Nicole Rapino

901709360

FSC 630 Forensic Science Internship

Marshall University Forensic Science Program

MU Topic Advisor: Dr. Pamela Staton (Reviewer)

Internship Agency Supervisor: Mr. Steven King, Tel. # 304-746-2185,

Stephen.c.king@wvsp.gov (Reviewer)

Internship Agency: West Virginia State Police, 725 Jefferson Rd. South Charleston WV, 25309,

Tel. #304-746-2185.

Technical Reviewer: Mrs. Catherine Rushton (Reviewer)

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Latent Print Development on Duct Tape Using Rhodamine 6G/ Tween 20 Solution on Simulated Evidence Samples

Nicole Rapino, BA

Marshall University Forensic Science Graduate Program

1401 Forensic Science Drive, Huntington, WV 25701

Stephen C. King

West Virginia State Police Forensic Laboratory

725 Jefferson Road, South Charleston, WV 25309

Catherine Rushton, MS

Marshall University Forensic Science Graduate Program

1401 Forensic Science Drive, Huntington, WV 25701

Pamela Staton, PhD

Marshall University Forensic Science Graduate Program

1401 Forensic Science Drive, Huntington, WV 25701

Abstract

Forensic examiners are able to obtain multiple forms of information from gray duct tape submitted as evidence to a crime. While this can include DNA and trace evidence, it is also possible to apply one of the oldest forensic disciplines: the development and examination of latent fingerprints. The development of latent fingerprints from duct tape can afford the forensic examiner undeniable information about the individuals who handled the tape, which may include a victim or a suspect. While there are multiple techniques used to process adhesive tape for latent prints, currently different procedures are employed for the processing of the adhesive side versus the non-adhesive side. A parent study to the research presented in this paper optimized a rhodamine 6G/tween 20 solution that was successful in allowing both sides of gray duct tape to be simultaneously developed for latent prints after cyanoacrylate fuming, therefore shortening the overall processing time and materials. The results obtained from the former study were dependent on the use of pristine tape samples not often received as evidence, whereas the focus of this research involves validating this optimized solution for use on tape samples representative of the conditions commonly found in real-life crime scenes.

The research presented summarizes the results obtained when samples of gray duct tape were prepared to simulate real-life evidence samples, separated, and subsequently processed for latent fingerprints. Tape sample preparation involved attaching the samples adhesive side to adhesive side, adhesive side to non-adhesive side, and simulations meant to represent the binding of a victim. Tape separation techniques included three currently employed by the West Virginia State Police Forensic Laboratory (WVSPFL), including the use of adhesive neutralizer un-du (un-du Inc., St. Louis Park, MN), a freezing technique, and the application of liquid nitrogen. After separation, each tape sample was processed using one of three processing techniques: rhodamine 6G/tween 20 solution, crystal violet (adhesive side) or P-methoxybenzylamino-4-

nitrobenz-2-oxa-1,3-diazole (MBD) (non-adhesive side). This paper also discusses three additional sub studies performed for troubleshooting purposes. The first sub study involved the investigation of seven basic strength gray duct tapes of different brand names, and the results obtained from processing with the optimized rhodamine 6G/tween 20 solution. The second and third sub studies investigated how two different fuming techniques and three different alternative light sources may affect the performance of the rhodamine 6G /tween 20 solution. Developed prints resulting from this research were rated on a five point Likert scale based on ridge detail obtained from the different separation and processing techniques. Results obtained in this study supported the conclusion that the parent study's optimized rhodamine 6G/tween 20 solution is a successful method for developing latent fingerprints simultaneously on both the adhesive and non-adhesive sides of gray duct tape, and produces results of equal if not better quality to two currently used processing methods for gray duct tape.

Introduction

Forensic Crime Laboratories are inundated with evidence from a variety of criminal acts on a regular basis. Items of evidentiary value can come in many forms, from those one would expect to see, like weapons and blood covered clothing, to those that would be surprising, like rocks and items of food. This variety often includes items commonly found in a household, one such example being gray duct tape. Gray duct tape is a product that even the most naïve to handyman services is familiar with, and it can be found rather inexpensively in most grocery, convenience, and hardware stores. Unfortunately this tape, known for its strong adhesive properties, is not only used in home improvement, but is commonly used in the commission of crimes, ranging from the packaging of drugs and explosives to the binding of victims. This illicit

use of duct tape has made it a reoccurring item seen in today's crime laboratories.
One of the most important pieces of forensic information that may be obtained from tape submitted as evidence is identification of suspects through latent fingerprints. Gray duct tape is the most widely encountered tape by fingerprint examiners, due to its reputation as a strong adhesive binder, and its ease in obtainment both financially and physically. Gray duct tape has been analyzed for fingerprint evidence for many years, and forensic laboratories nationwide have adopted a number of successful methods for processing these samples. One existing challenge is that common practice has shown that the adhesive side of duct tape needs to be processed separately from the non-adhesive side. Due to the different physical properties of the adhesive side versus the non-adhesive side, different processing techniques are also required to process each side of the tape. This challenge increases the time and the supplies it takes to fully process a piece of duct tape. In a study performed by Aldo Maldonado and Catherine Rushton, from the forensic science master's program at Marshall University, in conjunction with Stephen King from the West Virginia State Police Forensic Laboratory (WVSPFL), an optimized solution of the fluorescent dye rhodamine 6G, distilled water, and the ionic surfactant tween 20 was produced and shown to have success in simultaneously developing latent fingerprints on both sides of gray duct tape.[1] The success of the Maldonado, Rushton, King, and Staton study opened the door for the research that will be discussed in this report. Building on the results reported from the previous study which optimized the rhodamine 6G/tween 20 solution using pristine duct tape samples, the research discussed here will attempt to report similar success for samples labeled non-pristine, and meant to represent duct tape evidence commonly encountered at crime scenes.

To obtain latent prints from a piece of gray duct tape, it is necessary to chemically process the tape to make the prints visible. A challenge that is often faced before chemical processing can begin is the separation of the tape. Depending on the nature of the crime, tape samples encountered can be layered adhesive side to non-adhesive side, as in the case of taping bombs or drug packages, they can be found adhesive side to adhesive side, or a variety of both which is often the case in the binding of victims. Scenarios like these present the latent print examiner with the challenge of separating the tape before processing can continue. There are a few techniques currently utilized by examiners to complete this task. These include the use of adhesive neutralizers such as the commercial product un-du (un-du Inc., St. Louis Park, MN). Studies done on the separation of tape have reported success using this product primarily when presented with samples stuck adhesive side to non-adhesive side. A study performed by Tania Kapila and Katherine Hutches involved methods for separating duct tape including the use of un-du, and reported a high degree of difficulty when separating duct tape adhered adhesive side to adhesive side, with no success in development of latent prints on the adhesive side.[2] A second technique that has also shown better success with separating duct tape adhered adhesive side to non- adhesive side involves a freezing method, often performed by allowing duct tape evidence samples to sit in a freezer for a number of days, and beginning separation attempts immediately following removal from the freezer. Research performed by Björgvin Sigurðsson and Andrea McDonald on the separation and development of fingerprints on adhesive tapes, reported successful results using a freezing method. Their research reported successful separation and development of latent prints using a -80°C freezer on duct tape samples adhered adhesive side to non-adhesive side.[3] A third separation technique that has been shown to successfully develop latent prints on duct tape stuck not only adhesive side to non-adhesive side, but also adhesive side to adhesive side, is the utilization of liquid nitrogen. The application of liquid nitrogen, at approximately -195.8°C, allows the duct tape samples to be frozen at extremely low temperatures, lower even then the freezer technique can accomplish, and has shown to improve separation ability. A case study by B.G. Stephens involving the separation of duct tape by liquid nitrogen from a homicide victim, resulted in the successful development of latent prints on both the adhesive and non-adhesive side of tape that had been stuck adhesive side to non-adhesive side.[4] A second study by James Bailey showed similar success with developing latent prints on duct tape adhered adhesive side to non-adhesive side, this time with the use of a nitrogen cryogun, which is a device used to spray the liquid nitrogen.[5] In addition, a study performed by Joshua W. Bergeron on the use of liquid nitrogen for tape separation, reported success in developing latent prints on both sides of duct tape adhered adhesive side to adhesive side. It is important to note that in the Bergeron study only certain duct tapes were tested, with only a portion showing success in latent print development. The author notes that different duct tapes having different adhesive properties may show different results from those found in the Bergeron study. The tape chosen for the study discussed in this paper was not included in Bergeron's, so no prior assumptions could be made as to how this particular brand would react with the liquid nitrogen separation.[6] The results reported from this literature indicate that, like one would expect, separating the adhesive side of one piece of duct tape from the adhesive side of a second piece of duct tape presents with high levels of difficulty, thereby also proving further development and recovery of latent prints less than likely. Commercial adhesive neutralizers such as un-du, along with freezing techniques have shown success with separation of the adhesive side of duct tape from the non-adhesive side, with the application of liquid nitrogen being the only one to show success developing latent prints on tape samples stuck adhesive side to adhesive side.

The studies mentioned above employed numerous commonly used developing methods, though the research discussed in this paper was primarily focused on the developmental success of the optimized rhodamine 6G/tween 20 solution used in conjunction with the tape separation techniques. The results obtained from processing with the optimized rhodamine 6G/tween 20 solution were compared to results obtained from processing performed with crystal violet and MBD, the common processes currently used by the WVSPFL to develop the adhesive and non-adhesive side of duct tape sequentially. This extension from the previous study was intended to investigate whether the success of the rhodamine 6G/ tween 20 solution would continue to develop latent prints on both sides of gray duct tape simultaneously using tape samples representing what is seen from real-life crime scenes.

Methods and Materials

All research was performed at the West Virginia State Police Forensic Laboratory (WVSPFL), with a few days of troubleshooting spent at the Marshall University Forensic Science Program's Laboratory at the Fairfield building. Duct tape samples were rated by Stephen King using a 5 point Likert scale based on background interference and ridge detail visibility. A Likert scale applied was the same used in the Maldonado, Rushton, King, and Staton study (parent study); interpretation is summarized in Table 1.

Table 1. Likert Scale Interpretation[1]

1	2	3	4	5

Print is indistinguishable from background and/or background interference prevents visualization of print. No friction ridge detail is present.	Print can be adequately distinguished from background; however no friction ridge detail is present.	Print can be distinguished from background. Some friction ridge detail is present.	Print can be clearly distinguished from background. It is easy to see friction ridge detail.	Print is very clearly distinguished from background and there is no background interference. Friction ridge detail is clearly visible.

Troubleshooting:

Before the separation and processing of any samples, control samples were prepared to show the performance of MBD, crystal violet, and the rhodamine 6G/tween 20 solution on both sides of single pristine samples of the Duck brand Original Strength adhesive gray duct tape (ShurTech Brands, Avon, Ohio). The control samples initially processed using the rhodamine 6G/tween 20 solution failed to produce prints of the same quality as obtained in the Maldonado, Rushton, King, and Staton study. The prints observed in these controls were extremely faint and at times barely discernible from the background. An initial concern was that a different tape was purchased for this study, and that the rhodamine 6G/tween 20 solution was duct tape brand specific. A sub study was performed using seven different gray duct tape brands purchased from five different stores. These include Scotch Multi- Use (Scotch Brand, 3M, St. Paul, MN), Tool Bench (Greenbrier International, Inc. Chesapeake, VA), Duck brand Basic Strength (ShurTech Brands, Avon, Ohio), Duck brand Original Strength (ShurTech Brands, Avon, Ohio), 3M Multi-Purpose (3M, St. Paul, MN), Nashua General Purpose (Nashua Corportation, Vernon, CA) , and Project Source (Project Source LLC, South Florida). These brands were purchased at different stores including Target, Home Depot, Lowe's, Wal-Mart, and the Dollar Store. Three 10 cm pieces of duct tape from each of the seven rolls were prepared by depositing three fingerprints on both the adhesive and non-adhesive sides, after accumulating oils from the face. These samples were cyanoacrylate fumed in the parent study's portable fuming chamber, and processed with the optimized rhodamine 6G/tween 20 solution. The parent study's fuming process involved a disposable cyanoacrylate chamber bag which housed a Styrofoam cup of boiling water for humidity, and five drops of Loctite "Hard Evidence" cyanoacrylate (Henkel Corporation, Westlake, Ohio) placed in an aluminum fuming dish on a heating plate for five minutes. The rhodamine 6G/tween 20 solution was composed of a 10% tween 20 (viscous liquid, cell culture tested, Sigma-Aldrich Corporation, St. Louis, Missouri) solution of 0.05g rhodamine 6G (Lightening Powder Company, Jacksonville, Florida) in distilled water. This process was performed three times, resulting in three trials. The resulting prints were rated on the five point Likert scale by Stephen King, and the average ratings of the three prints deposited on each side of the three samples in each trial are summarized in Table 4 in the results section.

Though the results from the first sub study (Duck Brand Study) were positive for the rhodamine 6G/tween 20 solution, the samples from the Duck brand Original Strength duct tape, which had been showing faint and inconsistent prints in the controls, resulted in prints of good quality in this sub study. This indicated that the reason for the poor results at the WVSPFL was not resolved, and more troubleshooting was necessary. A second sub study was performed based on whether the fuming method was creating a difference in the rhodamine 6G/tween 20 solutions performance. Three 10 cm pieces of the Duck brand Original Strength gray duct tape were prepared with three fingerprints on both sides, fumed in the portable fuming chamber, and then processed with the rhodamine 6G/tween 20 solution. This was repeated with three more samples, the only difference being that these samples were fumed in the WVSPFL's fuming chamber (Air Science, Safefume 485, Fort Myers, Florida). The WVSPFL's fuming chamber was set to an 80% humidity level for twelve minutes, and thirty-five drops of cyanoacrylate was used. Each set of samples from the WVSPFL's fuming chamber and the portable fuming chamber were viewed under the WVSPFL's UltraLite ALS (BMT attachment 450 nm, CAO GROUP INC, West Jordan, Utah), and the Green Crime-Lite (500-525 nm, Foster and Freeman USA Incorporation, Sterling, Virginia) ALS used in the parent study. The average ratings of the three prints deposited on each of the three samples are summarized in Table 5 in the results section for both the adhesive and non-adhesive sides and based on fuming method used.

While conducting the previous sub study, it was observed that although the fuming technique seemed to show no difference in print development, switching between the Green Crime-Lite and the UltraLite ALS's did. The last difference between the parent study and this research was the type of ALS being used to visualize the prints. The WVSPFL utilizes a hand held UltraLite ALS, and the parent study utilized a Green Crime-Lite ALS. Rhodamine 6G is a dye recommended for visualization within 500-550 nm.[7] When attempting to visualize the controls in this study, the green light attachment of wavelength 525 was attached to the UltraLite ALS used by the WVSPFL, and no prints were able to be visualized. The samples were "drenched in green light" and no fluorescence was detected. It seemed as though the intensity was too great. The only attachment that showed any discernible prints using the WVSPFL's UltraLite ALS was the BMT attachment of wavelength 450, which was used originally on the controls and resulted in very faint prints. A second ALS utilized by the WVSPFL, the CRIMESCOPE (350-670 nm, Horiba Scientific, Edison, New Jersey), was investigated and found to easily discern prints at wavelength 515. No success was seen higher than this wavelength, and the CRIMESCOPE did not operate any lower in the 500 wavelength range, though a study performed by Scott Chadwick, investigating dye stain development on latent fingerprints, showed discernible prints using rhodamine 6G at 505 nm.[7] Based on these observations a third sub study was performed to show the difference in the visualization of prints processed with the rhodamine 6G/tween 20 solution based on type of ALS utilized. Three 10 cm pieces of the Duck brand Original Strength gray duct tape were prepared with three fingerprints on both sides, fumed with cyanoacrylate, processed with the rhodamine 6G/tween 20 solution, and then visualized with the WVSPFL UltraLite ALS with the BMT light attachment. This was repeated two more times with three samples each, the only difference being the ALS used. The average rating of the three prints deposited on each of the three samples are summarized in Table 6 in the results section for both the adhesive and non-adhesive sides based on the ALS used.

Controls:

The results obtained from the three troubleshooting sub studies indicated that the problem with the processing method controls was based on the ALS being used. Once this was resolved, the controls were performed again with the expected results. New controls were prepared by depositing three fingerprints on both sides of the Duck brand Original Strength gray duct tape. Both the adhesive and non-adhesive side of three 10 cm single strip pristine tape samples were processed with each technique (crystal violet, MBD, rhodamine 6G/ tween 20), photographed and then rated on a Likert scale based on ridge visibility. The average ratings are summarized in Table 7 in the results section.

Controls were also performed to determine if the separation techniques used in this research would affect print development on pristine samples. Three latent prints were deposited on both the adhesive and non-adhesive sides of a 10 cm piece of Duck brand Original Strength duct tape. Six samples were prepared for each separation technique, allowing two samples from each group of six to be processed by each processing method. The average ratings obtained over the two samples sharing the same separation and processing method are summarized in Table 8 in the results section.

Main Study:

Preparation

Three major variables were considered in this experiment: condition of tape, method of separation, and processing technique. To examine the various conditions of tape when encountered as evidence three subsets were set up under variable 1, including adhesive to adhesive (A/A) samples, adhesive to non-adhesive (A/N-A) samples, and samples simulating the binding of a victim. To examine separation techniques used on tape, three subsets were established under variable 2, including the use of un-du, a freezing technique, and liquid nitrogen. And lastly, to examine the effect of different processing techniques, three subsets were established under variable 3, including rhodamine 6G/tween 20, crystal violet, and MBD. Duck brand Original Strength gray duct tape (ShurTech Brands, Avon, Ohio) was cut into 10 cm strips and used exclusively throughout the experiment.

Under the first two subsets of variable 1 (A/A & A/N-A), 18 samples were prepared for each. Samples for these two subsets were defined as two 10 cm pieces of the gray duct tape placed either adhesive to adhesive or adhesive to non-adhesive. Fingerprints from the thumb, index, middle, and ring fingers were deposited on both sides of both pieces of tape prior to adhering them together. From the 18 samples prepared for each of the two subsets of variable 1 (condition of tape), one third were separated using un-du, one third were separated using a freezer, and the remaining were separated using liquid nitrogen. From each group sharing the same separation technique under each subset of tape condition, one third were processed with the optimized rhodamine 6G/tween 20 solution, one third were processed using crystal violet, and the remaining were processed with MBD. Table 2 summarizes these parameters.

Under the third subset of variable 1 (bound), 18 samples were prepared. Samples were prepared by simulating the binding and struggle of a victim bound by the wrists in gray duct tape. Each binding simulation was performed by wrapping the roll of duct tape around the volunteer's joined wrists four times. Fingerprints from the index, middle, and ring fingers were deposited on both sides of the tape on each revolution around the volunteer's wrists. From the 18 samples prepared, one third were separated using un-du, one third were separated using a freezer, and the remaining one third were separated using liquid nitrogen. From each group sharing the same separation technique, one third were processed with the optimized rhodamine 6G/tween 20 solution, one third were processed using crystal violet, and the remaining third were processed with MBD. Table 2 summarizes these parameters.

Table 2 . Parameters Showing Sample Size Break Down

Variable 1 (Condition)	**Variable 2 (Separation technique)**	**Variable 3 (Processing technique)**	**Time at room temp.**
A/A, A/N-A, or Bound (18 samples)	un-du (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks(1 sample)
			24hrs(1 sample)
		Crystal Violet (2 samples)	4wks(1 sample)
			24hrs(1 sample)
		MBD (2 samples)	4wks(1 sample)
			24hrs(1 sample)
	Freezer (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks(1 sample)
			24hrs(1 sample)
		Crystal Violet (2 samples)	4wks(1 sample)
			24hrs(1 sample)

		MBD (2 samples)	4wks(1 sample)
			24hrs(1 sample)
	Liquid Nitrogen (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks(1 sample)
			24hrs(1 sample)
		Crystal Violet (2 samples)	4wks(1 sample)
			24hrs(1 sample)
		MBD (2 samples)	4wks(1 sample)
			24hrs(1 sample)

Time Sensitivity

After the preparation of each sample under the subsets of variable 1(condition of tape), one half of each subset (18 samples per subset) was set aside to sit at room temperature for four weeks before any separation technique was employed. The remaining half was set aside for twenty four hours at room temperature before any separation technique was employed. This was done to record any changes in ease of separation or success of latent print development that might occur when time is manipulated as an additional variable.

Separation

From the sample size of 18 tape samples which sat at room temperature for four weeks, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound samples were separated using un-du. The un-du was applied drop by drop to a starting edge, and the tape was slowly peeled back. The separated end was anchored by a close pin to prevent the tape from sticking back together during the progression of separation. Drops of un-du were added continuously, followed by slow attempts to peel the sample apart after every drop-wise addition of un-du. From the original sample size of 18 which sat at room temperature for four weeks, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound tape samples were separated by placement in a freezer.

The samples were kept in an evidence freezer at the lab at ~ -20°C for two days, and immediate manual "pull apart" separation attempts were performed when removed. The freezer used in this study was the only one available to the lab, and so was of a different temperature capability from the one previously mentioned in the literature. From the remaining samples of the original 18 samples, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound tape samples were separated by application of liquid nitrogen. The tape samples were dipped into a pan of liquid nitrogen, and immediately the tape was slowly peeled back. Small amounts of liquid nitrogen were slowly poured continuously followed by attempts to peel after every application. The same three separation procedures were followed for the 18 twenty four hour samples, utilizing the same sample size breakdown for each process.

Development

Prior to the chemical processing, all samples, excluding those to be processed with crystal violet, were fumed with MicroBurst Cyanoacrylate glue (EVIDENT, Union Hall, VA) in the Safefume 485 chamber. From a sample size of 27 tape samples (the sum of half of each subset of variable 1) that were set aside to sit at room temperature for four weeks, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound tape samples were processed on both sides using the optimized rhodamine 6G/tween 20 solution. The rhodamine 6G/tween 20 solution was prepared with a 10% tween 20 (Polyoxyethylene 20-sorbitan monolaurate, Fisher Scientific, Fair Lawn, New Jersey) solution of 0.05g of rhodamine 6G (Acros Organics, Somerville, NJ) in distilled water. The separated tape samples were completely submerged in the solution for 15 seconds then rinsed under cool, gently running tap water and left to dry. The resulting samples were visualized with red goggles and the CRIMESCOPE ALS at 515 nm, and any ridge detail was documented with a digital SLR camera having a 1% orange-red (549 nm) long pass filter. From the original sample size of 27 tape samples that were set aside to sit at room temperature for four weeks, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound tape samples were processed on both sides using crystal violet. The crystal violet solution was prepared according to WVSPFL's procedural manual, using a solution of 0.1g of crystal violet crystals to 100 ml of distilled water.[8] The solution was applied to both sides of the separated tape samples and rinsed under cool, gently running tap water and left to dry. The resulting samples were visualized under ambient light and any ridge detail was documented with a digital SLR camera. From the original sample size of the 27 tape samples that were set aside to sit at room temperature for four weeks, 3 adhesive to adhesive, 3 adhesive to non-adhesive, and 3 bound tape samples were processed on both sides using P-methoxybenzylamino-4-nitrobenz-2-oxa-1,3-diazole (MBD). The MBD working and stock solutions were both prepared according to WVSPFL's procedural manual.[8] The MBD stock solution was prepared with 100 mg of MBD in 100 ml of acetone. The working solution was prepared with 10 ml of the stock solution combined with 30 ml of methanol, 10 ml of 2-propanol, and 950 ml of petroleum ether. The separated tape samples were completely submerged in the solution for 5 seconds and allowed to dry. The resulting samples were visualized under the UltraLite ALS and any ridge detail was documented with a digital SLR camera with a 1% orange-red (549 nm) long pass filter.

The steps described in the previous section were duplicated for the sample size set aside to sit at room temperature before separation for twenty four hours, using the same numbers for each subset of variable 1 (condition of tape). Print ratings for these samples are summarized in the results section in Tables 9, 10, 11, & 12.

Visualization and Documentation

Resulting prints were photographed using a digital SLR Nikon camera with the parameters tabulated below.

Table 3. Camera Settings for Rhodamine/Tween 20, Crystal Violet and MBD Documentation

Camera	ISO	F-stop	Shutter speed
Nikon	200	10	3,5,8

Results

Troubleshooting studies:

The ratings that resulted from sub study 1(Duct Tape Brand Study) did show some variance in the development of latent prints on the seven different brands of gray duct tape using the rhodamine 6G/tween 20 solution. The Scotch Multi-Use brand resulted in the highest average adhesive side print rating of a 4.6 on the Likert scale, with its most frequent rating being a 5. This brand also visually showed the least background fluorescence across samples. Differences seen in background fluorescence among brands may be attributed to the differing adhesive composition of the adhesive backing on the tape, and how the dye solution reacted to it. The other six tape brands resulted in average adhesive side print ratings ranging from 3.0 to 3.9, with the lowest being Project Source at 3.0. The brands Project Source, Duck Basic Strength, and 3M Multi-Purpose produced the most background fluorescence, corresponding to their lower average adhesive side print ratings and most frequent print rating of 3. The brand Tool Bench had the highest average non-adhesive side print rating of 4.4, with its most frequent rating of 4. Brands Scotch Multi-Use and 3M Multi-Purpose both resulted in comparable ratings, with an average non-adhesive side rating of 4.3 and most frequent rating of 5. The brands Duck Original Strength and Project Source tied for the lowest average non-adhesive side print rating of 3.5, and most frequent print rating of 3. Duck Original Strength and Scotch Multi-Use had the lowest difference in print ratings between their adhesive and non-adhesive sides (differences of 0 and .3 respectively), not necessarily making them both the best performing brands, since Duck Original Strength had one of the lowest non-adhesive side print ratings, but indicating successful equivalent development of both the adhesive and non-adhesive sides. Even with the varying average ratings among brands, all seven rated above a 3 on both their adhesive and non-adhesive sides, and no brands exceeded a difference of 1 point on the scale between the ratings of their adhesive versus non-adhesive sides, meaning ridge detail was obtained equivalently on both sides across the board. These results are summarized in Table 4.

Table 4. Average Ratings for Duct Tape Brand Sub Study

Brand	Average Adhesive Side Rating	Adhesive Side Mode	Average Non-adhesive Side Rating	Non-adhesive Side Mode
Scotch Multi	4.6	5	4.3	5
Tool Bench	3.6	4	4.4	4
Duck Basic	3.6	3	4.1	4
3M	3.3	3	4.3	5

Duck Original	3.5	4	3.5	3
Nashua	3.9	4	4.3	4
Project Source	3.0	3	3.5	3

The results from sub study 2 (Fuming Technique Study) showed that the average adhesive side print ratings of samples fumed with the WVSPFL fuming chamber were not significantly different from those obtained from the samples fumed with the portable chamber while using the same ALS. The WVSPFL chamber averaged a rating of 4.1 with the Green Crime-Lite handheld light source, and a 3.0 with the UltraLite handheld light source, while the portable chamber averaged a rating of 4.3 with the Green Crime-Lite and 2.9 with the UltraLite. The difference between ratings obtained from the different fuming chambers was more noticeable in the numbers obtained from the non-adhesive sides of the samples, but even the range from 4.1 (for the WVSPFL chamber with the Green Crime- Lite) to 3.6 (for the portable chamber with the Green Crime-Lite), and 3.4 (for the WVSPFL chamber with the UltraLite) to 3.0 (for the portable chamber with the UltraLite), was still not a significant difference in average print ratings, as all combinations obtained most frequent ratings of 3 or above indicating the presence of ridge detail. The results from this sub study did not indicate a significant difference in ratings given to prints developed from either fuming method. This indicated that the fuming technique was also not causing the failure to replicate the parent study's results with the controls of this study. Since the fuming method was determined to not have an effect on the development of latent prints, the remainder of this research utilized the WVSPFL's fuming chamber. These results are summarized in Table 5.

Table 5. Average Ratings for Fuming Technique Sub Study

Fuming Technique	**Alternative Light Source**	**Average Adhesive Rating**	**Adhesive Mode**	**Average Non-adhesive Rating**	**Non-adhesive Mode**
WVSPFL Chamber	Green Crime-Lite	4.1	4	4.1	4
	UltraLite	3.0	3	3.4	3
Portable Chamber	Green Crime-Lite	4.3	5	3.6	4
	UltraLite	2.9	3	3.0	3

The final troubleshooting sub study was performed based on observations made in sub study 2, and involved the investigation of different alternative light sources. The average adhesive print ratings obtained from the samples when visualized under the CRIMESCOPE and Green Crime-Lite resulted in the highest average print ratings of 3.9 and 4.1 respectively, with the UltraLite resulting in an average print rating of 3.0. The same average ratings were seen on the non-adhesive sides of these samples for both the CRIMESCOPE and Green Crime-Lite, with the UltraLite scoring slightly higher with an average non-adhesive print rating of 3.4. These results indicate that the CRIMESCOPE and Green Crime-Lite fall within the wavelength (~515nm) for the best visualization of the rhodamine 6G/tween 20 solution, resulting in better visualization of developed prints than the UltraLite. This can be seen with the most frequent rating for both the CRIMESCOPE and Green Crime-Lite being a 4, while UltraLite resulted in a most frequent rating of 3. Since the CRIMESCOPE ALS was determined to have the same success on the visualization of latent prints as the parent study's Green Crime-Lite ALS, the remainder of this research utilized the WVSPFL's CRIMESCOPE ALS for all rhodamine 6G/tween 20 samples. These results are summarized in Table 6.

Table 6. Average Ratings for Alternative Light Source Sub-Study

Alternative Light Source	Average Adhesive Rating	Adhesive Mode	Average Non-adhesive Rating	Non-Adhesive Mode
CRIMESCOPE	3.9	4	3.9	4
Green Crime-Lite	4.1	4	4.1	4
UltraLite	3.0	3	3.4	3

Controls:

Once the troubleshooting was complete, controls for the main tape separation study were performed. The controls for the processing methods resulted in the rhodamine 6G/tween 20 solution having the highest average print rating of 4.7 for the adhesive side. The MBD process, a common non-porous technique, came in second with an average adhesive print rating of 3.6. The highest average print ratings for the non-adhesive sides showed similar performance for both MBD and the rhodamine solution, with a 4.8 and 4.7 respectively. Crystal violet consistently produced developed prints at a rating of 2, with no ridge detail on the non-adhesive side, though had a most frequent rating of 3 for the adhesive sides. The average rating of the latent print development on the samples processed with rhodamine 6G/ tween 20 solution outperformed crystal violet on both the adhesive and non-adhesive sides. The samples processed with crystal violet resulted in very low ratings. This was expected for the non-adhesive side but not for the adhesive side, which resulted in a most frequent rating of 3, due to crystal violets common use as a processing method for the adhesive side of tape.[9] This deviation is believed to be due to the darker color of the adhesive side, which made the visibility of the dye very difficult. Though other processes have been shown to perform better on darker tapes, the brand used in this study was labeled and visibly seen as gray, and the WVSPFL latent print examiners concluded that crystal violet would be their chosen process if this tape were presented to them as evidence. The rhodamine 6G/tween 20 solution also outperformed MBD development on the adhesive side, and achieved comparable ratings to MBD on the non-adhesive side. The rhodamine 6G/tween 20 solution presented with identical development capabilities for both the adhesive and non-adhesive sides, with identical average ratings of 4.7 and most frequent ratings of 5. Overall, the results from these controls support the rhodamine 6G/tween 20 solution's success in the parent study, as well as confirm the reliability of crystal violet and MBD as developmental processes for duct tape. These results are summarized in Table 7.

Table 7. Average Control Ratings for Processing Method

Processing Method	**Avg. Adhesive Side Rating**	**Adhesive Mode**	**Avg. Non-adhesive Rating**	**Non-adhesive Mode**
MBD	3.6	4	4.8	5
Crystal Violet	3.1	3	2.0	2
Rhodamine 6G/T20	4.7	5	4.7	5

Controls prepared to investigate the effects of the separation techniques were performed next. The ratings from these controls show that use of adhesive neutralizer un-du had the most effect on print development. Since these samples were single pieces of tape and did not need to be separated, the un-du was applied by adding drops along the length of the tape samples on both sides. This resulted in the addition of more un-du than was actually needed to separate adhesive to non-adhesive samples, but less than was found to be needed to separate adhesive to adhesive samples. When visualized with the ALS, it was seen that the drops of un-du that had landed on the latent prints obscured them to some extent, affecting their subsequent rating. This is shown in the increase of print ratings of 3 on both sides of the tape, for both MBD and the rhodamine

6G/tween 20 processed samples. Crystal violet, which had previously shown some ridge detail on the adhesive side of the previous controls, also showed a decrease in average print ratings with a most frequent adhesive side rating of 2. The application of liquid nitrogen and the placement of the samples in a freezer seemed to have little effect on the development of prints in these controls. Average adhesive and non-adhesive print ratings for both the rhodamine 6G/tween 20 solution and MBD processed samples were comparable with most frequent ratings being 4 and 5. The crystal violet samples also returned to higher average adhesive side print ratings. Overall, without separation, the application of liquid nitrogen and the freezing of samples had no negative effect on development of prints no matter the processing technique. On the other hand, the application of un-du without separation obscured the development of latent prints, and lowered the most frequent print ratings obtained from control samples processed by all three methods. These results are summarized in Table 8.

Table 8. Average Control Ratings for Separation Technique

Separation Technique	Processing Method	Avg. Adhesive Side Rating	Adhesive Mode	Avg. Non-adhesive Rating	Non-adhesive Mode
un-du	MBD	3.5	3&4	3.5	3&4
	Crystal Violet	2.3	2	1	1
	Rhodamine 6G/T20	4	3&4&5	3.3	3
Liquid Nitrogen	MBD	4.2	4	4.3	5
	Crystal Violet	3.7	4	1	1
	Rhodamine 6G/T20	4.7	5	4.3	5
Freezer	MBD	4.5	4&5	5	5
	Crystal Violet	2.7	3	1	1
	Rhodamine 6G/T20	5	5	5	5

Separation Study Results:

Adhesive sides of Adhesive to Adhesive samples

Adhesive to adhesive samples that were separated using the adhesive neutralizer un-du, resulted in obvious changes in the condition of the tape's adhesive backing. The adhesive often became "mushy", and was seen to separate from the backing of the tape. The samples left to sit at room temperature for four weeks before being separated showed no latent print development when processed with any of the three processing techniques, resulting in an average rating of 1. The twenty four hour samples processed with the rhodamine 6G/tween 20 solution or crystal violet both showed a faint outline of the deposited prints, with no ridge detail, and resulted in average print ratings of 1. The twenty four hour sample processed with MBD showed only one developed latent, also faint with light ridge detail and resulting in an average print rating of 1.3. It's possible the process of separation was too destructive on the adhesive backing of the tape to preserve latent prints, resulting in little to no ridge detail.

Adhesive to adhesive samples that were separated using liquid nitrogen also resulted in damage to the adhesive sides of the tape samples. The adhesive often cracked and separated from the tape backing during separation attempts. The four week samples processed with MBD and crystal violet showed no latent print development and resulted in an average print rating of 1. The four week sample processed with the rhodamine 6G/tween 20 solution showed multiple developed prints with ridge detail appearing on parts of the tape that had less damage to the adhesive. These samples resulted in an average print rating of 2.5, with a most frequent rating of 3, indicating the presence of ridge detail. The twenty four hour sample processed with the rhodamine 6G/tween 20 solution also showed latent development with ridge detail, and resulted in an average print rating of 2.9 with a most frequent rating of 3. The twenty four hour sample processed with MBD developed two prints showing ridge detail, which resulted in an average print rating of 1.8. The twenty four hour sample processed with crystal violet resulted in only one print showing ridge detail resulting in an average print rating of 1.3. It seems that the process of separation was too destructive on a majority of these samples, but the increase in ridge detail seen for the samples processed with crystal violet and MBD may be the result of the “freshness” of the twenty four hour deposited prints.

Adhesive to adhesive samples that were placed in a freezer could not be separated, and therefore the adhesive sides of these samples were not processed. The samples were too difficult to separate, even after repeated placements in the freezer. This result was not affected by the time left to sit at room temperature before separation.

Overall, the rhodamine 6G/tween 20 solution was successful in developing ridge detail on the adhesive side of tape stuck adhesive to adhesive when liquid nitrogen was applied as a separation technique. The rhodamine 6G/tween 20 solution also outperformed crystal violet, a current processing technique used to develop the adhesive side of tape. Surprisingly MBD, a current processing technique for the non-adhesive side of tape, also showed some success in the development of ridge detail when liquid nitrogen was used. This is a promising result for both processes, since the separation of tape stuck adhesive to adhesive is not often accompanied by successful latent print development.

Non-adhesive sides of Adhesive to Adhesive samples

Adhesive to adhesive samples that were separated using the adhesive neutralizer un-du, showed latent print development on the non-adhesive sides of the tape samples when processed with both MBD and the rhodamine 6G/tween 20 solution. The four week MBD sample resulted in an average print rating of 3.5, with the twenty four hour sample resulting in an average print rating of 5. The four week rhodamine 6G/tween 20 sample resulted in an average print rating of 4.1, with the twenty four hour sample resulting in an average print rating of 4.8. The lower ratings may be attributed to damage to the prints during the separation process. For example, un-du accidentally getting on the non-adhesive side or tape manipulation as separation was attempted. The four week and twenty four hour samples processed with crystal violet resulted in no developed prints on the non-adhesive sides of the samples. This was an expected result based on crystal violets performance in the controls.

Adhesive to adhesive samples that were separated using liquid nitrogen also showed latent development on their non-adhesive sides when processed with both MBD and the rhodamine 6G/ tween 20 solution. The four week MBD sample resulted in an average print rating of 4.4, with the twenty four hour sample resulting in an average print rating of 3.5. The four week rhodamine 6G/tween 20 sample resulted in an average print rating of 3.3, with the twenty four hour sample resulting in an average print rating of 4.9. The prints developed on the non-adhesive sides of the samples processed with MBD and the rhodamine 6G/tween 20 solution were at times “smeared” with ridge detail no longer easily visible. These defects were most likely caused by the separation process, due to the excessive handling needed when applying the liquid nitrogen. This may be an explanation for the decrease in the ratings of the twenty four hour MBD and four week rhodamine samples. The four week and twenty four hour samples processed with crystal violet resulted in no developed prints on the non-adhesive sides of the samples. This was an expected result based on crystal violets performance in the controls.

Adhesive to adhesive samples placed in a freezer could not be separated, but the non-adhesive sides of these samples resulted in an average print rating of 4.6 for the four week MBD sample, and an average print rating of 3.5 for the twenty four hour MBD sample. The four week rhodamine 6G/tween 20 sample resulted in an average print rating of 3.8, with a 3.6 rating for the twenty four hour sample. The lower ratings obtained from these samples as compared to those from the development process controls, could be contributed to excessive handling and the attempts at separation. The four week and twenty four hour sample processed with crystal violet resulted in no developed prints on the non-adhesive sides of the samples. This was an expected result based on crystal violets performance in the controls.

Overall, the rhodamine 6G/tween 20 solution proved successful in developing ridge detail on the non-adhesive side of tape samples stuck adhesive to adhesive. This optimized processing solution obtained comparable, and at times better, ratings to MBD, a current processing technique for the non-adhesive side of tape. Table 9 summarizes the average ratings obtained from the adhesive to adhesive samples, based on separation method and development technique.

Table 9. Average Ratings from A/A Samples of Identical Variables 1, 2, &3.

Variable 1 (Condition)	**Variable 2 (Separation technique)**	**Variable 3 (Processing technique)**	**Time at room temp**	**Adhesive**		**Non-adhesive**	
				Av. Rating	**Mode**	**Av. Rating**	**Mode**
Adhesive to Adhesive (18 samples)	un-du (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	1	1	4.1	4&5
			24hrs	2.1	2	4.8	5
		Crystal Violet (2 samples)	4wks	1	1	1	1
			24hrs	1	1	1	1
		MBD (2 samples)	4wks	1	1	3.5	3&4
			24hrs	1.3	1	5	5
	Freezer (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	N/A	N/A	3.8	3
			24hrs	N/A	N/A	3.6	3

		Crystal Violet (2 samples)	4wks	N/A	N/A	1	1
			24hrs	N/A	N/A	1	1
		MBD (2 samples)	4wks	N/A	N/A	4.6	5
			24hrs	N/A	N/A	3.5	3&4
	Liquid Nitrogen (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	2.5	3	3.3	3
			24hrs	2.9	3	4.9	5
		Crystal Violet (2 samples)	4wks	1	1	1	1
			24hrs	1.3	1	1	1
		MBD (2 samples)	4wks	1	1	4.4	4
			24hrs	1.8	1	3.5	3

Adhesive sides of Adhesive to Non-adhesive samples

Adhesive to non-adhesive samples separated with the adhesive neutralizer un-du gave very little resistance to separation, and needed only two to three applications of the adhesive neutralizer for complete separation. No real difference was seen in the print ratings of the first piece of tape (labeled Top) whose adhesive side was adhered to the non-adhesive side of a second piece of tape (labeled Bottom). The top and bottom pieces of both the four week and twenty four hour MBD sample resulted in an average print rating of 3. The four week sample processed with the rhodamine 6G/tween 20 solution resulted in an average print rating of 3 for both the top and bottom piece, with the twenty four hour sample resulting in an average print rating of 4.8 for the top piece and 4.5 for the bottom piece. While time seemed to not affect the development of the MBD samples, the higher ratings for the twenty four hour rhodamine 6G/ tween 20 samples may be attributed to the “freshness” of the prints. The samples processed with crystal violet resulted in top and bottom piece average print ratings of 2 for both the four week and twenty four hour sample. Though prints were discernible on the adhesive sides of both samples, the crystal violet continued to result in extremely faint prints, with no ridge detail.

Adhesive to non-adhesive samples separated with liquid nitrogen were much easier to separate than their adhesive-adhesive counterparts. No real difference was seen in the print ratings of the adhered adhesive side, versus the non-adhered adhesive side of the samples. The four week sample processed with MBD resulted in an average print rating of 3 for both the top and bottom piece, with the twenty four hour sample resulting in an average print rating of 3.3 for the top piece and 3 for the bottom piece. The four week sample processed with the rhodamine 6G/tween 20 solution resulted in an average print rating of 3.5 for both the top and bottom piece, with the twenty four hour sample resulting in an average print rating of 5 for both the top and bottom piece. The rhodamine 6G/tween 20 twenty four hour sample's higher ratings may again be attributed to the "freshness" of the prints, though this was not seen in the MBD twenty four hour sample. The four week sample processed with crystal violet resulted in average print ratings of 2 for both the top and bottom piece, with the twenty four hour sample resulting in average print ratings of 3 for both the top and bottom piece. Though there was ridge detail observed in the twenty four hour samples, the darker gray color of the tape continued to result in extremely faint prints.

Adhesive to non-adhesive samples separated by placement in a freezer also gave little resistance to separation, and little difference between the top and bottom piece ratings. The four week sample processed with MBD resulted in an average print rating of 4 for the top piece and 3.3 for the bottom, with the twenty four hour sample resulting in an average print rating of 3 for both the top and bottom pieces. The four week sample processed with the rhodamine 6G/tween

20 solution resulted in an average print rating of 3 for both the top and bottom piece, with the twenty four hour sample resulting in an average print rating of 4.5 for both the top and bottom piece. The rhodamine 6G/tween 20 samples again seem to show higher ratings for the twenty four hour samples, with the MBD samples not following this pattern. The four week samples processed with crystal violet resulted in average print ratings of 2 for both the top and bottom piece, and the twenty four hour samples resulted in an average rating of 2 for the top piece and 2.3 for the bottom piece. Though prints were discernible on the adhesive sides of both pieces, the crystal violet continued to result in extremely faint prints, with little to no ridge detail.

Overall, the rhodamine 6G/tween 20 solution was successful in developing ridge detail on the adhesive sides of tape samples stuck adhesive to non-adhesive. This optimized solution outperformed a currently used processing technique for the adhesive side of tape, crystal violet.

Non-adhesive sides on Adhesive to Non-adhesive samples

In regards to the samples separated with un-du, development on the non-adhesive sides of samples stuck adhesive to non-adhesive resulted in little difference between the print ratings of the first piece of tape (labeled Top) whose adhesive side was adhered to the non-adhesive side of a second piece of tape (labeled Bottom). The four week sample processed with MBD resulted in an average print rating of 3.8 for the top piece and 3.5 for the bottom piece, with the twenty four hour MBD sample resulting in an average print rating of 5 for the top piece and 3.3 for the bottom piece. The four week sample processed with the rhodamine 6G/tween 20 solution resulted in an average print rating of 3.8 for the top piece and 3.3 for the bottom piece, with the twenty four hour sample resulting in an average print rating of 4.5 for the top piece and 3.5 for the bottom piece. There seems to be little consistency seen with print ratings whether they were four week samples or twenty four hour samples. This variation may be due to damage to the prints during separation with un-du. The samples that were processed with crystal violet resulted in no print development on any of the non-adhesive sides of the samples. This was an expected result based on crystal violets performance in the controls.

Adhesive to non-adhesive samples separated with liquid nitrogen also resulted in little difference between the print ratings of the non-adhesive sides of the top and the bottom tape pieces. The four week sample processed with MBD resulted in an average print rating of 3.8 for the top piece and 4 for the bottom piece, with the twenty four hour MBD sample resulting in an average print rating of 4 for the top piece and 3.3 for the bottom piece. The four week sample processed with the rhodamine 6G/tween 20 solution resulted in an average print rating of 3.8 for the top piece and 3 for the bottom piece, with the twenty four hour sample resulting in an average print rating of 4.5 for the top piece and 3.3 for the bottom piece. These samples also show no pattern in ratings for either the four week or twenty four hour samples, which may be due to the excessive handling needed for separation with liquid nitrogen. Again, samples processed with crystal violet showed no print development.

Adhesive to non-adhesive samples separated by placement in a freezer once again resulted in little difference between the print ratings of the non-adhesive sides of the top and the bottom tape pieces. The four week sample processed with MBD resulted in an average print rating of 4 for the top piece and 4.5 for the bottom piece, with the twenty four hour MBD sample resulting in an average print rating of 4.3 for the top piece and 3.3 for the bottom piece. The four week sample processed with the rhodamine 6G/tween 20 solution resulted in an average print rating of 4.3 for the top piece and 3.3 for the bottom piece, with the twenty four hour sample resulting in an average print rating of 3 for the top piece and 3.3 for the bottom piece. Once again, no pattern was seen in the ratings of the four week or twenty four hour samples, and the samples processed with crystal violet showed no print development.

Overall, the rhodamine 6G/tween 20 solution was successful in developing ridge detail on the non-adhesive sides of tape samples stuck adhesive to non-adhesive. This optimized solution was able to obtain ratings of comparable, and at times better, quality to a currently used processing technique for the non-adhesive side of tape, MBD. Tables 10 and 11 summarize the average ratings obtained from the top and bottom pieces of the tape samples based on condition of tape, separation method, and development technique.

Table 10. Average Ratings from A/N-A Samples of Identical Variables 1, 2, &3 on Top Piece.

Variable 1 (Condition)	Variable 2 (Separation technique)	Variable 3 (Processing technique)	Time at room temp	Top Adhesive		Top Non-adhesive	
				Av. Rating	Mode	Av. Rating	Mode
Adhesive to Non-adhesive (18 samples)	un-du (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3	3	3.8	3
			24hrs	4.8	5	4.5	5
		Crystal Violet (2 samples)	4wks	2	2	1	1
			24hrs	2	2	1	1
		MBD (2 samples)	4wks	3	3	3.8	4
			24hrs	3	3	5	5
	Freezer (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3	3	4.3	5
			24hrs	4.5	4&5	3	3
		Crystal Violet (2 samples)	4wks	2.3	2	1	1
			24hrs	2	2	1	1
		MBD (2 samples)	4wks	4	4	4	4
			24hrs	3	3	4.3	5
	Liquid Nitrogen (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3.5	3&4	3.8	3
			24hrs	5	5	4.5	4&5
		Crystal Violet	4wks	2	2	1	1

		(2 samples)	24hrs	3	3	1	1
		MBD (2 samples)	4wks	3	3	3.8	4
			24hrs	3.3	3	4	4

Table 11 . Average Ratings from A/N-A Samples of Identical Variables 1, 2, &3 on Bottom Piece.

Variable 1 (Condition)	Variable 2 (Separation technique)	Variable 3 (Processing technique)	Time at room temp	Bottom Adhesive		Bottom Non-adhesive	
				Av. Rating	Mode	Av. Rating	Mode
Adhesive to Non-adhesive (18 samples)	un-du (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3	3	3.3	3
			24hrs	4.5	4&5	3.5	3&4
		Crystal Violet (2 samples)	4wks	2	2	1	1
			24hrs	2	2	1	1
		MBD (2 samples)	4wks	3	3	3.5	3&4
			24hrs	3	3	3.3	3
	Freezer (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3	3	3.3	3
			24hrs	4.5	4&5	3.3	3
		Crystal Violet (2 samples)	4wks	3	3	1	1
			24hrs	2.3	2	1	1
		MBD (2 samples)	4wks	3.3	3	4.5	4&5
			24hrs	3	3	3.3	3
	Liquid Nitrogen (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3.5	3	3	3
			24hrs	5	5	3.3	3
		Crystal Violet (2 samples)	4wks	2	2	1	1
			24hrs	3	3	1	1
		MBD	4wks	3	3	4	3&5

		(2 samples)	24hrs	3	3	3.3	3

Adhesive sides of Bound samples

Bound tape samples varied in their ease of separation. Due to the “struggle” the volunteers simulated, parts of some samples became twisted and attached adhesive to adhesive. Since the binding was performed by winding the tape around the “victim’s” wrists four times, a majority of each sample was stuck adhesive to non-adhesive and these parts were easier to separate than the twisted parts. On many of the bound samples some of the twisted parts were extremely difficult to separate resulting in many of the deposited prints not developing.

Samples separated with the adhesive neutralizer un-du and processed with MBD reported an average adhesive side print rating of 1.5 for the four week sample, and 3 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average print rating of 3 for the four week sample, and 2.6 for the twenty four hour sample. While the tape samples that were adhered adhesive to non-adhesive and separated with un-du showed good print development, the bound samples separated with un-du resulted in low ratings. This is believed to be due to the fact that a small amount of un-du was needed to successfully separate the adhesive to non-adhesive samples. Whereas with the bound samples, due to the parts of the samples that became adhered adhesive to adhesive, more applications of un-du were needed to fully separate them. This caused the visibility of developed prints to mirror the ones seen in the controls for un-du as a separation technique. The adhesive neutralizer was shown to conceal ridge detail when drops were applied directly to a hidden print. The need for larger amounts of un-du to fully separate the bound samples, as well as the increased manipulation and handling needed for separation, is believed to be the reason for the difference in average print ratings of the bound samples from the adhesive to non-adhesive samples. The samples processed with crystal violet reported an average rating of 2 for the four week sample and 1.8 for the twenty four hour sample, showing the same failure to develop adequate ridge detail, again assumed to be caused by the brand and darker gray color of the duct tape used in this study.

The bound samples separated with liquid nitrogen and processed with MBD reported an average adhesive side print rating of 1.5 for the four week sample, and 3.1 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average print rating of 1.5 for the four week sample, and 2.8 for the twenty four hour sample. The samples processed with crystal violet reported an average print rating of 2.5 for the four week sample and 2.2 for the twenty four hour sample. The bound samples separated with liquid nitrogen presented with similar separation difficulties as those separated with Un-du. This again resulted in lower ratings for these samples as compared with those from the adhesive to non-adhesive samples. This is believed to be due to increased handling and manipulation during application and removal on the “victim”, as well as during separation. The application of the liquid nitrogen required thick gloves as personal protection equipment, and this contributed to some difficulty in separation, and may also have contributed to the lower print ratings.

The bound samples separated by placement in a freezer and processed with MBD reported an average adhesive side print rating of 2 for the four week sample, and 3 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average rating of 2 for the four week sample, and 2.3 for the twenty four hour sample. The samples processed with crystal violet reported an average rating of 2 for both the four week and twenty four hour samples. Once again, ratings on these samples were lower than the adhesive to non-adhesive freezer samples due to tape manipulation.

Overall, the rhodamine 6G/tween 20 solution was successful in developing latent print ridge detail on the adhesive sides of duct tape samples meant to simulate evidence from bound "victims." This optimized solution also outperformed crystal violet, a current processing technique for the adhesive sides of tape.

Non-adhesive sides of Bound samples

The non-adhesive sides of the bound samples separated by un-du and processed with MBD reported an average print rating of 3.2 for the four week sample, and 4 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average print rating of 3.3 for the four week sample, and 3 for the twenty four hour sample. The samples processed with crystal violet did not develop any latent prints. The print development on the non-adhesive sides of these samples encountered the same problems with print visibility from manipulation and distortion as the adhesive sides of these samples, resulting in lower ratings than the non-adhesive sides of the adhesive to non-adhesive samples.

The non-adhesive sides of the bound samples separated by liquid nitrogen and processed with MBD reported an average print rating of 3.5 for the four week sample, and 3.1 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average rating of 3.3 for the four week sample, and 2.7 for the twenty four hour sample. The samples processed with crystal violet did not develop any latent prints. Similar effects from manipulation and distortion were observed.

The non-adhesive sides of the bound samples separated by placement in a freezer and processed with MBD reported an average print rating of 3.3 for the four week sample, and 3.5 for the twenty four hour sample. Samples processed with the rhodamine/6G tween 20 solution reported an average print rating of 3.2 for the four week sample, and 3.4 for the twenty four hour sample. The samples processed with crystal violet did not develop any latent prints. Similar effects from manipulation and distortion were observed.

Overall, the rhodamine 6G/tween 20 solution was successful in developing latent print ridge detail on the non-adhesive sides of duct tape samples meant to simulate evidence from bound “victims.” The optimized solution was able to obtain comparable print ratings to MBD, a current processing technique for the non-adhesive side of tape. Table 12 summarizes the average ratings obtained from the samples based on condition of tape, separation method, and development technique.

Table 12 . Average Ratings from Bound Samples of Identical Variables 1, 2, &3.

Variable 1 (Condition)	Variable 2 (Separation technique)	Variable 3 (Processing technique)	Time at room temp	Adhesive side		Non-adhesive side	
				Av. Rating	Mode	Av. Rating	Mode
Bound (18 samples)	un-du (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	3	3	3.3	3
			24hrs	2.6	3	3	3
		Crystal Violet (2 samples)	4wks	2	2	1	1
			24hrs	1.8	2	1	1
		MBD (2 samples)	4wks	1.5	1	3.2	3
			24hrs	3	3	4	4
	Freezer (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	2	1&3	3.2	3
			24hrs	2.3	3	3.4	3
		Crystal Violet (2 samples)	4wks	2	2	1	1
			24hrs	2	2	1	1
		MBD (2 samples)	4wks	2	1&3	3.3	3
			24hrs	3	3	3.5	3
	Liquid Nitrogen (6 samples)	Rhodamine 6G/Tween 20 (2 samples)	4wks	1.5	1	3.3	3
			24hrs	2.8	3	2.7	3
		Crystal Violet (2 samples)	4wks	2.5	2&3	1	1
			24hrs	2.2	2	1	1
		MBD (2 samples)	4wks	1.5	1	3.5	3
			24hrs	3.1	3	3.1	3

Discussion and Conclusions

Overall, the rhodamine 6G/tween 20 solution was successful in simultaneously developing ridge detail on both the adhesive and non-adhesive sides of tape belonging to all seven brands of gray duct tape tested during troubleshooting. The differences were mostly seen in the amount of fluorescence observed on the background of the tape. This “background fluorescence” ranged from very light or non-existent, to heavy which made the visualization of the print from the background more difficult. Even with this variation among brands, discernible prints were developed for all seven brands, indicating the rhodamine 6G/tween 20 solution’s success in developing latent prints on both sides of gray duct tape spanning across brands.

The results from this research also indicate that different fuming techniques do not have a significant effect on the ratings of developed latent prints. Ratings with ridge detail were successfully obtained from two different fuming techniques in this research, with the only changes being the amount of cyanoacrylate used and source of humidity. The amount of cyanoacrylate and the source of humidity were chosen based on the specifications of the fuming chamber, and produced no significant difference in print ratings. The investigation of different ALSs also indicated that if the correct wavelength for visualization of the rhodamine 6G/tween 20 solution was used, approximately 515 nm for the CRIMESCOPE and 500-525 nm for the Green Crime-Lite, ridge detail could be obtained from developed latent prints.

Once the originally planned separation study was allowed to resume, the print ratings obtained from this research showed positive results for the rhodamine 6G/tween 20 solution. The rhodamine 6G/tween 20 solution was able to develop ridge detail from latent prints on tape samples stuck adhesive to adhesive, adhesive to non-adhesive, and simulated to represent the binding of victims. This solution consistently developed latent prints with higher ratings than crystal violet, which is a commonly used processing technique for the adhesive side of tape, no matter the condition of the tape or the separation method utilized. The rhodamine 6G/tween 20 solution was also successful in developing both sides of the tape samples, while crystal violet was only marginally successful in developing the adhesive side.

Samples prepared adhesive to non-adhesive did not result in developed prints that were significantly better for any particular separation technique. Print ratings for all adhesive to non-adhesive samples processed with MBD and the rhodamine 6G/tween 20 solution resulted in ridge detail rating 3, 4, and 5 for both their adhesive and non-adhesive sides. There did not seem to be a significant difference in how MBD performed as opposed to the rhodamine 6G/tween 20 solution, as both were successful in developing ridge detail on both sides of the tape. The "freshness" of the deposited prints also did not seem to make a significant difference in print ratings, as the four week and twenty four hour MBD and rhodamine 6G/tween 20 samples all obtained print ratings of 3, 4, and 5.

Samples prepared adhesive to adhesive were not able to be separated when the freezer was used as a separation technique. Only the rhodamine 6G/tween 20 solution, coupled with liquid nitrogen separation, was able to develop ridge detail on multiple occasions on the adhesive sides of both the four week and twenty four hour samples. Development on the non-adhesive sides of the adhesive to adhesive samples did not show a significant difference in print ratings based on processing technique, separation method, or time at room temperature before separation. The rhodamine 6G/tween 20 solution and the MBD process both achieved ratings of 3,4, and 5 for the non-adhesive sides of tape stuck adhesive to adhesive.

Samples prepared to simulate the binding of victims varied in their success in latent print development. There did not seem to be a significant difference in ratings based on the separation technique utilized. Both the rhodamine 6G/tween 20 solution and MBD process were successful in developing ridge detail on the adhesive sides, though higher ratings were obtained for more of the twenty four hour samples. The rhodamine 6G/tween 20 and the MBD processing technique both showed better ratings for the non-adhesive side of the tape samples, most likely resulting from when the “struggle” caused the samples to stick adhesive to adhesive and obscure latent prints that had been deposited on the adhesive sides.

In summary, this research has shown that the rhodamine 6G/tween 20 solution, optimized in the parent study, can successfully develop ridge detail in latent prints from gray duct tape representing evidence samples commonly found at crime scenes. Discrepancies observed among ratings may be attributed to handling during the separation attempts. In addition, the amount of oils deposited and pressure applied by each print deposit could not be specifically controlled and may have contributed to slight differences in print ratings. Overall, this process was successful in developing ridge detail simultaneously on both the adhesive and non-adhesive sides of Duck brand Original Strength duct tape, outperforming crystal violet and at times MBD. Future studies may consider further research into how the rhodamine 6G/tween 20 solution performs on additional brands of duct tape, or even further investigation into the performance of MBD on the adhesive sides of tape.

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