LATENT FINGERPRINT DEVELOPMENT ON ADHESIVE SURFACES AFTER APPLICATION TO FABRIC

by

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List of Abbreviations

BPT	Brown packing tape
CPT	Clear packing tape
DT	Duct tape
BWP	Black wet powder
CV	Crystal violet
SPR	Small particle Reagent

Abstract

One of the many items of evidence found at a crime scene that can yield breakthrough clues if handled and processed appropriately is adhesive tape. Through fracture matching and DNA analysis, a person can be linked to the tape and, therefore, the scene of the crime. Another way adhesive tape can link a person to the crime is with development of latent fingerprints. Thorough research and real-life case work have proven latent fingerprints can be developed from adhesive surfaces through a variety of processing techniques. A search of extant literature shows this to be true, but there is little information found on the ability to develop comparative latent fingerprints from adhesive surfaces after they have been applied to fabrics. This study adds to the literature through the deposition of simulant laden latent fingerprints on tan packing tape, clear packing tape and grey duct tape, then applying the tape to denim, polyester, and cotton fabric samples. The tape was processed utilizing crystal violet, black wet powder and small particle reagent. Careful processing and analysis of 135 samples of adhesives and 405 latent fingerprints determined adhesive and fabric types coupled with processing methods play a role in the ability to develop latent fingerprints from adhesive surfaces that have been applied to fabrics. The results of the study fill an apparent gap in the literature and provides investigators and lab analysts another means of potentially identifying persons of interest in criminal investigations.

Introduction

Everyone has peeled a sticker or label from their shirt and observed lint and other debris stuck to the adhesive side. In some instances, the adhesive might be too contaminated to reapply to the fabric. Common sense might dictate that any latent fingerprints that were possibly present on the adhesive would be lost due to the contamination of the adhesive by the fabric or absorption of the latent print material into the fabric. However, common sense is not the same as scientific research and results, and a search of extant literature on the topic yielded few, if any, clues. Therefore, this research sets out to answer the question of can a latent fingerprint be developed from an adhesive surface after it has been applied to fabric? In order to answer this question, the objectives and goals of the researcher are to (a) determine if the type of fabric affects the development of latent fingerprints after application to fabric, (b) determine if the type of adhesive tape affects the development of latent fingerprints after application to fabric, and (c) determine if different processing methods affects the development of latent fingerprints after application to fabric.

This study hopes to provide latent fingerprint examiners with additional methods of obtaining evidence in criminal cases. Prior research appears to focus on developing latent fingerprints under ideal settings, where the intent is to determine what processes and their application best develops latent fingerprints. These studies experiment with good quality latent fingerprints which is needed for best practices determination but does not help with actual real-world situations. There has been research conducted that attempts to develop latent fingerprints under less than ideal settings. Researchers such as Molina (2007), Bailey and Crane (2011) and Tan et al. (2020) looked to hone development processes for adhesives that were applied to various substrates. It is this type of research that needs to be conducted as latent fingerprint examiners often do not see ideal conditions of evidence when it is presented to them for analysis. What may work in controlled laboratory settings might not work or perform the same way in actual case work. Through showing there is a correlation between the variables of tape type, fabric type and processing method, latent fingerprint examiners would be better able to choose the appropriate processing method that is presented to them.

Body of Text

Development of latent fingerprints on adhesive surfaces has been studied and reported on in depth over the last twenty years and the results have helped to form the base knowledge on how to process latent fingerprints on adhesives. Students studying forensic science can learn from authors such as Houck and Siegel (2015), Fisher and Fisher (2012) and Fish, Miller, Braswell and Wallace (2015) that adhesives can be processed with gentian violet or sticky-side powder. Lennard (2007) reported gentian violet could be used on adhesive surfaces by immersing the adhesive in the solution, then rinsing off the excess solution with water. Olenik (2015) experimented with different preparations of basic yellow dye and was able to develop latent fingerprints from duct tape. The duct tape was fumed with cyanoacrylate and submerged in the dye solution, followed by rinsing the excess dye under running water. Sneddon (1999) studied the characteristics of duct tape and how latent fingerprints react with the adhesive. Looking under a microscope, the characteristics of the adhesive surface were observed, including the deposition of skin cells over the course of a depletion series of latent fingerprint deposition. Development of the latent fingerprints was accomplished through the application of a black powder solution.

Research has slowly experimented with methods that are considered outside of the normal means of processing adhesives. Wei et al. (2017) were able to develop a latent fingerprint on adhesive with soot from a candle. By holding adhesive tape over a lit candle, soot from the candle deposited onto the adhesive surface and bonded with the latent fingerprint. Careful removal of the soot around the latent fingerprint was accomplished with the use of a brush instead of running water. Cramer and Glass (2008) examined how freezing a latent fingerprint affected the ability to develop latent fingerprints from adhesive surfaces. Strips of duct tape, clear packing tape, Scotch tape, and electrical tape with latent fingerprints were placed into a freezer for various times. Using black powder and magnetic powder, latent fingerprints were able to be developed from the adhesive sides of the tape. Jasuja, Kumar and Singh (2015) developed an ability to develop latent fingerprints on adhesive surfaces that had been submerged in water. Using a certain preparation of a phase transfer catalyst dye stain, the authors provided another means of developing latent fingerprints on adhesive surfaces that outperformed gentian violet in the study.

Despite the abundance of literature that exists regarding processing adhesive, little to no literature was found regarding specifically the processing of adhesive after being applied to fabric. Discussion with two latent fingerprint examiners confirmed the potential absence of these types of studies. A review of the extant literature yielded two studies that discussed this issue. In the first study found, Zhang et al. (2018) applied technology to observe latent fingerprints deposited on adhesive surfaces when they were applied to fabric. After pressing multiple pieces of Scotch tape onto a fabric surface, the use of three-dimensional optical coherence tomography (3D OCT) allowed the authors to observe latent fingerprints on the adhesive surface that was in direct contact with the fabric. This technique offered a way to visualize and potentially analyze the latent fingerprint with minimal risk of damage. Although the study did not attempt to physically develop the latent fingerprint, it showed progress in adding to the literature on how to observe a latent fingerprint that had been applied to fabric.

The second study was from Tan et al. (2020) who placed adhesive tape on "cotton gauze fabric" (p. 2) and successfully developed latent fingerprints utilizing a black powder suspension. The nature of the study was primarily focused on how to modify the solvents used in untangling adhesive surfaces to maximize the potential for development of latent fingerprints. Although it was not apparent what the fabric material looked like in the study, the ability to develop latent fingerprints after adhesive was applied to fabric was substantiated with surprising results.

The three reagents chosen for this study were black wet powder, crystal violet and small particle reagent as they had different applications methods of brush-on, bath, and spray-on respectively. Black wet powder is considered a powder in suspension and is normally grouped with other powder solutions such as Wetwop and sticky side powder. These solutions are made up of a type of powder mixed with varying amounts of water, surfactants and other substances. Studies involving adhesive surfaces normally involve the use of powder solutions during the development process. Molina (2007) conducted an experiment to determine if Wetwop, sticky side powder or gentian violet was better at developing latent fingerprints on different types of adhesive surfaces after being applied to paper. Wetwop was brushed on the adhesives and immediately rinsed with water while sticky-side powder was brushed on, left for 10 to 15 seconds, then rinsed with water. The study revealed Wetwop produced the best results. Maceo and Wertheim (2000) experimented with ninhydrin and sticky-side powder to determine which produced the best results on adhesive after being separated from porous surfaces. Use of the sticky-side powder produced varying results. Bailey and Crane (2011) used Wetwop to process latent fingerprints on duct tape after the tape was separated by three different methods. After brushing the Wetwop on the tape and allowing to sit for 15 seconds, the sample was rinsed with water which had varying degrees of success based on the separation method applied.

Crystal violet is also another common reagent used in studies involving latent fingerprint development on adhesive surfaces. Also called gentian violet, the reagent stains the fatty components of latent fingerprint, but can also stain the surface of the substrate the latent fingerprint is found. The use of crystal violet yields good details of latent fingerprints depending on the varying strengths of the reagent and length of time the latent fingerprint is exposed to the reagent. Aronson (2011) experimented with powders in solution, amido black and gentian violet to determine which reagent yielded the best results for latent fingerprints left in blood on duct tape. The tape was placed in the reagent, left for 90 seconds, then rinsed with water. Results for the gentian violet were not as good as the powder solutions or the amido black. Garcia and Gokool (2020) attempted to compare the different reagents and different types of adhesive to determine best practices. Using gentian violet as one of the regents, the authors placed the tapes in the solution, adhesive side down, and let develop for two minutes, after which the strip was rinsed under water. Results showed the reagent was not as effective at developing latent fingerprints compared to reagents such as powders in suspension. Schiemer, Lennard, Maynard, and Roux (2005) studied how different processing techniques develop latent fingerprints on black electrical tape. The tape was placed in gentian violet for 45 seconds, then rinsed with water, dipped in Photo-Flo solution, and transferred to photographic paper. This method yielded positive results similar to black powder suspension.

Small particle reagent is a suspension of powder particles in solution and is normally sprayed onto the target substrate to develop latent fingerprints. Reserved for use on surfaces that are wet or have been wet such as a vehicle in a pond or a dumpster in the rain, Small particle reagent is not normally used to process adhesive tape. Maslanka (2016) studied the effects everyday household liquids had on latent fingerprint development with small particle reagent. Small particle reagent was applied per manufacturer instructions to glass slides containing latent fingerprints and enough detail was developed that allowed sufficient comparison between the samples. Williams and Elliott (2005) conducted a study to determine the ability of titanium dioxide (TiO_2) mixed in a solution of Kodak Photo-Flo and water to develop latent fingerprints from adhesive surfaces. The authors found the results of the spray application of the reagent were not as pronounced as other methods and could potentially affect the contrast necessary for evaluation. Schiemer et al. (2005) also used small particle reagent in their study and sprayed the reagent on the adhesive surface for 10 to 15 seconds, then rinsed the tape with water. Although latent fingerprints were able to be developed on black electrical tape, there was not enough contrast for assessment. Ruslander (2005) reported latent fingerprints were able to be developed from clear packing tape with small particle reagent by spraying the reagent on the adhesive surface, immediately rinsing off and placing tape strip on a fingerprint backing card. Although small particle reagent is normally used on wet, solid surfaces, there is promise the reagent can be used to develop latent fingerprints from adhesive surfaces.

Discussion with two different latent fingerprint examiners resulted in the decision to assess the fingerprints using technology rather than a latent fingerprint examiner in order to mitigate human error in the assessment. The examination, analysis and comparison of fingerprints is normally left to the trained and experienced eye of a latent fingerprint examiner. Researchers and latent fingerprint examiners have used scales such as CAST, UNIL and University of Canberra (UC) to assign values to various types of latent fingerprints. These scales are useful in assigning quantitative values to a latent fingerprint, but they rely on the training, experience and other factors of the latent fingerprint examiner conducting the assessment. After the National Academy of Science report was published in 2009, the forensic science community has been attempting to take the human element out of evidence analysis to limit error rates. Technology has played an important role in this process and the Federal Bureau of Investigation continues to lead the way in technical developments and guidance.

The Universal Latent Workstation (ULW) is software that allows latent fingerprint examiners to upload images, assess images and make comparisons (Federal Bureau of Investigation, 2015). The capabilities of the software are too numerous to mention in this paper, but one of the most interesting features of the software is the assessment tool included in ULW, the Latent Quality Metrics (LQMetrics) Software (Federal Bureau of Investigation, n.d.). LQMetrics allows a latent fingerprint examiner to upload an image of a latent fingerprint in the software, which then assigns four different scores for the quality of the image. This software has been utilized in various studies to assign value to latent fingerprints and to provide examples of alternative methods for assessing latent fingerprints. Pulsifer, Muhlberger, Williams, Shaler and Lakhtakia (2013) used the software in conjunction with two additional software programs to assess the quality of a latent fingerprint. Koertner and Swofford (2018) used the software to determine how latent fingerprint proficiency testing samples compared to the samples obtained from routine casework. Garcia and Gokool (2020) used the software to make comparison of different processing methods on adhesive surfaces.

Discussion with latent fingerprint examiners also determined the most effective way to consistently deposit over 400 latent fingerprints with one donor was to utilize a latent standards pad, or simulant. Simulants such as Sirchie’s Latent Print Standards Pad contain the oils, amino acids and salts, which allow the latent fingerprint examiner to conduct tests of reagents to ensure they are working correctly (Sirchie, n.d.). The use of simulants in prior research is limited and has been found to be inadvisable. The International Fingerprint Research Group (IFRG) stated it was acceptable to use simulants in research as long as conclusions on reagent performance were drawn only from natural fingerprint deposits (International Fingerprint Research Group, 2014). Zadnik, Bronswijk, Frick, Fritz, and Lewis (2013) showed the makeup of simulant pads did not accurately produce the same characteristics of natural latent fingerprints and was not a reliable indication of reagent performance. Sears, Bleay, Bandey, and Bowman (2012) also concluded the use of simulant pads cannot accurately replicate the makeup of natural latent fingerprints. Despite these findings and recommendations, the use of a simulant was still chosen due to its consistency and efficiency.

Method

Materials

- brown Packing Tape (Duck)
- clear Packing Tape (Scotch)
- grey Duct Tape (3M)
- blue denim fabric (10 ounce)
- grey cotton fabric
- grey polyester fabric
- Latent Print Standards Pad (Sirchie)
- Small Particle Reagent – Dark (Sirchie)
- Crystal Violet Premixed Solution (Evident)
- Wet Powder – Black (Evident)
- storage container
- hand weights
- particle board
- white printer paper
- stapler and staples
- manilla envelopes
- Fujifilm X-T1 Digital Camera and Fujifilm Fujinon XF 60mm macro lens
- camera tripod
- clear storage box for use as an elevated platform and modified light box
- work light
- clothes dryer (Whirlpool Model WED4900XW0)

- washing machine (agitatorless, Whirlpool Model WTW4950XW2)
- hand soap (Method Hollyberry)
- laundry soap (All Free Clear Mighty Pacs)
- cotton cloth hand towels
- permanent marker (Sharpie, black, fine point)
- photographic scale (grey and white)
- adhesive labels (white)
- latent fingerprint analysis software (LQMetrics – Universal Latent Workstation)
- computer (Microsoft Surface Pro)
- file conversion software (Simple Photo Converter)
- disposable fuming tray
- Pyrex dish for crystal violet and black wet powder
- camel hair brush
- forceps
- latent fingerprint fuming chamber.

Procedure

Fabric preparation. Fabric samples were cut into approximately 9” by 18” sections. One sample of each fabric type was set aside and placed in a clean manilla envelope. The remaining samples were laundered with ordinary household laundry in a residential washer and dryer. Common laundry detergent was utilized, and the wash/dry cycles were varied to account for normal household wash cycles. After undergoing five wash cycles, a sample of each fabric type were set aside and placed in an envelope. This process was completed a total of twenty times, with samples being set aside after ten, fifteen and twenty wash cycles.[1] The denim fabric sample edges were hemmed with a household sewing machine to minimize fraying of the edges. Fabric samples were stapled to a piece of cardboard to provide backing material and to ensure the fabric remained flat during the study. The number of wash cycles and fabric type was written across the top of the cardboard in permanent marker, and the processing methods WP, crystal violet and small particle reagent were written in columns above the fabric.

[1] The original study design included number of wash cycles as an independent variable. Due to small sample sizes, the wash cycle data was combined to increase the number of samples.

Latent fingerprint deposition. Author washed hands with household hand soap and water and dried with a cloth towel prior to all latent fingerprint depositions. An approximate five-inch section of tape was cut and laid on the work surface with the adhesive side up. The letters A, B, and C were written on the bottom of the tape in permanent marker to identify the approximate area where the latent fingerprint was to be deposited. A thumb was placed lightly on the standard pad, then pressed twice onto a piece of printer paper to dilute the simulant, then a left to right depletion series was deposited onto the adhesive surface. Visual examination of the clear packing tape and brown packing tape confirmed the successful deposition of latent fingerprints of value. There was difficulty in observing latent fingerprints of value were deposited on the duct tape, but the same procedure utilized for the previous tapes was utilized for the duct tape. Additionally, immediately after depositing the third latent fingerprint on the duct tape, the same thumb was placed on a piece of brown packing tape to ensure the deposition process was still working. Latent fingerprints were allowed to air dry for approximately one minute and then laid on the fabric. Tape was pressed firmly with fingers to ensure adherence to the fabric, being careful to not rub the tape onto fabric and risk damaging the latent fingerprint. This process was completed for all tape types. Each piece of tape was labeled with an identification number on the top left and the identification number was generated on a spreadsheet that identified the different variables of the of the samples. Once the fabric was covered with nine pieces of tape (Figure 1), it was placed under a piece of particle board cut to the same size as the cardboard, and two eight-pound hand weights were placed on the particle board to press the tape onto the fabric and ensure the tape did not release from the fabric. The entire process was completed another fourteen times. Prior to processing in the laboratory, latent fingerprints were deposited utilizing the same methods as above on three strips of all three tape types. These strips were not placed on fabric but were processed utilizing the three processing methods to be used as control groups for comparison purposes.

Figure 1. Example of completed fabric sample with tape

Latent fingerprint development. Tape strips to be processed with black wet powder were manually pulled from the fabrics and laid on a piece of countertop paper. An individual tape strip was placed inside glass dish. After shaking the contents, a small amount of black wet powder was poured into a disposable fuming tray. Per manufacturer instructions, black wet powder was applied to tape strip utilizing a camel hair brush, allowed to process on the tape for approximately 15 seconds, then rinsed off with cold running water from a faucet. Tape strip was hung in a latent fingerprint fuming chamber to dry. Once dry, the tape strip was returned to the countertop paper. This process was completed for all strips processed with black wet powder.

Tape strips to be processed with crystal violet were manually pulled from the fabrics and laid on a piece of countertop paper. After shaking contents of bottle, a small amount of crystal violet was poured into a glass dish. An individual tape strip was placed in the dish, adhesive side down and submerged with forceps to ensure air bubbles were not trapped under the tape. The tape was not allowed to touch the bottom of the dish during the submersion. Per manufacturer instructions, tape was allowed to stay in the solution for approximately two minutes, then taken out of the solution with forceps and rinsed under cold running water from a faucet. Tape strip was hung in latent fingerprint fuming chamber to dry. Once dry, the tape strip was returned to the countertop paper. This process was completed for all strips processed with crystal violet.

Tape strips to be processed with small particle reagent were manually pulled from the fabrics and laid on a piece of countertop paper. After shaking contents of bottle, small particle reagent was sprayed directly onto the adhesive side of an individual tape strip which was immediately rinsed under cold running water from a faucet. Tape strip was hung in latent fingerprint fuming chamber to dry. Once dry, the tape strip was returned to the countertop paper. This process was completed for all strips processed with small particle reagent.

Documenting latent fingerprints and adhesive condition. Once tape strips were removed from the fabrics, an overall photograph was exposed of each strip utilizing a digital camera. Camera was placed on a tripod with the lens of the camera approximately 16½” above the work surface. Photographs were exposed to document the condition of the tape prior to processing. Once processing was completed and the tape had dried, another overall photograph was exposed of each strip under the same conditions to document the condition of the tape after processing. The settings of the camera for the overall photographs were color, f/11, ISO 200 and the shutter speed set to allow a +1 overexposure to account for an exposure that was more consistent with what the human eye was observing. Tape was illuminated by overhead fluorescent lighting. A photographic scale with the identification number for the tape strip written on an adhesive label was placed next to the sample.

Examination quality images were then exposed of each individual latent fingerprint, or area where a latent fingerprint should have been found. Tape strips were placed on an elevated surface and the camera was placed on a tripod with the lens of the camera approximately 9½" above the work surface. This distance was chosen after trials with LQMetrics found when the photographic scale was placed directly adjacent to the latent fingerprint, the software seemed to confuse the markings on the scale with points of minutiae. To mitigate this, the scale was placed further away from the latent fingerprint in order to ensure the software focused on the latent fingerprint and not the scale. The settings of the camera for the close-up photographs were black and white, f/11, ISO 200 and the shutter speed initially adjusted to set the light meter to zero, and +1/0/-1 photographs were exposed. Tape was illuminated by overhead fluorescent lighting. A photographic scale with the identification number for the tape strip written on an adhesive label was placed next to the sample.

In an attempt to expose better images of the clear packing tape, the elevated surface the tape strips were placed on was converted into a modified light box. A piece of white printer paper was placed on the box and the clear tape strip was placed on the paper with the adhesive side facing up. An articulated work light was placed in a manner that half of the light entered one side of the box and the other half entered another side. Despite the attempt to improve the contrast of the fingerprints on the clear tape, the results were less than desired and the images utilizing overhead lighting was used in the analysis portion.

All photographs were exposed in RAW file format. However, in order for the ULW software to open and analyze the images, the images needed to be in Tagged Image File, or TIFF, format. The Fujifilm X-T1 could not shoot in TIFF and the images needed to be converted. A third-party software, Simple Photo Converter, was utilized to convert the RAW files into TIFF files and the ULW software was able to open and analyze the images.

Data Analysis and Interpretation

LQMetrics was utilized to analyze the latent fingerprints and the areas where the latent fingerprints should have been. The image of an individual latent fingerprint was uploaded into the LQMetrics software, which asks the user to choose what resolution the image was being uploaded as, 500 pixels-per-inch, 1,000 pixels-per-inch, or the image has a scale with 1" markings. The option to use the scale was chosen and a line was drawn in the software between the 3" and 4" markings on the photographic scale in the image. The distance identified the photograph as being 1,000 pixels-per-inch and the software adjusted the image. A moveable box representing a region of interest was presented on the image and the author placed this box over the portion of the latent fingerprint that had the most detail to establish the left and right boundary of the image in question. Next, a new region of interest was drawn around the latent fingerprint within the confines of the box and selected "Accept". Next, the Latent Quality button was right-clicked which produced a detailed report regarding the image (Table 1). This same process was conducted on samples where there was no visible latent fingerprint present, with the region of interest being drawn in the shape of a latent fingerprint in the area where the latent fingerprint was suspected to be deposited.

LQMetrics Data Categories	
Latent Quality Score (0-100%)	Predicted probability image would return a match
Value for Individualization (0-100%)	Predicted probability of image ability to be individualized
Value for Comparison (0-100%)	Predicted probability of image ability to be individualized or excluded
Clarity (0-100)	Level and quantity of friction ridge detail in impression

Table 1. LQMetrics data categories

While analyzing the images with LQMetrics, it was observed there were discrepancies with the results given by the software. Of 432 latent fingerprints, the software failed to qualify 58 latent fingerprints that were visible (Figure 2) and qualified 156 latent fingerprints that were not visible (Figure 3). There were an additional 14 latent fingerprints that appeared to be scored lower or higher than warranted compared to the latent fingerprints deposited immediately before or after.

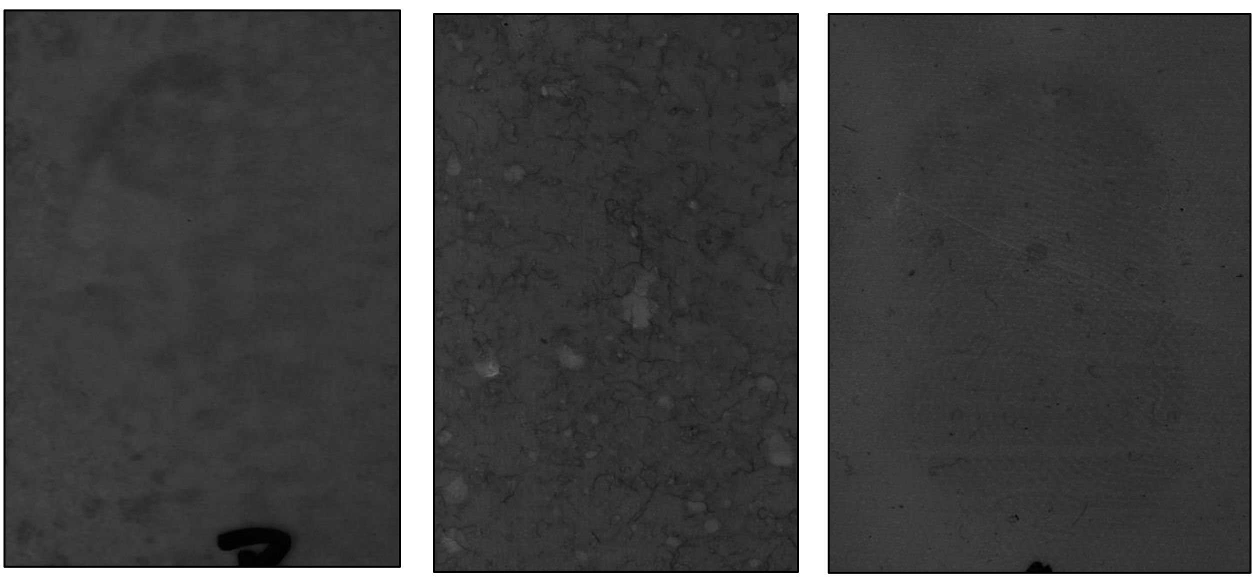

Figure 2. Examples of latent fingerprints not scored by LQMetrics

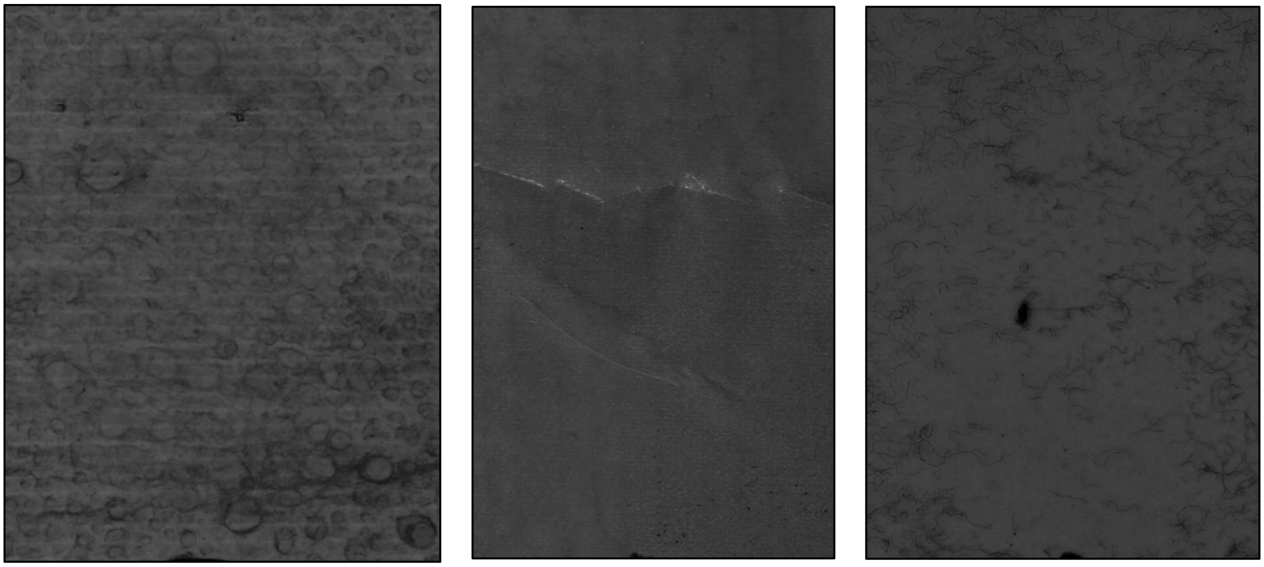

Figure 3. Examples of false positives scored by LQMetrics

Due to these discrepancies, it was decided to utilize another metric to score the latent fingerprints. Visual examinations were conducted on the images to determine if there was a latent fingerprint present in the image. It was decided to examine the images that were underexposed as they revealed the most contrast between the background and the latent fingerprint and to remain consistent with the analysis conducted in LQMetrics. A score of 1, 2 or 3 was assigned to each image. An additional scale was utilized to assess the quality of the latent fingerprint, and scores of 0, 1, 2, or 3 were assigned to each image. These scales did not follow any pre-existing scales from prior research and were kept simple to allow for analysis of the images by an individual who was not a latent fingerprint examiner. Additionally, the scales did not follow any type of scoring system utilized by latent fingerprint examiners in assessing levels of ridge detail. The scales were approved for use by practicing latent fingerprint examiners (Tables 2 and 3).

Latent Fingerprint Visual Scale	
3	Latent fingerprint present/ridge detail present
2	Latent fingerprint present/no ridge detail present
1	Latent fingerprint not present

Table 2. Description of visual scale

Latent Fingerprint Quality Scale	
3	Latent fingerprint/ridge detail visible and bold
2	Latent fingerprint/ridge detail visible but faint
1	Latent fingerprint/ridge detail visible with closer scrutiny or minimal ridge detail present
0	No latent fingerprint present

Table 3. Description of quality scale

Frequency tables were generated in Statistical Analysis System (SAS) to assist with the statistical portion of the analysis.[2] The first scores assessed were the visual scores (Table 4). Black wet powder scored the highest of the processing methods, scoring “3” for 128 images, followed by crystal violet and small particle reagent. A Chi-Square analysis was conducted which revealed a P value of <.0001 which showed there was a significant difference in how the type of processing method affected the development of a latent fingerprint (Table 5). Duct tape scored the highest of the types of tape, scoring “3” for 87 images, followed by clear packing tape and brown packing tape (Table 6). A Chi-Square analysis was conducted which revealed a P value of <.0001 which showed there was a significant difference in how the type of tape affected the development of a latent fingerprint (Table 7). Polyester scored the highest for the type of fabric, scoring “3” for 89 images, followed by cotton and denim (Table 8). A Chi-Squre analysis was conducted which revealed a P value of 0.0005 which showed there was a significant difference in how the type of fabric affects the development of a latent fingerprint (Table 9). A

[2] 27 control sample scores were included in the SAS statistical analysis and were not compared against the fabric sample scores.

multivariate Analyses of Variance (MANOVA) were conducted on all three variables and confirmed the results were significantly different with P values of <.0001 (Tables 10, 11, and 12).

Table of Method by Visual Scale				
Processing Method	**Visual Scale**			
Frequency **Percent** **Row Pct** **Col Pct**	**1**	**2**	**3**	**Total**
Black Wet Powder	13 3.01 9.03 10.92	3 0.69 2.08 3.90	128 29.63 88.89 54.24	144 33.33
Crystal Violet	36 8.33 25.00 30.25	41 9.49 28.47 53.25	67 15.51 46.53 28.39	144 33.33
Small Particle Reagent	70 16.20 48.61 58.82	33 7.64 22.92 42.86	41 9.49 28.47 17.37	144 33.33
Total	119 27.55	77 17.82	236 54.63	432 100.00

Table 4. SAS Frequency Table of Processing Method by Visual Scale

Statistic	**DF**	**Value**	**Prob**
Chi-Square	4	123.4383	<.0001
Likelihood Ratio Chi-Square	4	135.3219	<.0001
Mantel-Haenszel Chi-Square	1	95.9814	<.0001
Phi Coefficient		0.5345	
Contingency Coefficient		0.4714	
Cramer’s V		0.3780	

Table 5. SAS statistics for Table 4

Table of Tape by Visual Scale				
Tape Type	**Visual Scale**			
Frequency **Percent** **Row Pct** **Col Pct**	**1**	**2**	**3**	**Total**
Brown Packing Tape	67 15.51 46.53 56.30	12 2.78 8.33 15.58	65 15.05 45.14 27.54	144 33.33
Clear Packing Tape	25 5.79 17.36 21.01	35 8.10 24.31 45.45	84 19.44 58.33 35.59	144 33.33
Duct Tape	27 6.25 18.75 22.69	30 6.94 20.83 38.96	87 20.14 60.42 36.86	144 33.33
Total	119 27.55	77 17.82	236 54.63	432 100.00

Table 6. SAS Frequency Table of Tape Type by Visual Scale

Statistic	DF	Value	Prob
Chi-Square	4	43.3238	<.0001
Likelihood Ratio Chi-Square	4	42.9423	<.0001
Mantel-Haenszel Chi-Square	1	17.7929	<.0001
Phi Coefficient		0.3167	
Contingency Coefficient		0.3019	
Cramer's V		0.2239	

Table 7. SAS statistics for Table 6

Table of Fabric by Visual Scale				
Fabric Type	**Visual Scale**			
Frequency Percent Row Pct Col Pct	**1**	**2**	**3**	**Total**
Control	3 0.69 11.11 2.52	4 0.93 14.81 5.19	20 4.63 74.07 8.47	27 6.25
Cotton	43 9.95 31.85 36.13	23 5.32 17.04 29.87	69 15.97 51.11 29.24	135 31.25
Denim	51 11.81 37.78 42.86	26 6.02 19.26 33.77	58 13.43 42.96 24.58	135 31.25
Polyester	22 5.09 16.30 18.49	24 5.56 17.78 31.17	89 20.60 65.93 37.71	135 31.25
Total	119 27.55	77 17.82	236 54.63	432 100.00

Table 8. SAS Frequency Table of Fabric Type by Visual Scale

Statistic	DF	Value	Prob
Chi-Square	6	23.9209	0.0005
Likelihood Ratio Chi-Square	6	25.0882	0.0003
Mantel-Haenszel Chi-Square	1	1.6792	0.1950
Phi Coefficient		0.2353	
Contingency Coefficient		0.2291	
Cramer's V		0.1664	

Table 9. SAS statistics for Table 8

MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fabric Effect H = Type III SSCP Matrix for Fabric E = Error SSCP Matrix S=2 M=0 N=210.5					
Statistic	**Value**	**F Value**	**Num DF**	**Den DF**	**Pr > F**
Wilks' Lambda	0.90515937	7.20	6	846	<.0001
Pillai's Trace	0.09503671	7.05	6	848	<.0001
Hotelling-Lawley Trace	0.10456119	7.36	6	562.23	<.0001
Roy's Greatest Root	0.10244660	14.48	3	424	<.0001
NOTE: F Statistic for Roy's Greatest Root is an upper bound.					
NOTE: F Statistic for Wilks' Lambda is exact.					

Table 10. SAS MANOVA for fabric type

MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Tape Effect H = Type III SSCP Matrix for Tape E = Error SSCP Matrix S=2 M=-0.5 N=210.5					
Statistic	**Value**	**F Value**	**Num DF**	**Den DF**	**Pr > F**
Wilks' Lambda	0.81589308	22.65	4	846	<.0001
Pillai's Trace	0.18931158	22.17	4	848	<.0001
Hotelling-Lawley Trace	0.21927171	23.17	4	506.56	<.0001
Roy's Greatest Root	0.18474198	39.17	2	424	<.0001
NOTE: F Statistic for Roy's Greatest Root is an upper bound.					
NOTE: F Statistic for Wilks' Lambda is exact.					

Table 11. SAS MANOVA for tape type

MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Method Effect H = Type III SSCP Matrix for Method E = Error SSCP Matrix S=2 M=-0.5 N=210.5					
Statistic	**Value**	**F Value**	**Num DF**	**Den DF**	**Pr > F**
Wilks' Lambda	0.57157823	68.25	4	846	<.0001
Pillai's Trace	0.44304055	60.33	4	848	<.0001
Hotelling-Lawley Trace	0.72396565	76.50	4	506.56	<.0001
Roy's Greatest Root	0.68672181	145.59	2	424	<.0001
NOTE: F Statistic for Roy's Greatest Root is an upper bound.					
NOTE: F Statistic for Wilks' Lambda is exact.					

Table 12. SAS MANOVA for processing method

Frequency tables were also generated to analyze the quality scores for the latent fingerprints. Black wet powder scored the highest of the processing methods, scoring “3” on 101 images, followed by crystal violet and small particle reagent (Table 13). A Chi-Square analysis was performed which revealed a P value of <.0001, which showed there was a significant difference in how the processing method affects the quality of the development of latent fingerprints (Table 14). Duct tape scored the highest of the tape types, scoring “3” on 65 images, followed by brown packing tape and clear packing tape (Table 15). A Chi-Square analysis was performed which revealed a P value of <.0001, which showed there was a significant difference in how the different types of tape affects the quality of the development of latent fingerprints (Table 16). Polyester scored the highest of the fabric types, scoring “3” on 55 images, followed by denim and cotton (Table 17). A Chi-Square analysis was performed which revealed a P value of 0.0002, which showed there was a significant difference in how fabric type affects the quality of the development of latent fingerprints (Table 18).

Table of Method by Visual Quality					
Processing Method	**Visual Quality**				
Frequency **Percent** **Row Pct** **Col Pct**	**0**	**1**	**2**	**3**	**Total**
Black Wet Powder	16 3.70 11.11 8.16	6 1.39 4.17 23.08	21 4.86 14.58 26.92	101 23.38 70.14 76.52	144 33.33
Crystal Violet	77 17.82 53.47 39.29	10 2.31 6.94 38.46	35 8.10 24.31 44.87	22 5.09 15.28 16.67	144 33.33
Small Particle Reagent	103 23.84 71.53 52.55	10 2.31 6.94 38.46	22 5.09 15.28 28.21	9 2.08 6.25 6.82	144 33.33
Total	196 45.37	26 6.02	78 18.06	132 30.56	432 100.00

Table 13. SAS Frequency Table of processing method by Quality Scale

Statistic	DF	Value	Prob
Chi-Square	6	179.6559	<.0001
Likelihood Ratio Chi-Square	6	188.6408	<.0001
Mantel-Haenszel Chi-Square	1	144.9489	<.0001
Phi Coefficient		0.6449	
Contingency Coefficient		0.5420	
Cramer's V		0.4560	

Table 14. SAS statistics for Table 13

Table of Tape by Visual Quality					
Tape Type	**Visual Quality**				
Frequency Percent Row Pct Col Pct	**0**	**1**	**2**	**3**	**Total**
Brown Packing Tape	79 18.29 54.86 40.31	4 0.93 2.78 15.38	13 3.01 9.03 16.67	48 11.11 33.33 36.36	144 33.33
Clear Packing Tape	60 13.89 41.67 30.61	13 3.01 9.03 50.00	52 12.04 36.11 66.67	19 4.40 13.19 14.39	144 33.33
Duct Tape	57 13.19 39.58 29.08	9 2.08 6.25 34.62	13 3.01 9.03 16.67	65 15.05 45.14 49.24	144 33.33
Total	196 45.37	26 6.02	78 18.06	132 30.56	432 100.00

Table 15. SAS Frequency Table of tape type by Quality Scale

Statistic	DF	Value	Prob
Chi-Square	6	72.6404	<.0001
Likelihood Ratio Chi-Square	6	72.4848	<.0001
Mantel-Haenszel Chi-Square	1	6.2354	0.0125
Phi Coefficient		0.4101	
Contingency Coefficient		0.3794	
Cramer's V		0.2900	

Table 16. SAS statistics for Table 15

Table of Fabric by Visual Quality					
Fabric Type	**Visual Quality**				
Frequency Percent Row Pct Col Pct	**0**	**1**	**2**	**3**	**Total**
Control	7 1.62 25.93 3.57	2 0.46 7.41 7.69	4 0.93 14.81 5.13	14 3.24 51.85 10.61	27 6.25
Cotton	66 15.28 48.89 33.67	9 2.08 6.67 34.62	30 6.94 22.22 38.46	30 6.94 22.22 22.73	135 31.25
Denim	77 17.82 57.04 39.29	10 2.31 7.41 38.46	15 3.47 11.11 19.23	33 7.64 24.44 25.00	135 31.25
Polyester	46 10.65 34.07 23.47	5 1.16 3.70 19.23	29 6.71 21.48 37.18	55 12.73 40.74 41.67	135 31.25
Total	196 45.37	26 6.02	78 18.06	132 30.56	432 100.00

Table 17. SAS Frequency Table of fabric type by Quality Scale

Statistic	DF	Value	Prob
Chi-Square	9	31.5282	0.0002
Likelihood Ratio Chi-Square	9	31.8991	0.0002
Mantel-Haenszel Chi-Square	1	2.1403	0.1435
Phi Coefficient		0.2702	
Contingency Coefficient		0.2608	
Cramer's V		0.1560	

Table 18. SAS statistics for Table 17

Research Results and Discussion

Fabric Type Results

As the results of the SAS analysis determined there was a significant difference in the three variables tested, further analysis was conducted utilizing Microsoft Excel's Data Analysis tool.[3] The mean scores were calculated for both the fabric visual and quality scores (Tables 19 and 20) which found polyester scored the highest with a visual mean score of 2.4963 and quality mean score of 1.6889. These numbers showed the polyester fabric was the best fabric in the study for producing clearer latent fingerprints more often with cotton and denim following respectively in both scores.

Fabric Type Means (n = 135)	
Polyester	2.4963
Cotton	2.1926
Denim	2.0519

Table 19. Overall mean visual scores of fabric type

Fabric Type Means (n = 135)	
Polyester	1.6889
Cotton	1.1778
Denim	1.0296

Table 20. Overall mean quality scores of fabric type

The next analysis conducted was to determine how the fabric type interacted with both the tape type and processing method independently. The mean visual scores were calculated for the variable pairs (Table 21 and Figure 4) which determined latent fingerprints were developed more often from the polyester fabric then cotton or denim across all tape types with the best results coming from duct tape. Cotton fabric was the next best fabric for all but the clear packing tape, of which denim scored slightly higher in. Regarding the interaction with the processing

[3] Control samples were omitted from the sample sizes for the analysis in Excel.

method, the polyester fabric yielded more latent fingerprint development than the other fabrics using crystal violet and small particle reagent. Denim fabric yielded more latent fingerprint development using black wet powder and had a mean score of 2.8889, with polyester closely following with a mean score of 2.8222.

	Tape Type (n = 45)			***Processing Method (n = 45)***		
	BPT	**CPT**	**DT**	**BWP**	**CV**	**SPR**
Polyester	2.1778	2.6222	2.6888	2.8222	2.8000	1.8667
Cotton	1.9111	2.2667	2.4000	2.7778	2.0444	1.7556
Denim	1.6667	2.3778	2.1111	2.8889	1.6889	1.5778

Table 21. Interaction of fabric type to other variables using visual scale

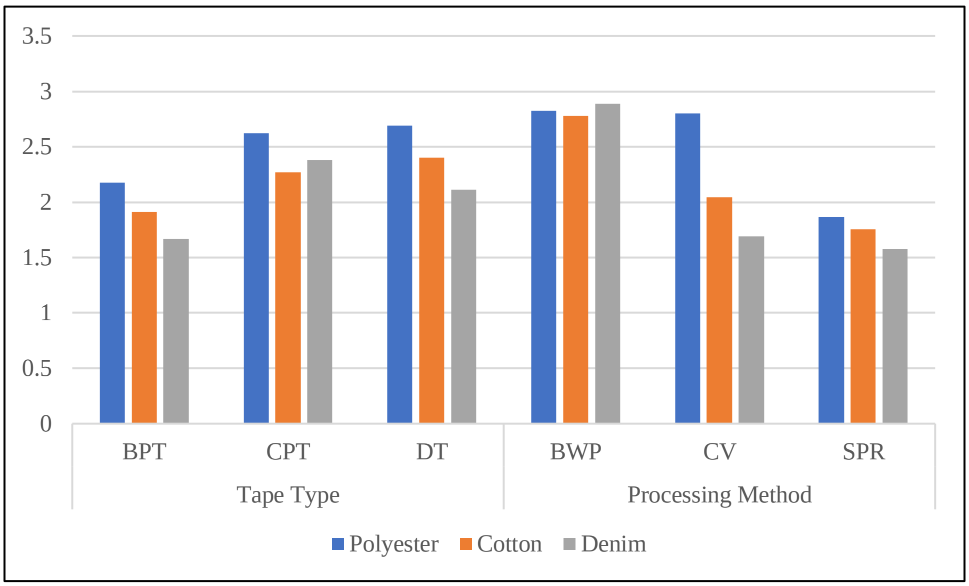

Figure 4. Interaction of fabric type to other variables using visual scale

The mean quality scores were calculated for the variable pairs (Table 22 and Figure 5) which determined polyester developed better quality latent fingerprints across all tape types, with the best interaction occurring with duct tape with a score of 1.9778. Cotton and denim scored second and third respectively across the tape types with both scoring best with duct tape with scores of 1.5111 and 1.2667. Regarding the interaction with the processing method, polyester quality scores were higher for crystal violet and small particle reagent (1.9778 and 0.6000) and denim scored higher for black wet powder (2.4889).

	Tape Type (n = 45)			***Processing Method (n = 45)***		
	BPT	**CPT**	**DT**	**BWP**	**CV**	**SPR**
Polyester	1.4000	1.6889	1.9778	2.4889	1.9778	0.6000
Cotton	1.0222	1.0000	1.5111	2.3556	0.6444	0.5333
Denim	0.9333	0.8889	1.2667	2.5556	0.2444	0.2889

Table 22. Interaction of fabric type to other variables using quality scale

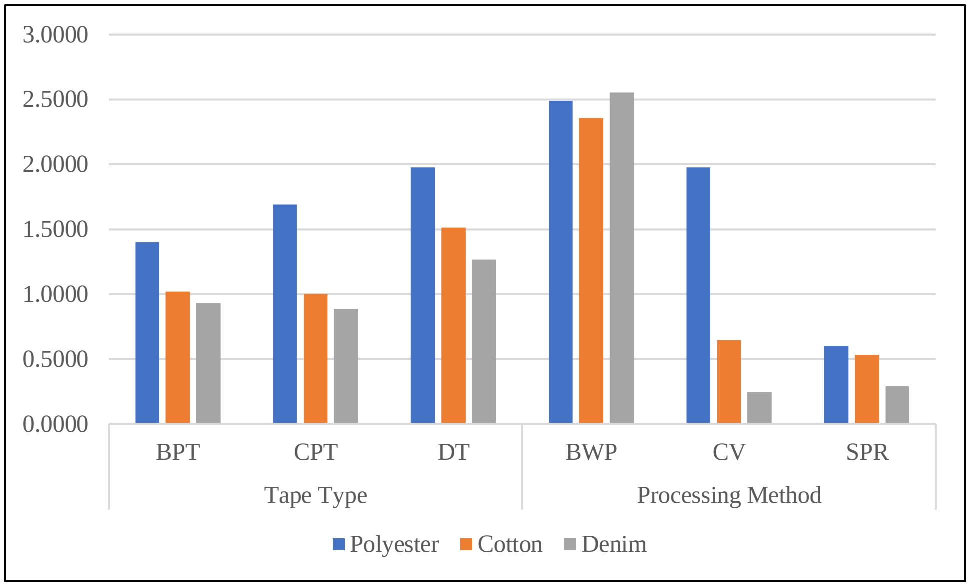

Figure 5. Interaction of fabric type to other variables using quality scale

These results reinforce what was observed during the processing and photographing of the developed latent fingerprints in that the polyester seemed to yield the most consistent results, followed by the cotton and denim fabric. Although there was no way to quantify the lint debris that was observed on the tape after separation from the fabric types, the polyester appeared to have the least amount of debris, followed by the cotton, then the denim. The visual score means for the fabric types follow the SAS frequency tables, but the quality scores do not as the frequency table ranked denim number two, but the means scored denim as number three. Although the denim outscored the cotton in frequency, the denim had more scores of zero which could have affected the mean score. These results help to satisfy the first objective of the study which was to determine if the type of fabric affects the development of latent fingerprints. The SAS analyses confirms there is a significant difference between the three fabrics, and the mean scores referenced above show fabric type does affect the development of latent fingerprints on adhesive surface after application to fabric.

Tape Type Results

The mean scores were calculated for both the tape visual and quality scores (Tables 23 and 24) which found minute differences in the rankings of the tapes. The clear packing tape ranked first in visual score and second in quality score with mean scores of 2.4222 and 1.1926 respectively. Duct tape ranked second in visual score and first in quality score with mean scores of 2.4000 and 1.5852 respectively. The difference between clear packing tape and duct tape for visual score was minute (0.0222) compared to the difference in quality scores (0.3926). These numbers show there might not be any difference in the ability to develop latent fingerprints on clear packing tape or duct tape after being applied to various fabric surfaces, but the quality of the developed latent fingerprint might be better on the duct tape.

Tape Type Means (n = 135)	
Clear Packing Tape	2.4222
Duct Tape	2.4000
Brown Packing Tape	1.9185

Table 23. Overall mean visual scores of tape type

Tape Type Means (n = 135)	
Duct Tape	1.5852
Clear Packing Tape	1.1926
Brown Packing Tape	1.1185

Table 24. Overall mean quality scores of tape type

The next analysis conducted was to determine how the tape type interacted with both the fabric type and processing methods independently. The mean visual scores were calculated for the variable pairs (Table 25 and Figure 6). latent fingerprints were developed more often from duct tape after being applied to polyester and cotton and from clear packing tape after being applied to denim. Brown packing tape was consistently not as reliable as the other two tape types, scoring third for all fabric types. Regarding the interaction with the processing method, brown packing tape and duct tape had the strongest scores for black wet powder with mean scores of 3.0000 for both. Clear packing tape had the best results when paired with crystal violet and small particle reagent, with mean scores of 2.4889 and 2.2889 respectively. Duct tape and brown packing tape followed clear packing tape respectively in those two processing methods.

	Fabric Type (n = 45)			***Processing Method (n = 45)***		
	Polyester	**Cotton**	**Denim**	**BWP**	**CV**	**SPR**
Brown Packing Tape	2.1778	1.9111	1.6667	3.0000	1.7556	1.0000
Clear Packing Tape	2.6222	2.2667	2.3778	2.4889	2.4889	2.2889
Duct Tape	2.6889	2.4000	2.1111	3.0000	2.2889	1.9111

Table 25. Interaction of tape type to other variables using visual scale

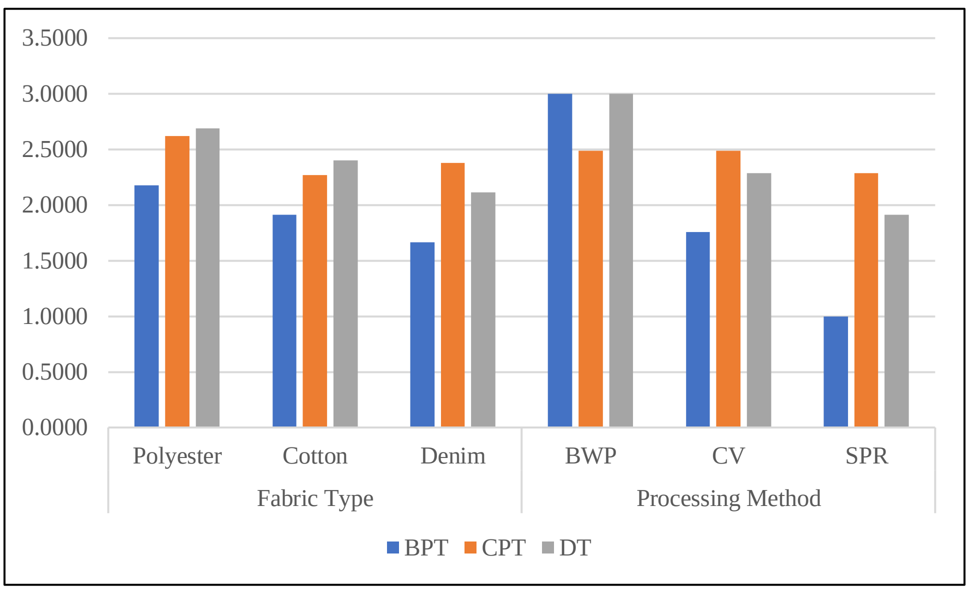

Figure 6. Interaction of tape type to other variables using visual scale

The mean quality scores were calculated for the variable pairs (Table 26 and Figure 7) which determined duct tape developed better quality latent fingerprints across all fabric types, with the best interaction occurring with polyester with a score of 1.9778. For cotton and denim, brown packing tape and clear packing tape scored second and third respectively, but the pair reversed order for polyester. Regarding the interaction with the processing method, duct tape scored the highest for black wet powder and crystal violet with mean scores of 3.0000 and 1.3556 respectively. Clear packing tape scored highest for small particle reagent with a mean score of 1.0222. Brown packing tape scored lowest for crystal violet and small particle reagent with 0.4889 and 0.0000 respectively.

	Fabric Type (n = 45)			***Processing Method (n = 45)***		
	Polyester	**Cotton**	**Denim**	**BWP**	**CV**	**SPR**
Brown Packing Tape	1.4000	1.0222	0.9333	2.8667	0.4889	0.0000
Clear Packing Tape	1.6888	1.0000	0.8889	1.5333	1.0222	1.0222
Duct Tape	1.9778	1.5111	1.2667	3.0000	1.3556	0.4000

Table 26. Interaction of tape type to other variables using quality scale

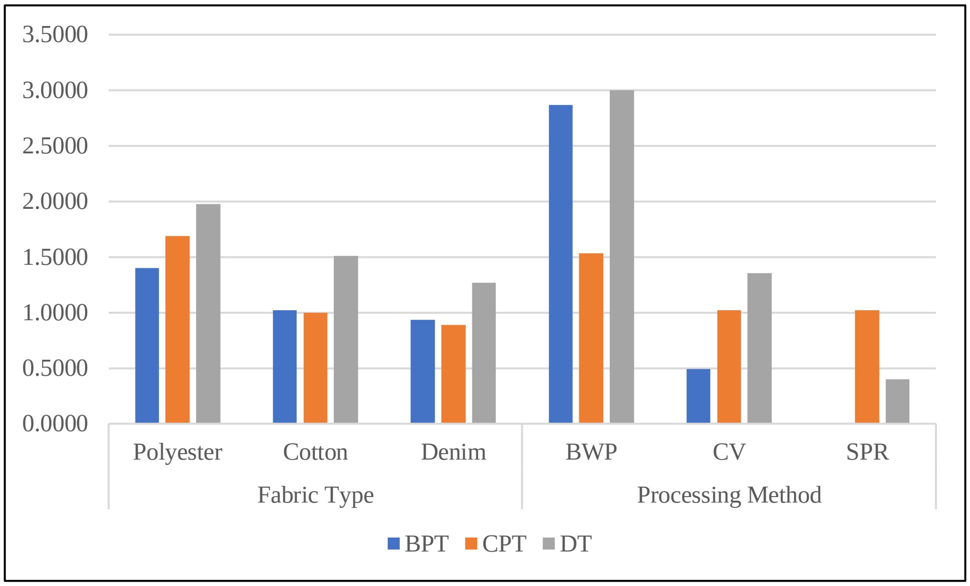

Figure 7. Interaction of tape type to other variables using quality scale

Although these results support the SAS frequency tables for both visual and quality scores, they are not in line with what was observed while conducting the study. The duct tape and brown packing tape appeared to develop latent fingerprints more consistently than the clear packing tape and with greater quality and clarity. Data does not support this and the discrepancy could be due to the clear packing tape not developing latent fingerprints as vividly as the other two tapes. It was not until closer examination of the images revealed the latent fingerprints were present. The lack of a contrasting background also could have skewed the observation during processing as duct tape and brown packing tape have a highly contrasting background whereas the clear packing tape does not unless it is placed on a secondary contrasting background. These results help to satisfy the second objective of the study which was to determine if the type of tape affects the development of latent fingerprints. The SAS analyses confirms there is a significant difference between the three tapes, and the mean scores referenced above show tape type does affect the development of latent fingerprints on adhesive surface after application to fabric.

Processing Method Results

The mean scores were calculated for both the processing method visual and quality scores (Tables 27 and 28) which found black wet powder scored the highest for both visual and quality means with scores of 2.8296 and 2.4667 respectively. The visual scores were close for all methods with crystal violet behind black wet powder with a score of 2.1778. The quality score means were not as close, with crystal violet scoring 0.9556 and small particle reagent scoring 0.4741. These numbers show that although it is possible to develop latent fingerprints using both black wet powder and crystal violet, the quality of the development will be better with the black wet powder.

Processing Method Means (n = 135)	
Black Wet Powder	2.8296
Crystal Violet	2.1778
Small Particle Reagent	1.7333

Table 27. Overall mean visual scores of processing method

Processing Method Means (n = 135)	
Black Wet Powder	2.4667
Crystal Violet	0.9556
Small Particle Reagent	0.4741

Table 28. Overall mean quality scores of processing method

The next analysis conducted was to determine how the processing type interacted with both the fabric type and tape type independently. The mean visual scores were calculated for the variable pairs (Table 29 and Figure 8). Black wet powder developed latent fingerprints more consistently across all fabric types, followed by crystal violet and small particle reagent. The fabric that saw the closest score was polyester, with black wet powder having a mean score of 2.8222 and crystal violet 2.8000. Small particle reagent was not as reliable at developing latent fingerprints ranking third in all fabrics. Regarding the interaction with the tape type, black wet powder outperformed the other two methods for brown packing tape and duct tape with mean scores of 3.0000 for each tape. Black wet powder and crystal violet both had mean scores of 2.4889 for clear packing tape, with small particle reagent scoring 2.2889. Although the black wet powder and crystal violet outscored the small particle reagent, it is possible to develop latent fingerprints with all three processing methods on clear packing tape.

	Fabric Type (n = 45)			***Tape Type (n = 45)***		
	Polyester	**Cotton**	**Denim**	**BPT**	**CPT**	**DT**
Black Wet Powder	2.8222	2.7778	2.8889	3.0000	2.4889	3.0000
Crystal Violet	2.8000	2.0444	1.6889	1.7556	2.4889	2.2889
Small Particle Reagent	1.8667	1.7556	1.5778	1.0000	2.2889	1.9111

Table 29. Interaction of processing method to other variables using visual scale

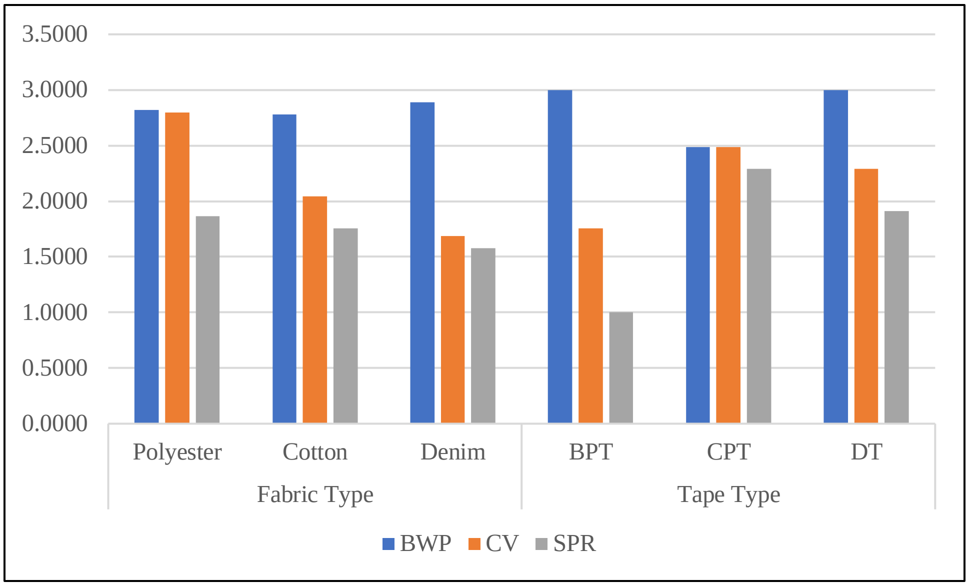

Figure 8. Interaction of processing method to other variables using visual scale

The mean quality scores were calculated for the variable pairs (Table 30 and Figure 9) which determined black wet powder developed better quality latent fingerprints across all fabric types, with the best interaction occurring with denim with a score of 2.5556. Crystal violet scored second in quality for polyester and cotton, with the best mean score of 1.9778 for polyester. Small particle reagent scored second in quality for denim with a mean score of 0.2889. Regarding the interaction with the tape type, black wet powder developed better quality latent fingerprints across all tape types with best quality of 3.0000 for duct tape and 2.8667 for brown packing tape. Crystal violet scored second in quality for brown packing tape and duct tape and tied with clear packing tape with a score of 1.0222.

	Fabric Type (n = 45)			***Tape Type (n = 45)***		
	Polyester	**Cotton**	**Denim**	**BPT**	**CPT**	**DT**
Black Wet Powder	2.4889	2.3556	2.5556	2.8667	1.5333	3.0000
Crystal Violet	1.9778	0.6444	0.2444	0.4889	1.0222	1.3556
Small Particle Reagent	0.6000	0.5333	0.2889	0.0000	1.0222	0.4000

Table 30. Interaction of processing method to other variables using quality scale

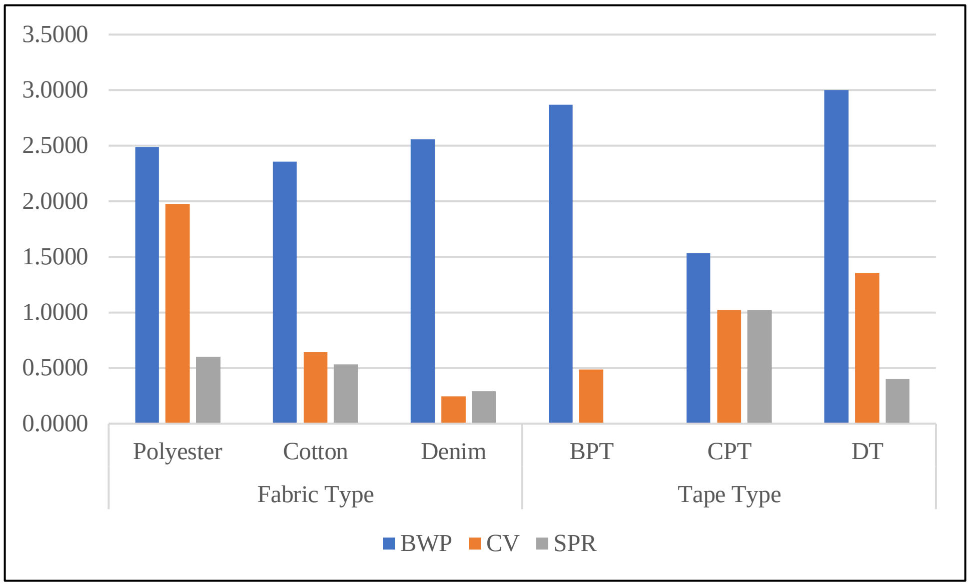

Figure 9. Interaction of processing method to other variables using quality scale

These results support the SAS frequency tables for both visual and quality scales and the observations made during the conduct of the study. It was observed black wet powder was able to consistently develop more latent fingerprints, particularly on brown packing tape and duct tape, but was not as consistent on clear packing tape. These results also reinforce existing literature that suggests there are other, more effective methods to employ on adhesive surfaces other than small particle reagent. These results help to satisfy the third objective of the study which was to determine if the processing method affects the development of latent fingerprints. The SAS analyses confirms there is a significant difference between the three processing methods, and the mean scores referenced above show processing method does affect the development of latent fingerprints on adhesive surface after application to fabric.

Overall Results

In order to determine how the three variable combinations compared to each other, the mean scores were calculated from the samples, broken down by fabric type, followed by tape type and processing method, which provided a sample size of 15 per variable combination. After determining the mean scores, the variable combinations were ranked based on the visual score means and quality score means (Tables 31 and 32). Means for the visual scores revealed a tie between six of the variable combinations with mean scores of 3.0000. All three fabric types made up the fabric variable of the combinations. Brown packing tape and duct tape accounted for the tape variable of the combination. Black wet powder was the only processing method of the top six combinations. Means for the quality scores revealed a tie between four of the variable combinations with mean scores of 3.0000. All three fabric types made up the fabric variable of the combinations. Duct tape accounted for three of the tape types with brown packing tape accounting for the fourth. Black wet powder was the only processing method of the top four. Reviewing both the visual and quality mean score rankings, the small particle reagent and crystal violet accounted for the lower rankings while the black wet powder accounted for a majority of the higher rankings. The fabric appears to be consistently dispersed along with the tape type, with clear packing tape clustering closer to the middle rankings.

Rank	Fabric/Tape/Processing Method	Mean (n = 15)
1	Cotton/Brown Packing Tape/Black Wet Powder	3.0000
	Cotton/Duct Tape/Black Wet Powder	3.0000
	Denim/Brown Packing Tape/Black Wet Powder	3.0000
	Denim/Duct Tape/Black Wet Powder	3.0000
	Polyester/Brown Packing Tape/Black Wet Powder	3.0000
	Polyester/Duct Tape/Black Wet Powder	3.0000
7	Polyester/Clear Packing Tape/Crystal Violet	2.9333
	Polyester/Duct Tape/Crystal Violet	2.9333
9	Denim/Clear Packing Tape/Black Wet Powder	2.6667
10	Polyester/Brown Packing Tape/Crystal Violet	2.5333
11	Polyester/Clear packing Tape/Black Wet Powder	2.4667
	Polyester/Clear Packing Tape/Small Particle Reagent	2.4667
13	Cotton/Clear Packing Tape/Black Wet Powder	2.3333
14	Cotton/Clear Packing Tape/Crystal Violet	2.2667
	Denim/Clear Packing Tape/Crystal Violet	2.2667
16	Cotton/Clear Packing Tape/Small Particle Reagent	2.2000
	Denim/Clear Packing Tape/Small Particle Reagent	2.2000
18	Cotton/Duct Tape/Crystal Violet	2.1333

	Polyester/Duct Tape/Small Particle Reagent	2.1333
20	Cotton/Duct Tape/Small Particle Reagent	2.0667
21	Denim/Duct Tape/Crystal Violet	1.8000
22	Cotton/Brown Packing Tape/Crystal Violet	1.7333
23	Denim/Duct Tape/Small Particle Reagent	1.5333
24	Cotton/Brown Packing Tape/Small Particle Reagent	1.0000
	Denim/Brown Packing Tape/Crystal Violet	1.0000
	Denim/Brown Packing Tape/Small Particle Reagent	1.0000
	Polyester/Brown Packing Tape/Small Particle Reagent	1.0000

Table 31. Overall ranking of print development visual scale

Rank	**Fabric/Tape/Processing Method**	**Mean (n = 15)**
1	Cotton/Duct Tape/Black Wet Powder	3.0000
	Denim/Duct Tape/Black Wet Powder	3.0000
	Polyester/Brown Packing Tape/Black Wet Powder	3.0000
	Polyester/Duct Tape/Black Wet Powder	3.0000
5	Cotton/Brown Packing Tape/Black Wet Powder	2.8000
	Denim/Brown Packing Tape/Black Wet Powder	2.8000
	Polyester/Duct Tape/Crystal Violet	2.8000
8	Polyester/Clear Packing Tape/Crystal Violet	1.9333
9	Denim/Clear Packing Tape/Black Wet Powder	1.8667
10	Polyester/Clear Packing Tape/Small Particle Reagent	1.6667
11	Polyester/Clear Packing Tape/Black Wet Powder	1.4667
12	Cotton/Clear Packing Tape/Black Wet Powder	1.2667
13	Polyester/Brown Packing Tape/Crystal Violet	1.2000
14	Cotton/Clear Packing Tape/Small Particle Reagent	1.0000
15	Cotton/Duct Tape/Crystal Violet	0.9333
16	Cotton/Clear Packing Tape/Crystal Violet	0.7333
17	Cotton/Duct Tape/Small Particle Reagent	0.6000
18	Denim/Duct Tape/Small Particle Reagent	0.4667
19	Denim/Clear Packing Tape/Crystal Violet	0.4000
	Denim/Clear Packing Tape/Small Particle Reagent	0.4000
21	Denim/Duct Tape/Crystal Violet	0.3333
22	Cotton/Brown Packing Tape/Crystal Violet	0.2667
23	Polyester/Duct Tape/Small Particle Reagent	0.1333
24	Cotton/Brown Packing Tape/Small Particle Reagent	0.0000
	Denim/Brown Packing Tape/Crystal Violet	0.0000
	Denim/Brown Packing Tape/Small Particle Reagent	0.0000
	Polyester/Brown Packing Tape/Small Particle Reagent	0.0000

Table 32. Overall ranking of print development quality scale

Result Discrepancies

These results show there are significant differences in how tape type, processing methods and fabric type affect latent fingerprint development on adhesive surfaces. It is possible the combination of all three variables have the most significant effect on development, or it is possible a combination of only two variables can have a dramatic impact on development. Prior research has shown powder solutions and crystal violet are two of the widely used methods to process latent fingerprints on adhesive surfaces. These developments are mostly conducted under ideal situations where the focus is on what type and application of specific methods generates the best results. Gentian violet can be used to develop latent fingerprints on adhesive surfaces (Figure 10), but in this study the apparent lint debris that was picked up by the tape affected the development of the latent fingerprints (Figure 11).

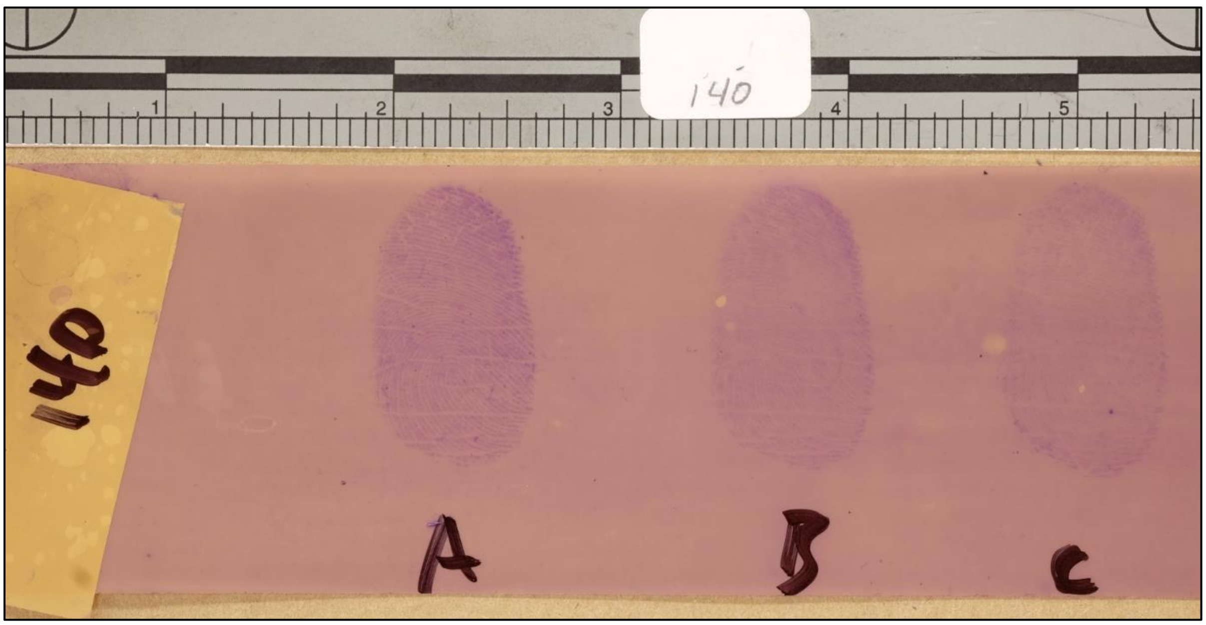

Figure 10. Post-processing of crystal violet on brown packing tape

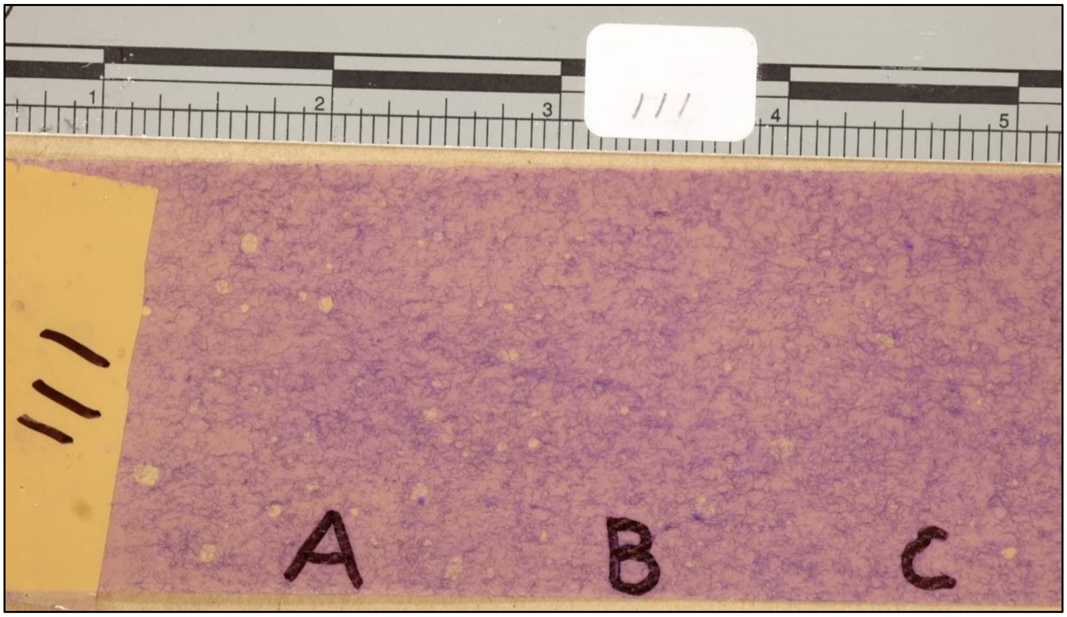

Figure 11. Post-processing of crystal violet on brown packing tape applied to denim

It is also possible the fabric interacts with the latent fingerprint in a way that lessens the detail of the latent fingerprint or actually transfers the latent fingerprint to the fabric. Perez-Avila (2008) found a latent fingerprint can be transferred from one substrate to another. During the examination of a paper envelope with an adhesive stamp, processing of the stamp did not reveal a latent fingerprint, but the area directly behind the stamp on the envelope yielded a latent fingerprint. It was presumed the latent fingerprint transferred from the stamp to the envelope. This could have been the case with this study where the latent fingerprint either absorbed into the fabric or was possibly transferred.

Another factor that could have affected the results is the physical makeup of the adhesive on the tape. Visual and physical examination of all three types of tape reveal differences in texture and tackiness of the adhesive and adhesive backing. These differences could have an effect on the processing method as was apparent with the small particle reagent. The visual and quality scores for the small particle reagent were better for the clear packing tape then they were for the brown packing tape and duct tape. The difference could also affect the way the fabric interacts with the adhesive. An adhesive that has less adhesive qualities might not pick up as much lint debris from the fabric as others, which could affect the processing method as seen in Figure 11.

Lastly, the fabrics could play a vital role in the ability to develop a latent fingerprint from an adhesive surface. As stated earlier, there was no mechanism on hand to measure the amount of lint debris each type of tape picked up. Throughout the study it was observed the polyester deposited little, if any, lint debris compared to the cotton or denim. The makeup of the fabric plays a part in how much lint is shed which in turn affects how well the processing method develops the latent fingerprints.

Conclusion

This study sought to fill an apparent void in the literature concerning the ability to develop latent fingerprints on adhesive surfaces after being applied to fabric surfaces. As discussed earlier, there are multiple studies conducted on the ability to develop latent fingerprints on adhesive surfaces. There are a variety of best practices, with each latent fingerprint examiner employing the technique the are most comfortable with or that resources allow. The author is aware there could be studies that have been conducted that addressed the issue of how application to fabrics affect the ability to develop latent fingerprints on adhesive. However, author was not able to find research as such. Through experimenting with the fabric type, tape type and processing methods, the initial research question of can a latent fingerprint be developed from an adhesive surface after it has been applied to fabric has been answered. This study has shown that latent fingerprints can be developed after an adhesive surface has been applied to various fabric types. The three variables studied do affect the ability to develop latent fingerprints and the quality of the developments. Brown packing tape, duct tape and black wet powder were the top producers on all three fabric types based on the ranking of the variable combinations. This study will assist latent fingerprint examiners with determining the appropriate processing method for adhesive that has been applied to fabric based on fabric type and tape type. Rather than take a processing method that has proven to work in ideal situations, examiners can identify the appropriate processing method that fits their need. This study can also reinforce the need for crime scene personnel to properly attempt to document the condition of how the adhesive was found. Documenting if the tape was recovered from a victim's legs who was wearing jeans or from the arms of a victim who was wearing a moisture wicking shirt will help the latent fingerprint examiner properly assess the best method to process the evidence.

This study also adds to the literature pertaining to the use of LQMetrics as an analysis tool in research. As stated earlier, more and more studies are beginning to use the software in an attempt to take human subjectivity out of the analysis process. These studies appear to be conducted under ideal settings with good-quality latent fingerprints with findings being reported based on the results of the software. This study found the software to be unreliable in analyzing the images presented. The software scored images where there was no latent fingerprint present and failed to score those where there was one present. It should be noted that this author received no formal training on the use of the software, to include when to employ it, the capabilities and the actual operation of the software. It is possible the author was using the software in a manner it was not intended for, but it is important to report the discrepancies found in the conduct of this research study.

It should also be noted that although the results show latent fingerprints can be developed from adhesive surfaces after being applied to fabric, this does not mean an identification can be made from the latent fingerprints. The developed latent fingerprints were not scored and analyzed by a latent fingerprint examiner. The scoring scales simply identified if a latent fingerprint with ridge details was present (3), if a latent fingerprint without ridge detail was present (2), and if there was no latent fingerprint present (1). Additionally, the score of 3 could account for a whole latent fingerprint with ridge detail, or it could only account for a small portion of the area identified as containing a latent fingerprint with ridge detail. Analysis of detail levels was not assessed of the latent fingerprints and therefore, this study cannot confirm the results can lead to positive identification or exclusion.

Study Limitations

Despite the positive results of this study, there were some limitations that were identified. The first being there was no consistent means of depositing the latent fingerprints onto the tape and no ability to directly confirm the presence of latent fingerprints on the tape prior to depositing onto the fabric. Although the process was repeated the same for all samples, the pressure used to apply the simulant, blot the latent fingerprint, and apply to the tape was not measured. Also, the duct tape proved to be difficult in observing if a latent fingerprint was successfully deposited. It is possible some of the samples that did not have latent fingerprints could have been the result of poor latent fingerprint deposition. Incorporating a method to measure the pressure of each press of the finger and confirm the presence of a latent fingerprint would ensure confidence the pressure was applied the same for all samples.

The second limitation is the employment of appropriate personnel to address specific needs. Due to time constraints, it was not possible to send the latent fingerprint images to a latent fingerprint examiner for analysis. It was also not possible to coordinate with individuals who were trained in the use of software such as LQMetrics or the application of statistics. This would have benefited the analysis portion and the statistics portion of the research.

The third limitation is the washing of the fabric samples. One of the initial objectives of this research was to determine how the number of wash cycles affects the ability to develop latent fingerprints from adhesive surfaces. The fabric samples were washed according to the study design, but it was determined the data from the wash cycles did not have enough samples to be statistically significant. These wash cycles could have affected the development of the samples, but to what degree, if any, is uncertain.

The fourth and limitation identified is the inability to combine the three different exposures. Often called high dynamic range (HDR), this process can be accomplished in third-party software and allows the user to combine various exposures. This is useful in examination quality images, as bracketing of exposures allows the observer to see details differently with each exposure. Ideally, the combining of the -1, 0, +1 images would create an image that showed all details as one image. This could have affected the way LQMetrics analyzed the images and could have affected the subjective scoring accomplished during the research.

Future Research

This study can be expanded on in a variety of ways. The first is to determine if the wash cycles affect the development of latent fingerprints on adhesive surfaces. Although it might not be important for a latent fingerprint examiner to know or care about how many times a fabric had been washed, the interaction of the lint properties in the garment and the effect on latent fingerprint development would be interesting. Studies have been conducted on the number of microfibers released during the laundering process and how the microfibers affect the marine ecosystem (Zambrano et al., 2019). These types of studies can help with the literature review and can give a good framework for study design.

This study can also be expanded on by varying the variables of fabric type, processing methods and tape type. Denim, cotton and polyester were chosen as they were common fabrics encountered at crime scenes. The denim represented common jeans, the cotton represented a common t-shirt and the polyester represented a moisture-wicking athletic shirt or pants. Varying the fabric types to include sweatshirt material or nylon would help further the research. Varying the processing methods could include time or method of application of the three methods. The crystal violet appeared to be lighter than it should have been and perhaps would have better results if left in the solution for longer. Duct tape, brown packing tape and clear packing tape was chosen as they are common adhesives submitted to laboratories for examination. Studying how adhesives such as electrical tape, stickers or address labels could further the research and make positive contributions to the literature.

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