experiment. The aging periods here were chosen based on the idea that following the commission of a crime, the perpetrator may try to clean potential evidence by exposing it to bleach.

Comparison to Current Nonporous Sequential Processing Sequence

Figure 7 is a breakdown of the comparison to the current nonporous processing sequence (parts 1 and 2) grades per metal and matrix type. Appendix F has the raw grades from this experiment. Grades for the standard sequence whether before (R6G in Figure 7) or after processing with the RECOVER (RECR6G in Figure 7) were assessed at the dye stain step (R6G). All samples were photographed at each step in the standard processing sequence (CAE, R6G, and powder). Based on observations during preservation, the authors chose to use the R6G images as a proxy for the standard processing sequence because R6G tended to produce the best overall version of the impression out of all the methods in the sequence. Individual impressions were not graded at each method; however, this could be performed at a later date. Some degree of development was seen for 69% of EccBr samples, 29% of EccSt samples, 100% of SebBr samples, and 75% of SebSt samples. Overall, 68% of samples were limited development or higher.

Considering the R6G grades, of samples aged 1 day, 60% were grade 2 and 35% were grades 3 and 4. At the 1-week mark, 45% were grade 2 and 20% were grades 3 and 4. Of samples that were aged 1 month, 55% were grade 2 and 25% were grades 3 and 4. At 3 months, 35% were grade 2 and 15% were grades 3 and 4. Finally, samples that were aged for 6 months revealed that 45% were grade 2 and 10% were grades 3 and 4.
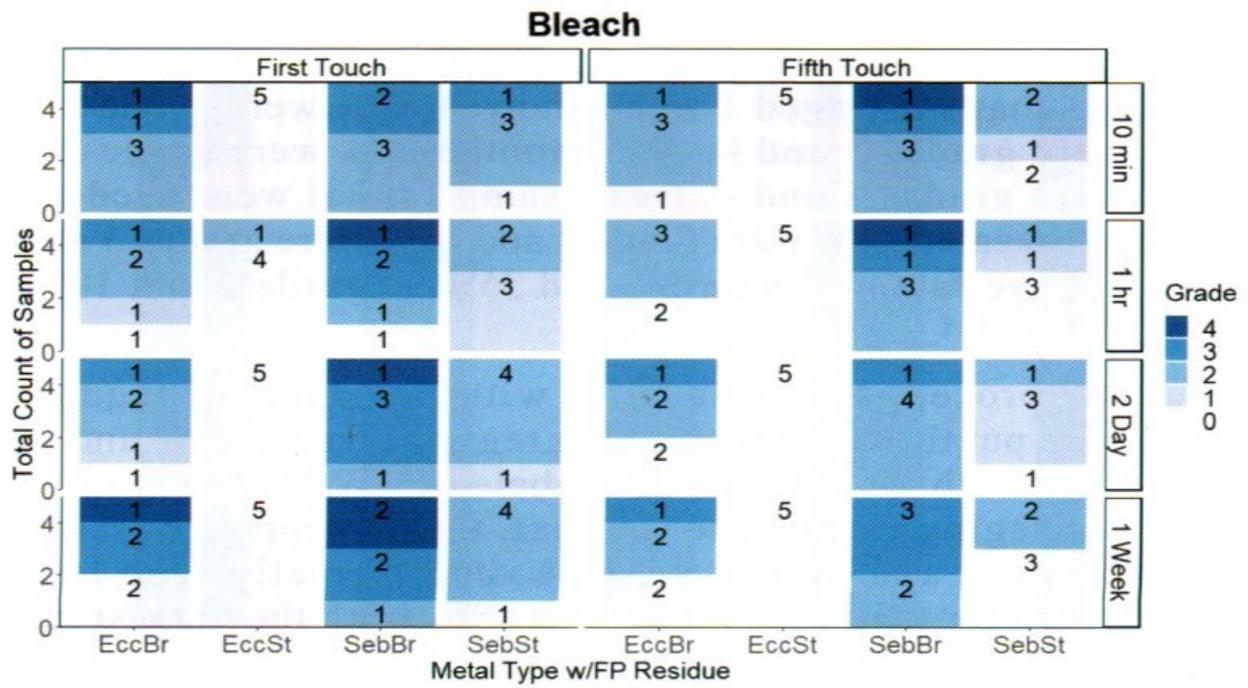
Bleach

Figure 6

Counts per grade category by metal and matrix combination and when cleaned with bleach.
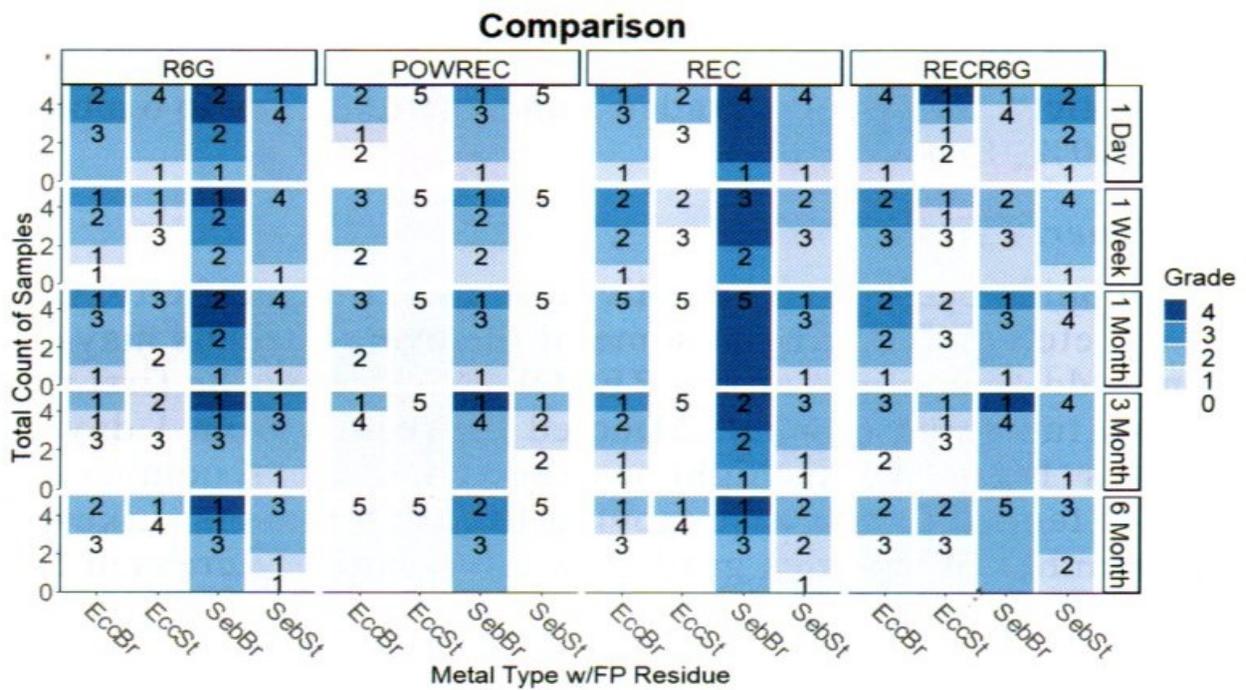
Comparison

Figure 7

Counts per grade category by metal and matrix combination and processing sequence.

The grades for the RECOVER samples (REC) showed that at 1 day 45% were grade 2 and 30% were grades 3 and 4. Samples that were aged 1 week showed 20% were grade 2 and 35% were grades 3 and 4. At 1 month, 40% were grade 2 and 30% were grades 3 and 4. Next, samples that were aged for 3 months revealed 30% were grade 2 and 25% were grades 3 and 4. The last age factor, 6 months, had 35% as grade 2 and 10% as grades 3 and 4.

After processing the samples with the standard sequence, they were put through the washing regimen (see above) and then processed with the RECOVER (labeled POWREC in Figure 7). From one aging category to the next, the percentage of samples with grade 2 and grades 3 and 4 varied greatly. The lowest percentage for grade 2 samples was 15%, with the highest being 30%. The samples with grades 3 and 4 were 5% (one sample) for each aged factor with the exception of the 6 months factor with 10% (two samples graded as a 3).

The samples that were initially processed with the RECOVER were then processed with the traditional sequence (labeled RECR6G in Figure 7) and the grading was assessed at the dye stain step. During this trial, the percentage of grade 2 samples increased from 1 day to 1 week (40% to 50%), dipped slightly at 1 month (30%), then continued to increase to 60% for both the 3-month samples and the 6-month samples. The opposite effect was noticed for samples graded 3 and 4 (from 1 day to 6 months: 15%, 10%, 15%, 5%, 0%).

General Trends

Stepping back from the individual studies (specificity, sensitivity, etc.) and looking at some of the overall trends may shed some additional light on the RECOVER system. The first trend is how the aging of prints affected the results from 1 day to 6 months (Figure 8). As might be expected, the total number of 3s and 4s tended to decrease moving toward 6 months. Likewise, the number of samples graded as a 0 steadily increased from 1 day to 6 months.

The next trend is the traditional sequence (R6G) versus the RECOVER (REC), from Part I of the comparison experiment (Figures 9 and 10). The overall grades for REC had more than double the number of samples that were graded as a 4 than did R6G. Beyond that grade, the grading was slightly more favorable for R6G. R6G received 14 grades of 3, 48 grades of 2, 11 grades of 1, and 20 grades of 0. REC received 11 grades of 3, 34
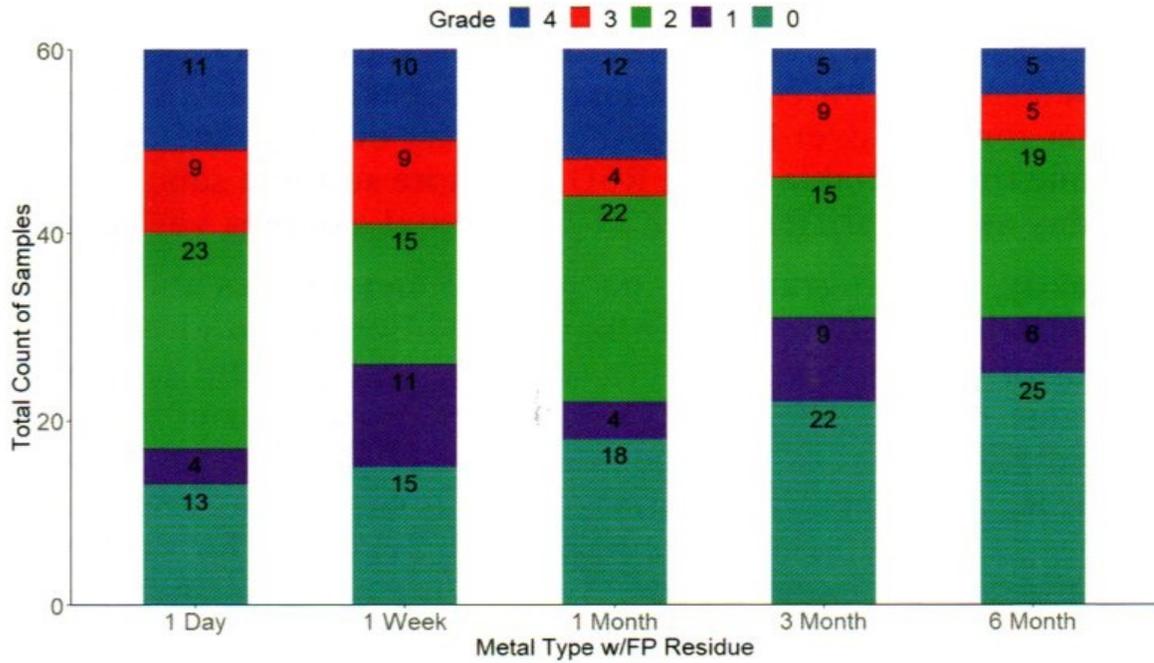
Figure 8

This figure shows the overall trend from 1 Day to 6 Month time factors without taking metal type and matrix into consideration. As samples aged, the number of samples graded 3 and 4 diminished whereas the number of samples graded 0 increased.
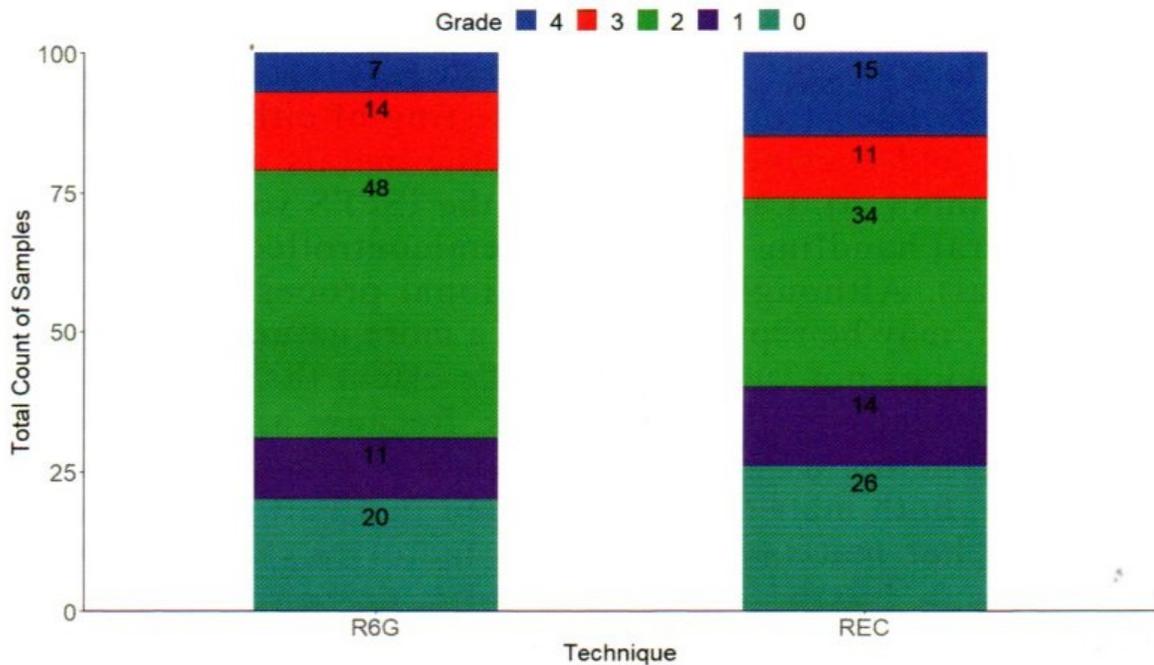

Figure 9

This figure pits R6G versus RECOVER without taking metal type and matrix into consideration. R6G had more grades of 2 and 3 and fewer grades of 0; RECOVER had twice as many grades of 4.

grades of 2, 14 grades of 1, and 26 grades of 0. Comparing R6G to REC as the samples aged revealed that the number of samples deemed suitable for comparison (grades 3 and 4) was equal to or greater for REC over R6G for the majority of the time variables. The one time variable where R6G had more suitable samples was at 1 day and the difference was seven total samples versus six.

Lastly, overall grades for each of the metal types and matrix combinations can be seen in Figure 11. EccSt had almost 200 grades of 0 with few other grades. SebSt and EccBr had about the same number of grade 2 and a similar number of grade 0. They differed in regard to the number of grades 1, 3, and 4, with EccBr having several more grade 3 and fewer grade 1. SebSt did not have a single sample graded as a 4. SebBr performed quite well through all experiments by receiving a similar number of grades 2, 3, and 4, with very few grades of 0 and 1.

Discussion

Previous work by Bleay et al. [16] has been done on a prototype version of the RECOVER, therefore, it was essential to put the commercial version through similarly extensive experiments to determine whether this version would produce similar results. Although ISPFS' experimental design differed in many aspects to theirs, similar conditions were tested. One of the biggest differences between the two studies is that the first phase of this study used fingerprints consisting of either eccrine or sebaceous and eccrine matrices on the metals as opposed to natural prints [16]. Later phases of the ISPFS validation used more natural handling conditions (semicontrolled and pseudo-operational). Although the depositional process detailed by Bleay et al. may be representative of a more natural latent print residue, it does not fully examine the effect the S_2N_2 process has on sebaceous-based fingerprints. Because an analyst does not know whether a latent print consists of eccrine material or sebaceous, both matrices were studied in an attempt to determine whether matrix is a limiting factor in the RECOVER development. Furthermore, during the design phase of this study, a survey of the literature on S_2N_2 revealed that none used sebaceous-based fingerprints [11–13, 16], with the exception of lightly groomed fingerprints used in the improvised explosive device portion of Wilkinson et al. [2] However, a recent study by Pontone et al. [18] incorporated sebaceous-based fingerprints in their assessment of the RECOVER on cartridge cases. The use of the RECOVER on cartridges and cartridge cases was not explored in this study, so no direct comparison can be made.
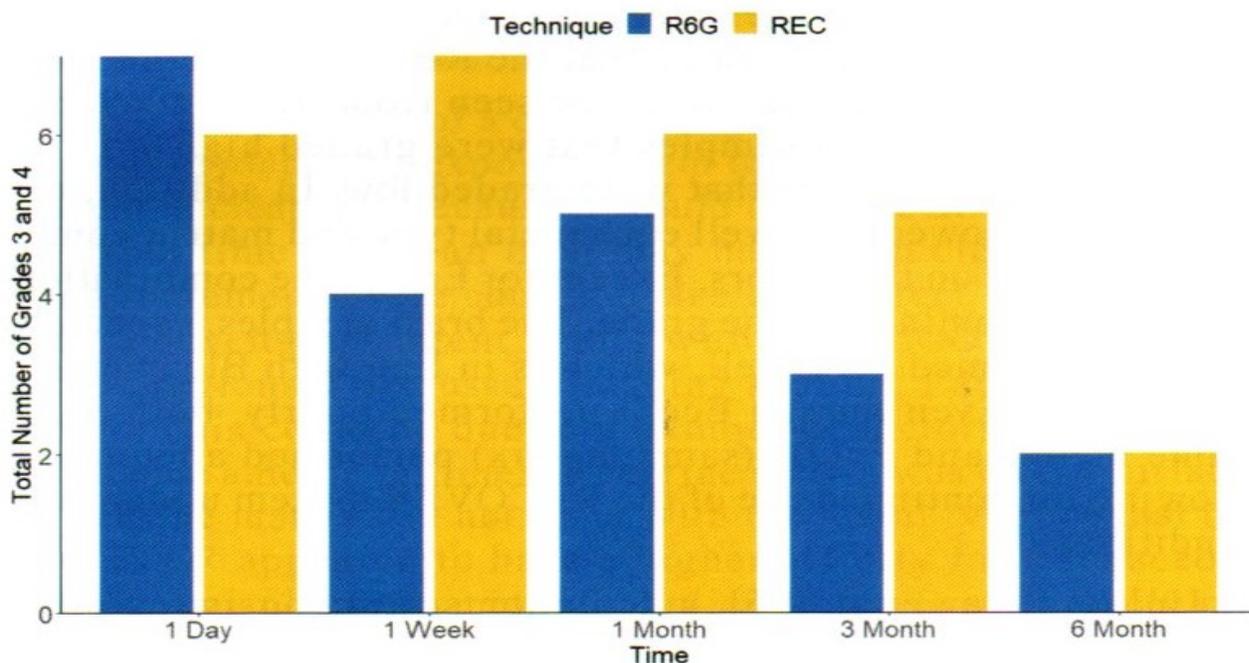
Figure 10

*Comparison of R6G to RECOVER processed samples over time without
regard for metal type or matrix shows a slight advantage for RECOVER with
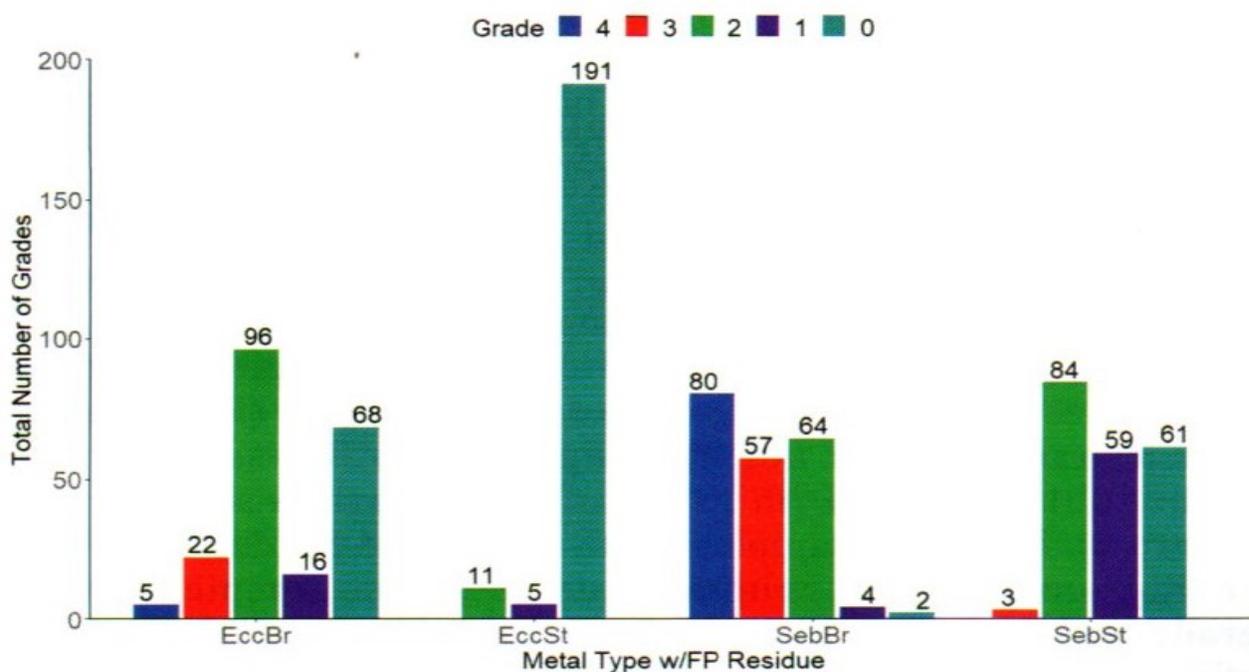the number of grades 3 and 4.*

Figure 11

*All grades from the first phase of the validation were tabulated for each of the
metal types and matrix combinations.*

In the specificity experiment, 37 donors provided samples. This experiment demonstrated that the RECOVER worked well across many of the donors. It can be seen from Appendix A that some donors provided samples that were graded high whereas others provided samples that were graded low. In addition, this experiment showed how well each metal type and matrix combination worked on the donors. Except for EccSt, the combinations were not predominately one grade. The brass samples, especially SebBr, performed very well, which is in line with Bleay et al.'s results [16]. Even though EccSt performed poorly, both SebSt (same metal) and EccBr (same matrix) performed adequately, allowing for continued use of the RECOVER system under these conditions.

Unlike Bleay et al. [16], a depletion series consisting of six depositions was chosen for the practical purposes of the sensitivity experiment. All of the metal and matrix combinations with the exception of EccSt demonstrated some level of ridge development down to the sixth touch. This exceeded the requirement of needing at least the first touch to develop friction ridge detail (one of the objectives of the study).

Early recommendation from Foster and Freeman, likely based on preliminary results from Wilkinson et al. [2], was to prewash everything, to remove other contaminants that may interfere with the RECOVER. Because of these recommendations, this washing regimen was not only chosen for this study but also by Pontone et al. [18] It was discovered later on by Lam et al. [3] that there may have been a misunderstanding regarding what was washed (fired samples) in the Wilkinson et al. study [2]. The idea of cleaning (warm soapy water followed by acetone and paper towel buffing) was meant to be used only after firing. Our data demonstrates that, although brass items can be washed, the grading decreased quite a bit (four samples with a grade of 4 for not washing down to two samples with grade of 4 and two with grade of 3 for washed samples; see Figure 4). The steel samples, both EccSt and SebSt, went from having some samples with a grade of 2 to no sample having a grade higher than 0. These results call into question the utility of washing before processing with the RECOVER system. In addition, during the processing comparison experiment, all of the samples that were processed with the traditional sequence (CAE, R6G, powder) were washed before being processed with the RECOVER and again demonstrated that, although the brass samples can be washed, the grades they received were lower than their unwashed counterpart (Figure 7). The steel samples had

only three samples that were graded higher than 0, all of which were SebSt at the 3-month mark.

After commission of a crime, offenders may attempt to clean items of evidence by exposing them to bleach or other common household cleaners. Because it would likely be difficult to know the exact time frame an item may have been cleaned, several aging increments were chosen to see what effect, if any, bleach had on developing latent prints with the RECOVER. Similar to the previously discussed washing section, EccSt performed poorly. This could be due to a number of factors which could include the amount of time the eccrine matrix was on the surface, the eccrine matrix did not react with the metal type, or that the RECOVER appeared to have a higher affinity for a sebaceous matrix. Any cleaning method applied to EccSt will likely not produce any fingerprints. The SebSt steel fared well with one sample that was graded a 3 and several graded a 2. Bleach did not have as much of an impact on the SebSt samples as the washing regimen did. So, either the soap and water wash, rubbing with acetone, lack of vigorous buffing (samples were only exposed to bleach and rinsed with water followed by dabbing with a towel), or some combination of those factors led to minimal results for the SebSt. Both EccBr and SebBr performed well. Based on the results, the samples were better the older they were. One possible explanation for this was that the matrix had a longer time to react with the metal prior to bleach exposure. Processing with the RECOVER can produce fingerprints on items that have been subjected to bleach, more specifically on the SebSt, EccBr, and SebBr samples.

The results from the first part of the comparison experiment showed that the RECOVER performed on par with the current ISPFS processing sequence. For EccSt samples, the standard sequence (R6G) performed better than the RECOVER (REC) whereas the SebSt and EccBr samples were developed equally well with either technique. The RECOVER produced the best results on SebBr samples. In the second portion of the comparison experiment, the opposite technique than what was done in the first part was applied to the samples in order to observe how the different sequences might interact. Recall that those samples that were processed with the current nonporous sequence were subsequently washed following the protocol of Wilkinson et al. [2] then fumed with the RECOVER (POWREC). All samples received lower grades than at the corresponding R6G step. In fact, almost all of the steel samples received a 0. This was likely due to the washing regimen that was used. Different results may

be obtained if the washing step were omitted. The brass samples fared better than the steel but only received 1 grade of 4 and only 5 grades of 3 compared to the 7 grades of 4 and 12 grades of 3 at R6G. The samples that were initially fumed with the RECOVER were run through the standard sequence and were graded at the dye stain step, not after powder (RECR6G). Often, the steel samples (both EccSt and SebSt) received better grades at the R6G step following the RECOVER than the RECOVER alone. Many times the brass samples, especially SebBr, were graded lower. Based on the results of this phase of the validation, the use of the RECOVER on the steel did not outperform the standard method; however, results may vary based on differing silver-colored metal compositions.

Run Time Consideration

Prior to starting this study, there was concern for overfuming the SebBr samples, so SebBr samples were fumed separately from EccBr samples. SebBr samples were fumed from 5 to 15 minutes where often fingerprints would develop a dark blue color in as little as 3 to 5 minutes. Those samples that were allowed to age for longer periods of time benefited from a longer fume time. EccBr samples were fumed up to 45 minutes to allow enough time for development. The run time for SebBr was similar to the run times reported by Wilkinson et al. [2] and Pontone et al. [18], whereas the run time for EccBr fell in line with Bleay et al. [16] Again, based on pretesting, steel samples were initially fumed for 2.5 hours until a webinar by Foster and Freeman suggested that there is little risk of overfuming silver-colored metal so the fuming process can be launched before leaving for the night and stopped the next morning for a total run time of about 15 hours.

In an attempt to determine whether there is a risk of overfuming, both sebaceous and eccrine fingerprints on brass were fumed with more reagent and for a longer period of time. These brass samples were first processed as if they were silver-colored metal: run overnight (15 hours) with the R2 reagent (Figures 12a and 12b). Although the sebaceous fingerprint (Figure 12a) appeared to have more reagent buildup on the ridges and discoloration in the furrows, the quality of the fingerprints was still very high (representative of a grade 4). The sample with the eccrine fingerprint (Figure 12b) appeared to have a darkened background, with white ridges. The combination of darkened background with white ridges for eccrine fingerprints on brass occurred several times during this validation. Although not as high of quality as the sebaceous fingerprints, the eccrine finger-

print had great quality. These same fingerprints were subjected to another round of R2 for an additional 15 hours (Figures 12c and 12d). It was during this round of excessive fuming that detrimental effects were seen. A halo developed around the sebaceous fingerprints (Figure 12c), the ridges were heavily darkened, and the distinction between ridge and furrow was not as crisp. For the eccrine print (Figure 12d), the background continued to darken, but the contrast between ridge and furrow increased, with some background noise development. With this information, it can be deduced that there is little risk of overfuming sebaceous fingerprints even if they are fumed together with eccrine fingerprints for up to an hour.

(a)

(b)

(c)

(d)
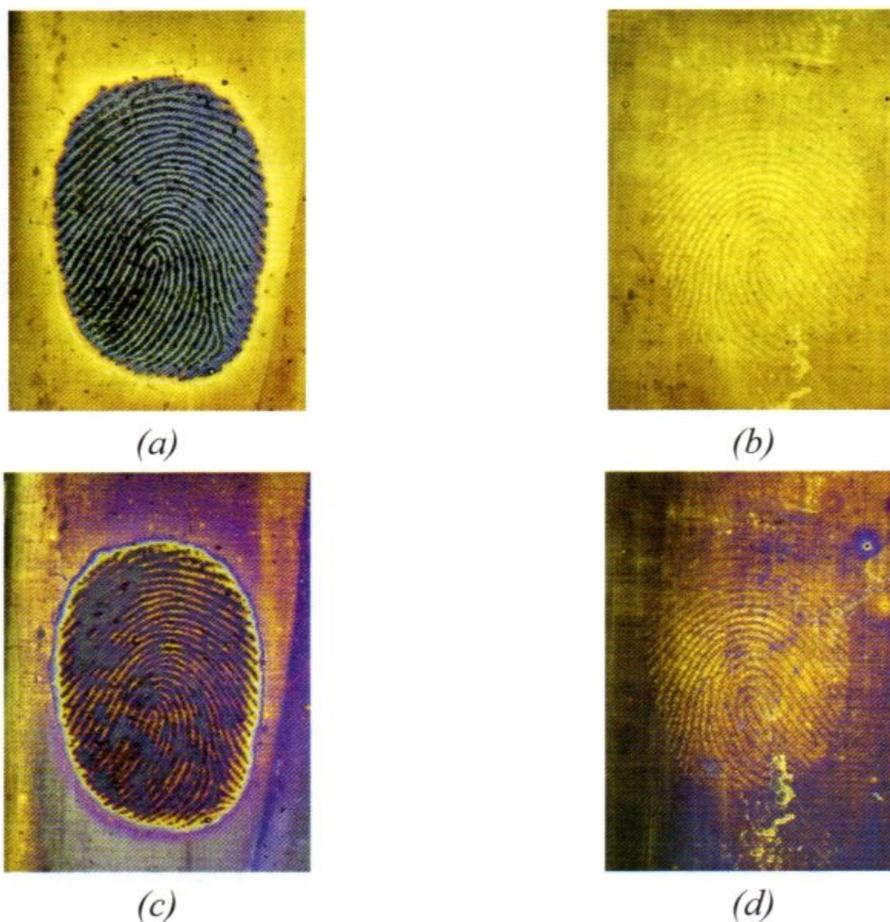
Figure 12

Sebaceous-based and eccrine-based fingerprints on brass were purposefully overfumed with the RECOVER with more reagent (R2, which has been developed for silver-colored metals) for longer run times: (a) sebaceous-based fingerprint run for 15 hours; (b) eccrine-based fingerprint run for 15 hours; (c) sebaceous-based fingerprint run for two 15-hour intervals each with new reagent; and (d) eccrine-based fingerprint run for two 15-hour intervals each with new reagent.

Unusual Samples (Eccrine Fingerprint Color)

Previous research [11, 12] has indicated that fingerprints developed with the S_2N_2 process were blue and black in color. Although this was the case for many of the samples in this study, particularly those samples that were on brass with fingerprints consisting primarily of a sebaceous matrix, there were also many samples where the background darkened revealing white ridges (brass samples with eccrine matrix) and many samples where the fingerprint was yellowish orange (steel samples). Tonal reversed prints (white ridges) were also noted elsewhere [2, 3]. No analysis or investigation into determining the cause or situation that led to the differences in color were performed beyond noting that color differences existed. Occasionally, when digitally processing fingerprints that appeared more yellow in color, adjusting yellow in Photoshop instead of just converting to grayscale produced greater contrast between ridge and furrow.

Steel Chosen

It is important to point out that the results from this study were dependent on the metals chosen (brass and steel). The fingerprints on the steel, especially the steel samples with an eccrine matrix (Figure 11), did not develop to the level of the brass samples. The steel was not stainless, which was the type of steel chosen in other studies [16, 17] and although the stainless-steel results from those studies appeared to have performed better than the steel in this study, the stainless steel overall did not perform as well as the other metal types [16]. The steel in this study was chosen at the recommendation of the metal supplier.

Continued Development

In a few instances, some ridge detail faded from one day to the next. For this reason, it is recommended that samples be photographed soon after processing. Opposite to this, one donor's sensitivity set on brass at some point over the course of three months after processing greatly improved (Figure 13). It is unknown at what point the development improved or what caused the change. Photographing the improvement proved difficult because of the coaxial light guide not being able to capture an adequate image. Figure 13b was ultimately photographed in the dark with a long shutter speed.
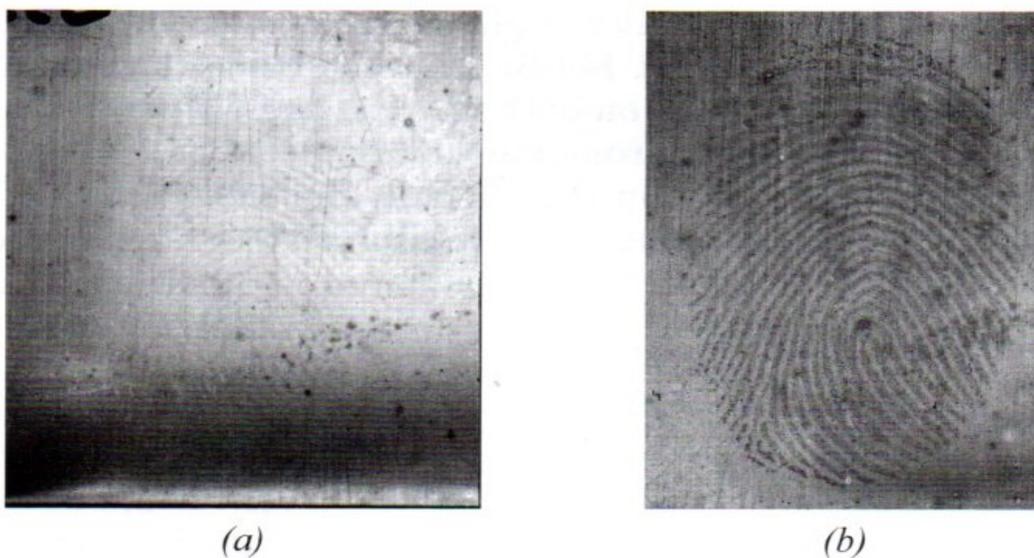
(a)   *(b)*

Figure 13

Images of the same fingerprint photographed three months apart:
(a) photographed in July 2021 and (b) photographed in October 2021.

Conclusions

This study evaluated the commercially available RECOVER instrument and consisted of controlled experiments on brass and steel plates. Conditions that were tested included specificity, sensitivity, prewashing items, bleach, aging, and comparison to a standard processing sequence. The specificity experiment showed that fingerprints can be developed from the majority of donors with the RECOVER. As was expected, there was a wide interperson variation in the quality of prints; some donors had fingerprints that were graded high whereas others had fingerprints that were graded low. The highest grades were seen on SebBr, followed by EccBr. For the sensitivity experiment, the grades from the first touch to the last touch decreased on three of the four metal and matrix combinations (EccBr, SebBr, SebSt). EccSt had only one instance of a grade higher than 0. Apart from EccSt, this experiment accomplished the goal of friction ridge development on the first set of fingerprints in the depletion series but also showed that high grades could be achieved even at the sixth touch in the depletion series for SebBr. During the prewash experiment, samples that were washed prior to being processed with the RECOVER did not receive as high of grades as those that were not washed. The data from this experiment showed that prewashing is not optimal, especially with regard to the steel. Some instances of friction ridge detail were noted on brass after washing, but these were generally not graded as high as those that had not been washed. The aging experiment

demonstrated that there was a slight decrease in grades for most samples other than SebBr. SebBr showed strong development from 1 day up to 6 months on both the first and fifth touches. In general, there was not a strong correlation between the amount of time a print was left on the surface and the quality of its development. This experiment also reinforced that higher graded samples were obtained on SebBr compared to other matrix and metal types. The bleach experiment demonstrated that development could be obtained after exposure to bleach, even on steel. Although the outcome of this experiment did not affect the main goals of the study, it was good to see that should a perpetrator try to clean evidence with bleach, the RECOVER could develop friction ridge detail. In the comparison to the standard processing sequence experiment, the RECOVER slightly outperformed the standard sequence. This was due in part to how well SebBr developed friction ridge detail. Although the RECOVER works well as a standalone method, more testing is needed to determine whether it should be incorporated into a processing sequence.

Overall, ISPFS' objectives were achieved. The majority of donors developed friction ridge detail. With the exception of EccSt, friction ridge detail was able to be developed up to the sixth touch in a depletion series. Again, with the exception of EccSt, friction ridge detail was developed on the majority of aged samples. Finally, the RECOVER met the objective of performing equal to or better than the standard processing sequence.

Additional consideration for RECOVER testing includes natural matrix and handling conditions, different metal compositions and items, environmental conditions, the impact of prewashing fired cartridges, and continued comparison between the RECOVER and the standard processing sequence.

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