FACTORS EFFECTING FRICTION RIDGE TRANSFER THROUGH GLOVES USED DURING CRIME SCENE PROCESSING

by

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List of Definitions/Acronyms

Double-Gloving	The application of two gloves of the same size to one hand
DSLR	Digital Single-Lens Reflex
Friction Ridge Detail	The ridged and furrowed detail of the skin on the palmar surface of the hand or plantar surface of the feet
Nonporous	A surface without absorbent capabilities; impervious to liquid permeation
Porous	A surface with absorbent capabilities
PPE	Personal Protective Equipment
Substrate	Deposition surface

Abstract

A pillar of the crime scene processing curriculum, Locard's Exchange Principle states that every place one goes, they take something with them and also leave a trace behind. The ultimate goal of crime scene processing is to collect valuable forensic evidence while minimizing the effects of Locard's Exchange Principle. The use of personal protective equipment (PPE) is one of the most common ways the forensic community mitigates the risk of cross-contamination during crime scene processing. Through trial, error, and research, it is known that friction ridge detail can transfer through gloves. The objective of this research is to help the field of crime scene investigation to develop best practices for minimizing scene contamination by way of this transfer. Though the community agrees it is possible to deposit this detail, it is lesser known what practices can intensify that chance, and more importantly – what can prevent it. This research tests two sets of circumstances in an attempt to determine best practices for mitigating friction ridge transfer during crime scene processing.

This study determines the effect of hand condition, glove size, and utilization of the double-gloving method on the transfer of friction ridge detail to a glass surface through nitrile examination gloves. The findings were that the condition of the hands prior to donning the glove(s) did not impact this transfer, but that wearing two pairs of gloves significantly reduced the occurrence of friction ridge detail on the deposition surface as compared to one pair of gloves.

Keywords: *Fingerprint transfer, latent fingerprints, glove fingerprints, friction ridge transfer*

Introduction

This research in particular tests the following factors: glove size, hand condition, and doubling of gloves. During this study, researchers don gloves, manipulating the above variables, and deposit fingerprints on a piece of glass. The researchers then observe that piece of glass and process it for latent fingerprints using oblique lighting and fingerprint powder. Researchers will determine based on this processing whether friction ridge detail has been transferred onto the surface. By conducting this research, recommendations can be made for best practices regarding glove use across the forensic community. This is important work as it prevents the crime scene investigator's friction ridge detail from being transferred onto items at the scene, avoiding the unnecessary expenditure of resources to classify and identify the source of the friction ridge detail.

Ideally, all crime scene investigators would have access to the proper glove size based on their hand size, but factors like funding, allocation of resources, and time spent on scene can mean that crime scene personnel may have to wear gloves that are too large or too small. Wearing properly fitting gloves may have an impact on the ability for friction ridge detail to permeate the gloves and later be transferred onto surfaces at a crime scene. Likewise, the condition of a crime scene personnel's hands at the time they don their gloves may also be of concern. Studies have shown that as sweat production on the hands increases, so does the chance of depositing friction ridge detail onto a surface (Willinski, 1980). Though not studied, the condition of a person's hands may influence the ability of friction ridge detail to permeate a glove and later deposition onto a surface. This research focuses on three possible hand 'conditions': 1) freshly cleaned with soap and water, 2) recent application of hand sanitizer and 3) recent application of lotion. This study aims to determine whether there is a correlation between conditions of the hands and permeation of friction ridge detail through nitrile gloves. Finally, this study determines whether wearing two gloves, herein referred to as double-gloving, fully prevents permeation of friction ridge detail, even with applying the above sets of circumstances.

Importance of Research

The ultimate goal of crime scene personnel is to apply the field of forensic science in such a way that a crime scene can be documented thoroughly enough to allow for reconstruction (if the situation warrants). From the moment a crime is committed, evidence begins to disintegrate. Trace fibers can be blown away by air conditioning; the sun can melt footwear impressions left in the snow, and animals can walk through bloodstain patterns. Furthermore, the crime scene can be naturally self-contaminating, so crime scene personnel must always do their best not to add on to this contamination. One of the primary methods of mitigating personnel contaminants both to and from the scene is personal protective equipment. According to the National Institute of Justice's (NIJ) 2009 publication on "Equipment Needed for Crime Scene Processing", personal protective equipment is considered one of the "essential items for crime scene personnel". NIJ further stipulates that personal protective equipment includes "gloves, booties, hair covering, overalls and mask" (para. 3). The NIJ's 2016 Fingerprint Sourcebook states that, "proper evidence handling begins with the use of latex, nitrile, PVC, or other suitable gloves" (National Institute of Justice, 2009, p. 7-5). It is well established in the crime scene processing community that contamination is an issue; one of the ways the community fights to prevent it is through the use of personal protective equipment and in particular, gloves.

To give an example of this: if there were a crime scene where an assault had taken place and based on the witness and victim's statements; the weapon wielded by the perpetrator was a glass bottle, the crime scene personnel would further process that bottle to try to visualize identifiable friction ridge detail. They may attempt to fume the bottle using cyanoacrylate and submit it to a laboratory, or dependent on their agency policies, they may try to powder the bottle and lift any apparent fingerprints visualized on the bottle. Both of these methods require handling of the item of evidence. To do so, the crime scene technician would don a pair of gloves in accordance with their agency standards and handle the item of evidence, taking special care to avoid touching the areas the perpetrator most likely touched. The idea behind this level of care is that the item of evidence remains as close as possible to the condition it was in when the incident was terminated. Now if the bottle had been processed and there were several areas of friction ridge detail, the crime scene technician would take the proper next steps. In the interest of thoroughness, the crime scene personnel would take the time to visualize, photograph, preserve, and even potentially lift all of those potential fingerprints. For anyone who has done this, they know it can be a painstaking process. The item, the lifts, and the photographs would be sent to the laboratory for comparison, where on-scene personnel would receive feedback about whether or not the prints were identifiable and able to be used for comparison to a known exemplar of potential suspects. Fingerprints that are deemed suitable for comparison are entered into the Combined DNA Indexing System (CODIS) to try to find a potential match to an unknown suspect or compared to a known exemplar. No further steps are taken with fingerprints that are determined unsuitable for comparison.

As a latent print examiner will confirm, there are many reasons prints could be deemed not suitable for comparison. The fingerprint could be lacking the necessary level of visible detail, the substrate could be unsuitable for a clear print, the fingerprint might not have been properly fixed prior to transport, or the photograph used for comparison might not have been of high enough quality. Regardless the reason, reaching the conclusion that the print is not suitable for comparison requires the same amount of time, effort, and expertise on the part of the personnel involved. If, like in the example described above, there are prints that are determined unsuitable for comparison, no additional steps are taken. This is a common occurrence and can be extremely frustrating for crime scene personnel who spend potentially hours delicately powdering, photographing, and lifting prints at a scene. In this respect, the personnel on scene may be their own worst enemies. Based on the research conducted in this study, technicians on the scene could be unknowingly depositing fingerprints through their gloves and inadvertently increasing their workload exponentially. The importance of this research is to realize the time and patience it takes to process a crime scene, and to mitigate any process known to unnecessarily warrant additional time, resources, and expertise from crime scene and laboratory personnel.

Background Information

Preservation of the Scene

Scene degradation is inevitable, and it starts the moment the incident is terminated. The duty of the crime scene technician is to best preserve the scene while minimizing the creation of post-incident artifacts. Crime scene personnel will create post-incident artifacts simply by being present in the scene. They will inevitably enact damage on the evidence that is present upon their arrival. Crime scene personnel must do everything they can to limit their alteration of the evidence as they handle it. This includes special care to avoid adding to the evidence, moving it from its original position, or breaking or damaging the evidence (Gardner, 2012). This especially applies to evidence that is not easily visible with the naked eye, such as DNA, hairs and fibers, and friction ridge detail. This becomes particularly important regarding fingerprint evidence, because of its potential to be extremely incriminating while still being fragile.

Fingerprints and Friction Ridge Detail

Fingerprints are unique to the individual. Even identical twins, who share the same Deoxyribonucleic Acid (DNA), have different fingerprints. This makes fingerprints essential to placing an individual at the scene of a crime. Though the weight fingerprint evidence carries is strong and impactful, fingerprints themselves are extremely delicate. Fingerprints are composed mostly of water – 98%, making them extremely susceptible to obliteration through time, elements, and manipulation (Gardner, 2012). Fingerprints are deposited because of friction ridge detail, which is a type of skin only present on the palmar and plantar surfaces of the hands and feet (Houck, 2010). There are three types of detail that fall under friction ridge detail: level one, two, and three. The classification of these levels of detail are extremely comprehensive, but overall can be summarized as the following: level one detail exhibits some sort of ridge pattern, level two detail includes the visualization of minutiae (smaller details such as ridge bifurcations or endings), and level three adds in the visualization of even finer detail such as sweat pores (Maltoni, 2009).

Fingerprints are deposited onto a surface when the friction ridge detail on the skin comes into contact with that surface, leaving an impression of the unique details. This impression can be latent, patent, or plastic. Latent prints are considered invisible until processed by physical or chemical means, patent prints are able to be seen with the naked eye, and plastic prints are three-dimensional impressions left in a pliable substrate (U.S. Department of Justice, 2016).

Deposition Factors

There are three types of conditions that directly impact the ability to visualize or develop fingerprints. But only two of these conditions directly influence this research in particular: pre-transfer conditions and transfer conditions, where post-transfer conditions did not play a role. One of the most prominent pre-transfer conditions is residue on the friction ridge skin. This includes not only the type of residue, but the amount as well (U.S. Department of Justice, 2016). The transfer conditions can include the amount of pressure applied by the source as well as the substrate condition, including texture, cleanliness, and shape. When a fingerprint is deposited on a nonporous surface such as glass, both the water soluble and water insoluble elements remain on the surface. This makes the print more susceptible to damage but can also make it easier to visualize. Post-transfer conditions include considerations such as time, fingerprint interference, and environmental factors like humidity (Daluz, 2019).

Crime Scene Development of Fingerprints

The most important task crime scene personnel can perform is to preserve evidence as soon as it is discovered. As previously mentioned, fingerprint evidence is extremely important and also extremely fragile. This means that as soon as crime scene personnel can visualize this evidence, they need to photograph it. They then follow their respective agency's procedures escalating from least invasive to most invasive means of development. After ambient light visual inspection, the best tool is visual inspection with an alternate light source. An oblique light source is a great tool because it "uses low-angle illumination to show details by creating shadows", which can be seen in the ridges and furrows of a fingerprint, providing further clarity to crime scene personnel (U.S. Department of Justice, 2016, p. 8-14). Depending on the end goal (whether it be to develop and lift a print on scene or to submit an entire item of evidence to a laboratory), the next step may be to further develop the visibility of the friction ridge detail using a powder method. Despite new methods, technology, and ever-developing research, powder and brush is still considered the main method by which to develop latent prints on a nonporous surface (Gardner, 2012). For that reason, this is the method that will be utilized in this particular study.

Fingerprint powders are used primarily to develop contrast, allowing for clearer visualization of the print. Most fingerprint powders function similarly and are comprised of two basic components: the pigment and the binder. The pigment is the primary means of contrast, while the binder actually adheres to the residue that comprises the latent print (U.S. Department of Justice, 2016). Black powder is considered best for use on lighter-colored, nonporous surfaces such as windows or mirrors, for example (Daluz, 2019). It is recommended that powders be applied to nonporous surfaces using a soft brush, usually comprised of either "animal hair, fiberglass filaments, or sometimes feathers" (U.S. Department of Justice, 2016, p. 7-12).

Previous Research

As previously mentioned, several reputable sources from which agencies derive their crime scene processing policies mention the possibility that friction ridge detail can permeate through gloves and transfer onto a secondary surface. For example, Houck (2010) states that crime scene personnel should, "wear gloves to avoid leaving fingerprints – but be aware that after about 30 minutes, it is possible to leave fingerprints through latex gloves" (p. 38). Similarly, the National Institute of Justice (2016) warns, "it should be noted that the use of gloves does not preclude the transfer of friction ridge detail from the examiner to the exhibit" (p. 7-5). Along the same lines, Ramotowski (2012) cites "a number of reports of people wearing gloves and leaving latent prints on surfaces" (p. 171). Ramotowski was the source which most veraciously substantiated the claim, further explaining the hypothesis that dependent on the thickness of the glove; it is possible for latex gloves to "conform to the surface structure of the finger and (along with contaminant on the glove surface), could lead to clear friction ridge detail" (p. 171). Ramotowski further explains that friction ridge detail has been seen to transfer even when the subject wears two pairs of gloves. This phenomenon can vary depending on the brand of gloves.

There are two studies in particular which tested the transfer of friction ridge detail through varying types of gloves worn by crime scene personnel. Both focused primarily on the amount of time the glove was worn. The first study of note was previously mentioned and was conducted in 1991 by Gary Willinski at the Optical Component Evaluation Laboratory (OCEL) on Kirtland Air Force Base in Albuquerque, New Mexico. Willinski tested permeation of friction ridge detail through several types of gloves, including vinyl, polyvinyl chloride, latex, and 100% cotton. This study tested the permeation of fingerprints based on the wear-time of these types of gloves. The permeation was studied at intervals of 0, 5, 10, 20, 40, and 60 minutes. The study showed that the longer an individual wears their PPE, the more likely they are to transfer the friction ridge detail of their fingerprint to a glass surface (Willinski, 1991).

Another pertinent study to mention is that of David Lounsbury and L. Frank Thompson, conducted in 2004 at Florida Gulf Coast University. Lounsbury and Thompson tested permeation of friction ridge detail through multiple types of gloves as well, including nitrile, latex, and vinyl. The participants wore their gloves continuously for one hour before attempting to create fingerprints on white fingerprint lift cards using a moderate touch. They then attempted to create fingerprints every 15 minutes thereafter for two hours. After their final attempt, participants ran their gloved hand through their hair and attempted to make one last fingerprint. The results concluded that friction ridge detail was visible only after the "intentional contamination" of participants running the gloved hand through their hair, and only with the use of the vinyl glove. Other glove types produced patterns or outlines, but none that researchers deemed to be friction ridge impressions.

It is important to note here that while the Lounsbury and Thompson study targeted gloves worn for the use of crime scene processing in particular, the Willinski study aimed to determine the best glove or glove combination for use with highly specialized optical components. For this reason, the conclusion of the Willinski study does not take into account the need for personal protective equipment on the part of the glove-wearer, and rather accounts solely for the mitigation of damage to an optical component. Because of this, Willinski recommends the use of a cotton glove or a cotton glove with a surgical glove underneath. Catering specifically to crime scene personnel however, Lounsbury and Thompson recommend either a double-glove or a vinyl glove with a cotton glove underneath based on their results. Based on this information, the researcher designed an experiment with a previously untested set of circumstances, but with an informed idea of what conditions could prevent friction ridge transfer.

Materials

The following materials are necessary for this research (Note: parentheses indicate the exact brand researchers used in this experiment):

1. One box of small nitrile gloves (Medline FitGuard® Touch Powder Free Exam Gloves)
2. One box of medium nitrile gloves (Medline FitGuard® Touch Powder Free Exam Gloves)
3. One box of large nitrile gloves (Medline FitGuard® Touch Powder Free Exam Gloves)

4. One container of liquid antibacterial soap (Dial Complete® Liquid Antibacterial Hand Soap – White Tea Scented)
5. Sink/water source
6. Paper towels
7. Two pipettes
8. One source of oblique light (Crime-Lite® 82L)
9. Glass microscope slides (AmScope® Blank Microscope Slides)
10. One container of hand sanitizer (Purell® Advanced Refreshing Gel Hand Sanitizer)
11. One container of unscented lotion (Jergens® Ultra Healing Extra Dry Skin Moisturizer)
12. One container of black fingerprint powder (SFPL® Silk/Black Latent Print Powder)
13. One fingerprint powder brush (Lynn Peavey® Single Scene Brush)
14. One pair of plastic tweezers
15. One DSLR camera (Nikon® D850)
16. Macro camera lens (Nikon® AF-S Micro NIKKOR 60mm f/2.8G ED)
17. Camera memory card (SanDisk® Ultra 32GB)
18. Means of stable examination quality photography (i.e. quadpod, photo table, etc.)

Methods

Determination of Materials and Methodology

Based on the literature relied upon by many agencies when establishing their crime scene processes and procedures, it was determined that there does not tend to be an overall recommendation for a glove material or brand. Crime scene personnel seem to gravitate toward latex-free gloves in order to accommodate those with latex allergies, and also tend to gravitate toward powder-free gloves in order to mitigate deposition of trace powders at crime scenes.

Based on information for the best camera settings to photograph examination-quality friction ridge detail, the researcher in this study photographed with the following settings for the following reasons. A macro lens was used to ensure a close enough image to capture the necessary level of detail. The researcher shot the photographs with an ISO setting of 100, as is recommended for all examination-quality photographs (Vecellio, 2018). The researcher employed the shutter priority setting on the camera for optimal manipulation of the aperture as necessary, which was set to F22 in order to maximize the depth of field. Most of the photographs were taken monochromatically to eliminate unnecessary color and maximize contrast.

Though many agencies do not have a particular brand preference, it is important to note that all latex-free, powder-free gloves are not created equally. Most glove brands include textured fingertips to assist with manipulation. There are different types of gloves that indicate different thicknesses and are approved for certain uses. The gloves used in this research, for example, are powder-free, nitrile examination gloves. The finger thickness is 3.1 millimeters, the palm thickness is 2.4 millimeters, and they have textured fingertips. The same company makes surgical gloves as well, which have a finger thickness of 9.1 millimeters (FitGuard Touch Nitrile Exam Gloves, n.d.). The selection of gloves for this research was made under the assumption that oftentimes agencies might not be aware of the thickness of gloves they employ. For this reason, the researcher chose a relatively thin glove to provide information about the possibility of friction ridge detail transfer in the most likely environment – thinner gloves and a nonporous surface. In considering the scope of this research, there were conversations about including various substrates or multiple glove types/thicknesses, but it was ultimately decided that there was a need for definitive data with optimal transferability conditions before further research could be conducted regarding less-than ideal conditions.

Data Collection Process

The primary researcher determined their glove size using the Grainger® (2019) guidelines. The researcher washed and dried their hands in accordance with the Center for Disease Control guidelines (2019). The researcher then used plastic tweezers to assist in donning the appropriately sized glove on their hand without touching the outer portion. Only the researcher's left hand was used throughout the course of the study. The researcher then immediately pressed three fingers of the gloved hand (index finger, middle finger, and ring finger) onto the face of the microscope slide with the pressure consistent with ink fingerprinting. The slide was examined and photographed under oblique light and dusted with fingerprint powder to determine if friction ridge detail was able to be visualized. The researcher doffed the glove, washed and dried their hands and then applied 1 mL of hand sanitizer utilizing a glass pipette, rubbed their hands together (front and back) until dry, and immediately repeated the process. The researcher doffed the glove, washed and dried their hands and then applied 1 mL of lotion, rubbed their hands together (front and back) until absorbed, and immediately repeated the process. The researcher doffed the glove, then repeated the above processes using a glove one size too small, a glove one size too big, and two gloves of the appropriate size (double-gloved). Each iteration was conducted five times in order to obtain sufficient data suggesting the presence or absence of friction ridge detail and its ability to be attributed to the condition being tested.

Both upon each stage of processing and through post-experiment review of photographs, the researcher categorized each condition of deposition and each stage of development using an ordinal scale. The scale that was used is as follows: a score of 0 indicated that nothing was visible on the deposition surface. A score of 1 indicated that there was an outline or a smudge, but no visible friction ridge detail. A score of 2 indicated that there was an outline or smudge that displayed friction ridge detail but was mostly comprised of non-friction ridge markings. And finally, a score of 3 indicated that there was visible friction ridge detail, and that this detail made up most (more than 50%) of the mark.

Based on the scale provided, the results gathered during all phases of the research will be either positive or negative for some level of visible friction ridge detail. The analysis of this data, however, is in the strength of the correlation between the presence or absence of friction ridge detail and the evaluated circumstance. The expected result in this research was that the application of lotion would result in the greatest transfer, followed by soap and water, then hand sanitizer. Transferability was expected to increase with gloves that are too small, decrease with gloves too big, and double-gloving would fully eliminate friction ridge transfer. The reasoning for this expected result has to do with the previously discussed “deposition factors”. The hand condition has more to do with pre-transfer factors. Prior to conducting this experiment, researchers hypothesized there may actually be permeation of latent print residue through the membrane of the glove. Therefore, it was anticipated that the substances on the fingerprints depositor’s hand would directly impact the ability for friction ridge transfer. Because lotion contains oily elements and hand sanitizer contains alcohol (a drying element), it was surmised that they would result in stronger and weaker friction ridge detail, respectively. The glove size/number has more to do with transfer conditions, as the fit, tightness, and thickness of the barrier directly influences the ability to deposit a clear fingerprint.

Limiting Factors

Most limiting factors in this research were minimal and are not presumed to have impacted the overall results in any way. A known limiting factor going into the data collection phase of the research was the impossibility of applying the same amount of pressure for fingerprint deposition every iteration. The researcher mitigated this inconsistency by having the same person deposit the fingerprints using the same three fingers in every iteration. They made every effort to use the same amount of pressure when depositing each iteration.

The first unforeseen limiting factor upon beginning data collection was the state of the surface on which the fingerprints were to be deposited. The researcher took special care to remove the microscope slides from their container and prevent deposition of any marks on the surface so they would be presumably “clean” when the fingerprints were deposited. It was discovered through the initial stages of data collection that the microscope slides often came out of their box “dirty”. It is presumed that the spots and marks on the microscope slides were a result of their cleaning process during manufacturing. The researchers considered adding a step to the methods of the experiment wherein the microscope slides would be cleaned but determined that allowed too much opportunity to deposit additional streaks and potentially even friction ridge detail in the handling of the slides. There was also consideration given to the expected condition at a crime scene, knowing that it is typically not expected to encounter a pristine or clean item at a scene. This in some cases made the fingermarks more difficult to photograph but did not make them more difficult to visualize with the naked eye.

The researcher also encountered the unexpected limiting factor of what will be referred to herein as “glove lines”. These occurred more often as the size of the gloves used increased and resulted from folds on the fingertips of the gloves during fingerprint deposition. This obscured the potential for and visualizing of friction ridge transfer in some cases but was considered as a transfer factor and viewed as a non-friction ridge element of the images and fingerprints analyzed.

Another unforeseen factor had to do with the measurement of substances used to create hand conditions. The hand soap and hand sanitizer proved easy to measure accurately onto the hand, while the hand lotion proved to be more difficult to measure because of its viscosity. For this reason, it is possible that the intended 1 mL amount of hand lotion the researcher planned to use in each lotion iteration was not precisely 1 mL, but likely very close to that amount.

Results

A visible mark was left in every iteration and every combination of variables tested. The task then became classifying these finger marks based on their friction ridge detail, which is thoroughly covered in the data analysis and interpretation section. The detail in the marks became increasingly clear with every step of development.

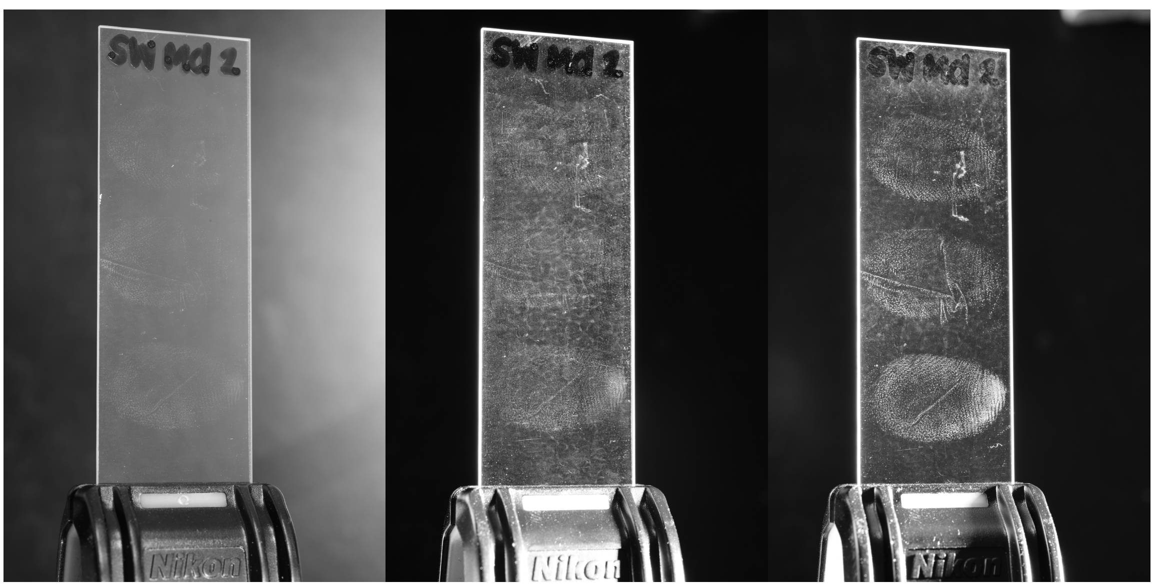

Figure 1, *Photographic series showing each step of development for an iteration of fingerprints deposited wearing medium gloves after washing hands with soap and water. From left to right: (1) ambient lighting, (2) oblique light, and (3) dusted with black fingerprint powder.*

Upon first glance and without further analysis, the hand condition appeared to have very little effect on the quality or amount of friction ridge detail deposited. Double-gloving, however, seemed to be a consistent factor in a lack of friction ridge detail.

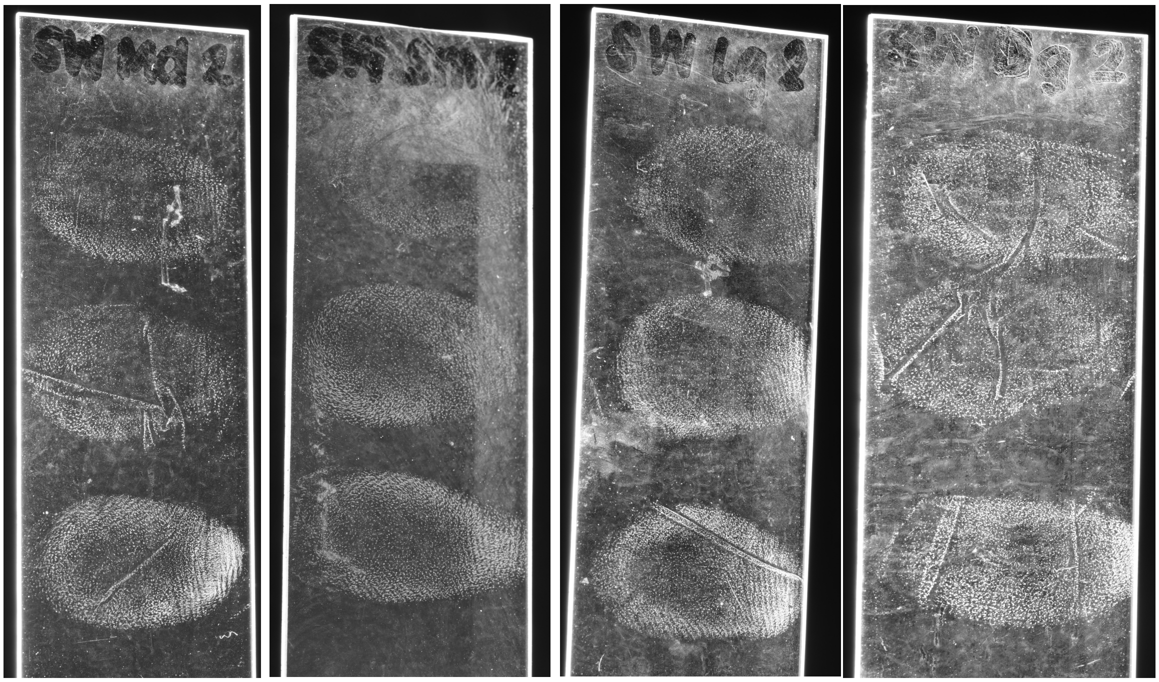

Figure 2, *Photographic series showing glove size/number for an iteration of fingerprints deposited wearing gloves after washing hands with soap and water. From left to right: (1) correct size, (2) one size too small, (3) one size too large, and (4) double-gloved. Note the visible "glove lines" which are particularly prominent in the 4th image.*

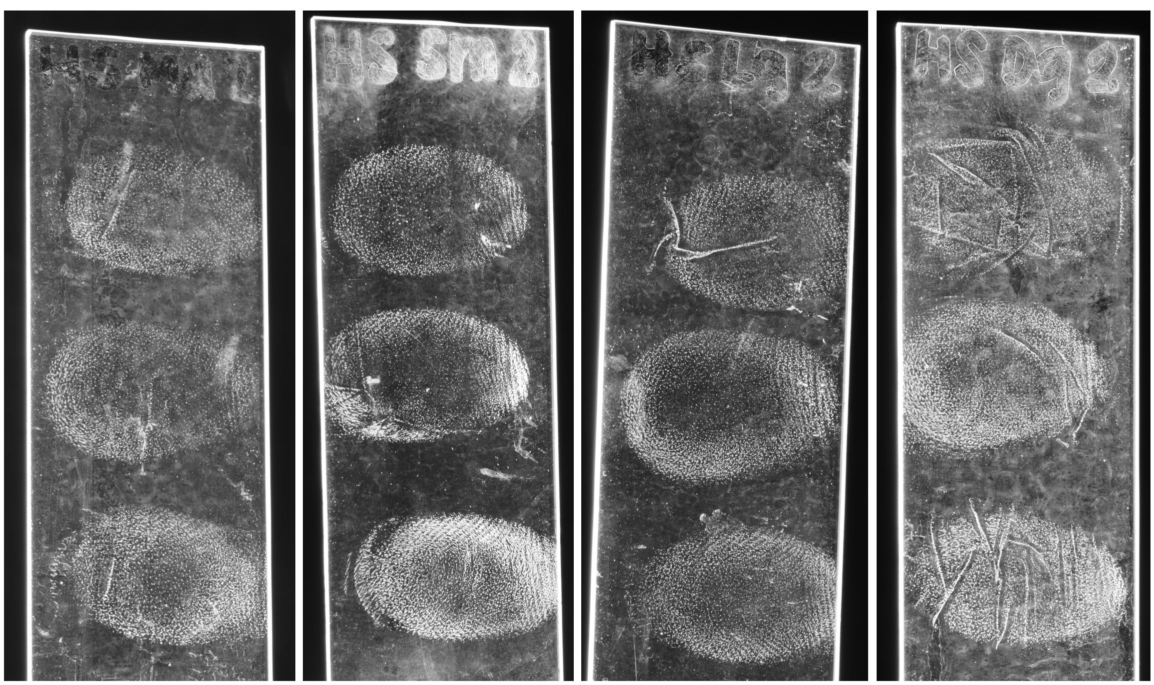

Figure 3, *Photographic series showing glove size/number for an iteration of fingerprints deposited wearing gloves after applying hand sanitizer. From left to right: (1) correct size, (2) one size too small, (3) one size too large, and (4) double-gloved.*

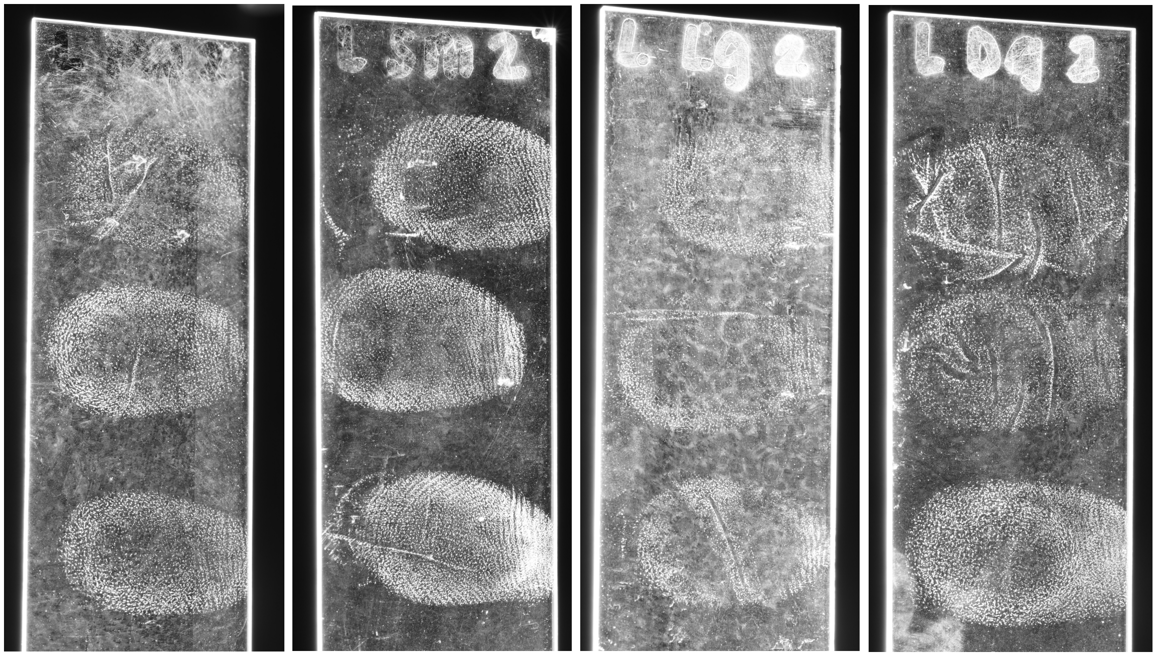

Figure 4, *Photographic series showing glove size/number for an iteration of fingerprints deposited wearing gloves after applying lotion. From left to right: (1) correct size, (2) one size too small, (3) one size too large, and (4) double-gloved.*

Data Analysis and Interpretation

As mentioned in the methodology section, each deposition of fingerprints was rated using the following ordinal scale: a score of 0 indicated that nothing was visible on the deposition surface, 1 meant there was an outline or a smudge, but no visible friction ridge detail, 2 meant there was an outline or smudge that displayed friction ridge detail but was mostly not friction ridge, and 3 meant there was visible friction ridge detail, and that this detail made up most (more than 50%) of the mark. Examples of each score will be exhibited below for reference (See Figure 5). There were, however, no iterations that received a score of zero.

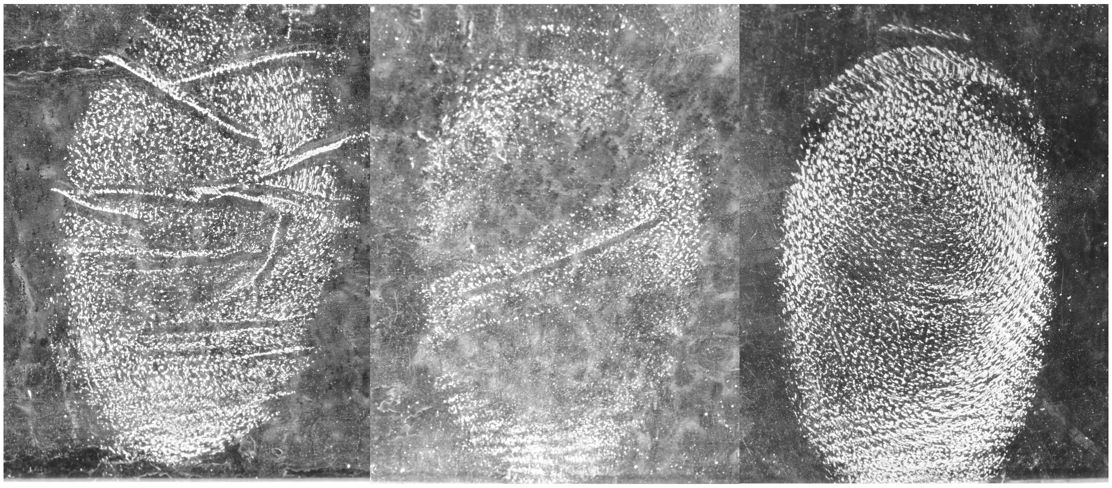

Figure 5, *zoomed-in results of fingerprint deposition which received a score of 1, 2, and 3, respectively. Note the complete lack of friction ridge detail in the first photograph, the presence of friction ridge detail in the second photo near the bottom of the mark, and the almost complete presence of friction ridge patterns in the last photograph.*

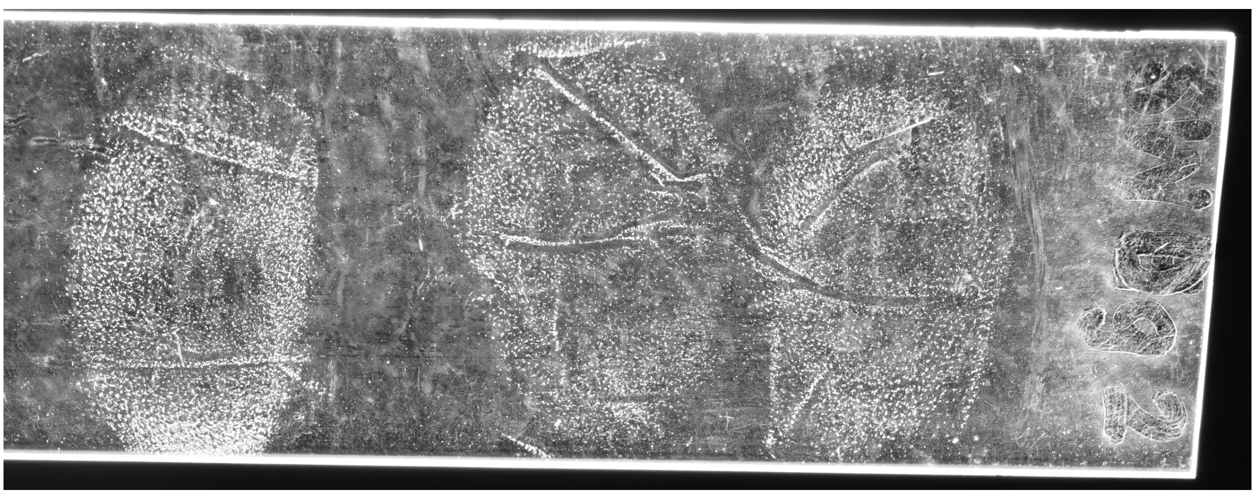

Figure 6, *results of full fingerprint deposition which received a score of 1. Note the complete lack of friction ridge detail.*

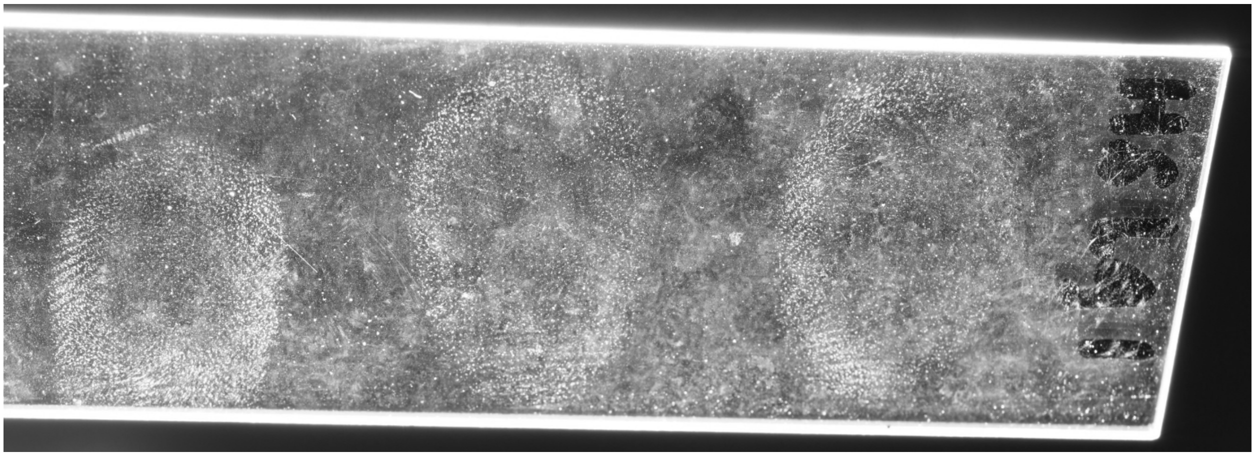

Figure 7, *results of full fingerprint deposition which received a score of 2. Note the presence of friction ridge detail in the photo near the edges of the marks, but an overall lack of ridge detail.*

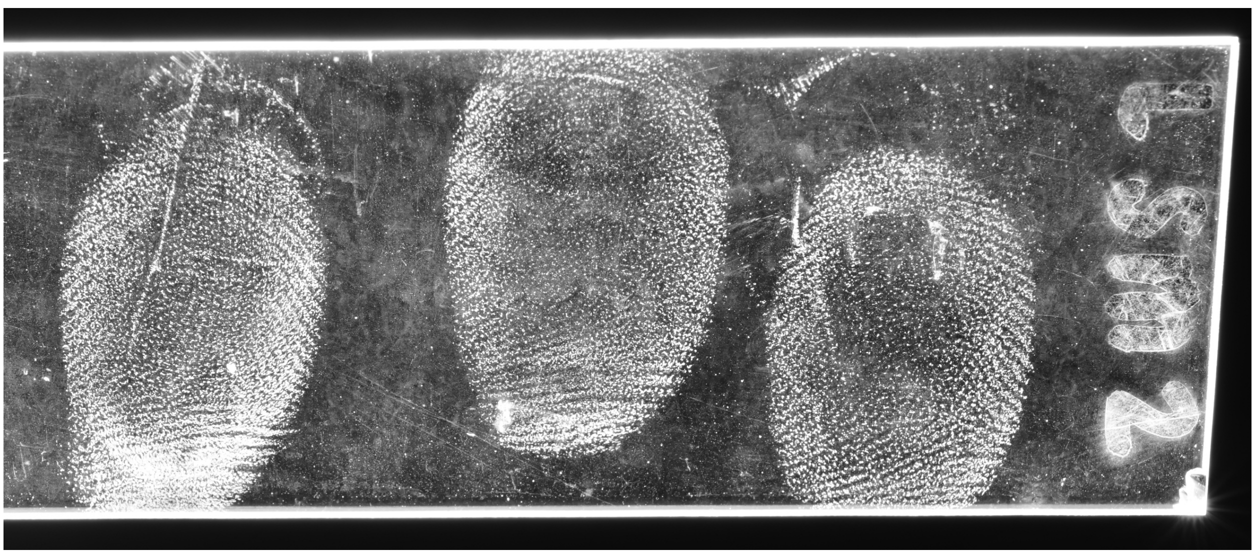

Figure 8, *results of full fingerprint deposition which received a score of 3. Note the almost complete presence of friction ridge patterns in this photograph.*

A score was assigned for each iteration, and each stage of processing as well (inspection under ambient light, oblique light, and once powdered). This resulted in a total of 120 data points. An average of the scores in each iteration was calculated and plotted on a chart to get a visual representation of the data points and how they improved with each step of the development process (See Figures 9, 10, and 11). All further analysis was conducted using only the powdered scores of each iteration. The powdering step of development was determined to help with visualization of the mark (likely due to its contrast) and therefore was determined to be the best representation of the friction ridge detail (or lack thereof) deposited on the surface. The researcher then created a visual representation of the raw scores achieved through the powdering step of processing, which can be seen in Figures 12 and 13. These pie charts visually depict that the presence and amount of friction ridge detail tended to decrease as the glove size/number variable increased. They also visually depict that there was minimal change in the lack or presence of friction ridge detail transferred as a result of the hand condition. However, soap and water had the highest number of iterations that received a score of 3, followed by hand sanitizer and lotion, respectively. This was surprising as the researcher originally hypothesized lotion as the hand condition that would cause the highest amount of friction ridge transfer.

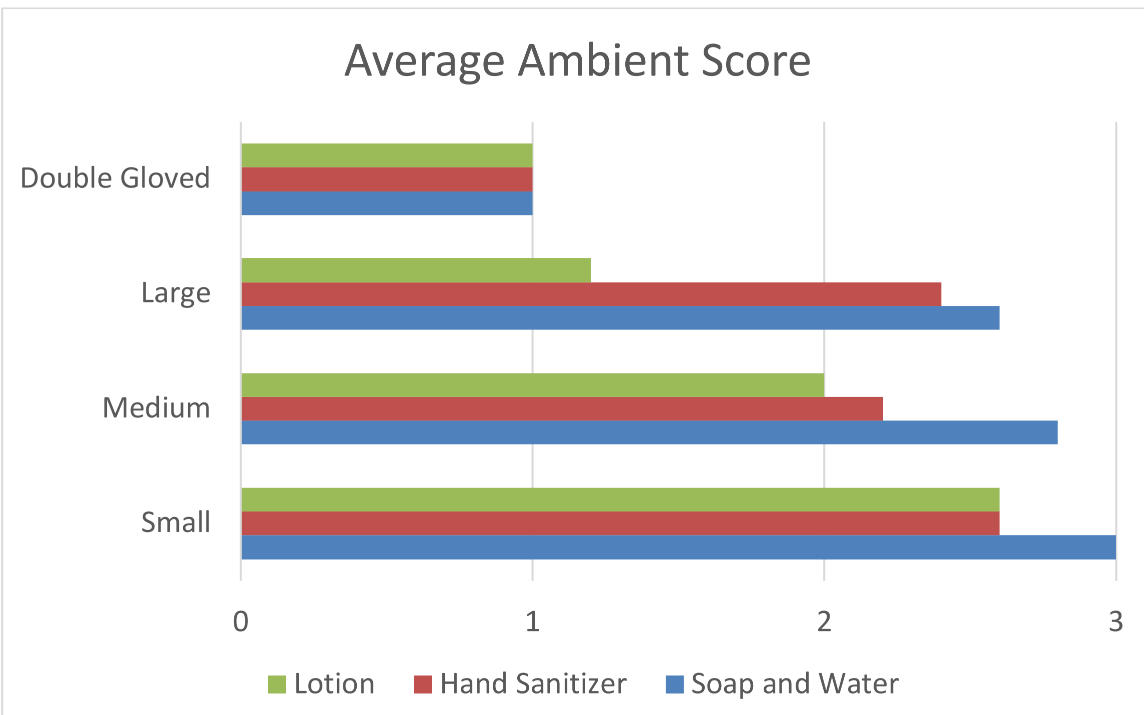

Figure 9, *average scores of each variable combination when viewed under ambient lighting conditions.*

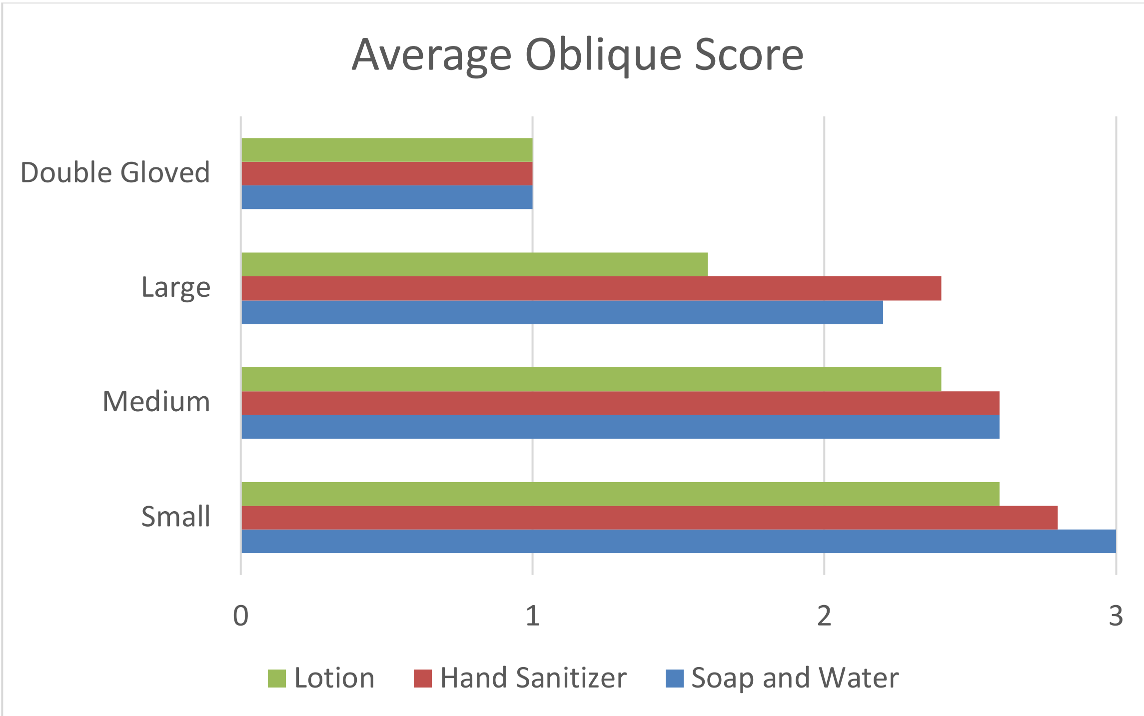

Figure 10, *average scores of each variable combination when viewed with an oblique light source*.

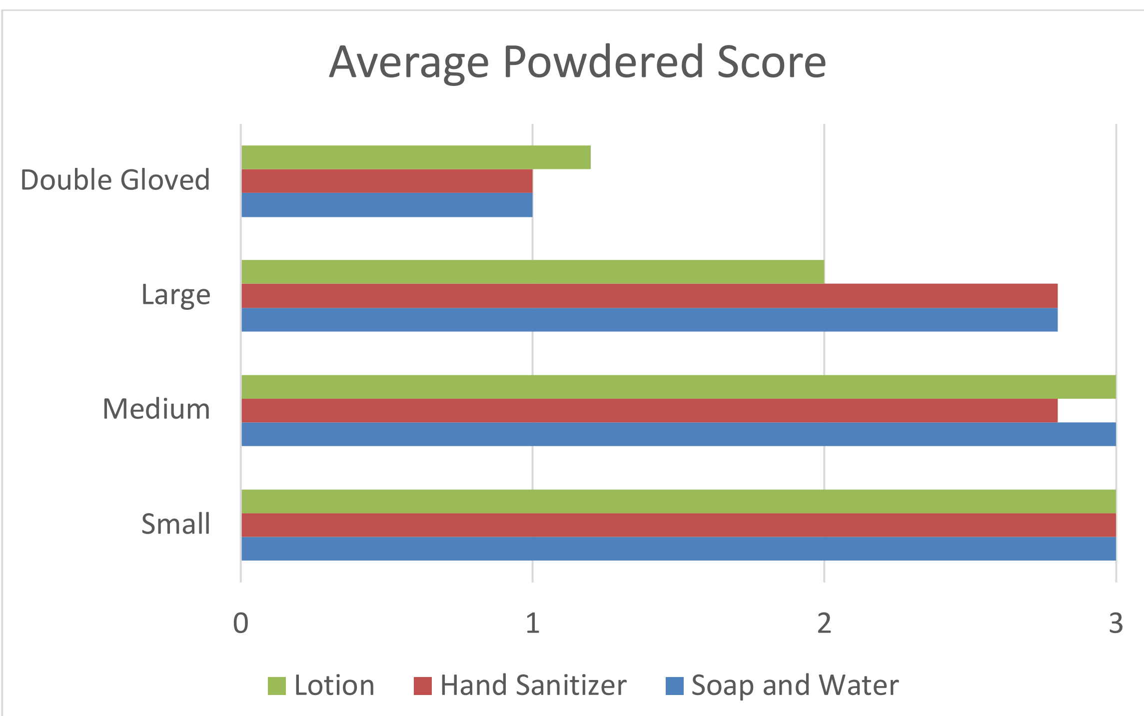

Figure 11, *average scores of each variable combination when developed with black fingerprint powder*.

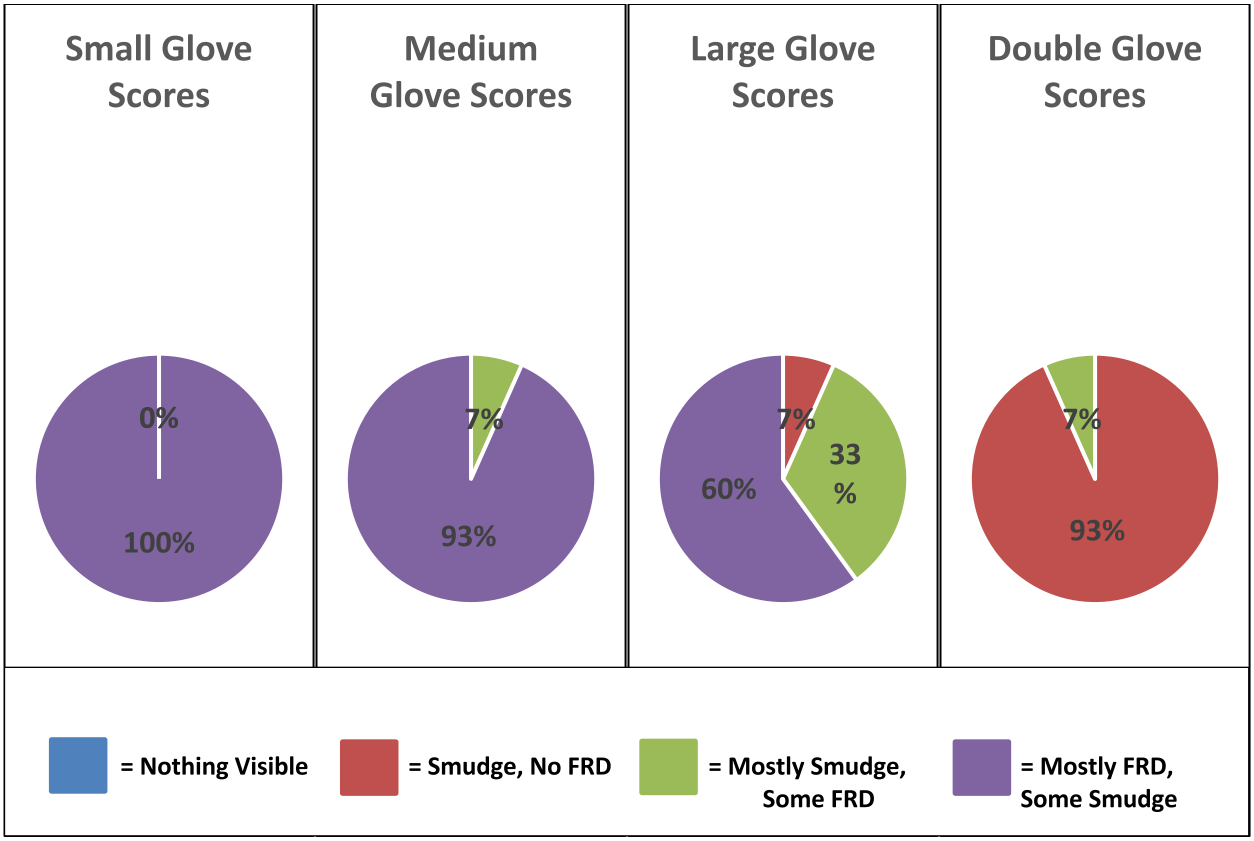

Figure 12, *Pie chart representation of scores given after processing with fingerprint powder. Note that the occurrences of friction ridge detail decrease with the progression of the glove size/number variable.*

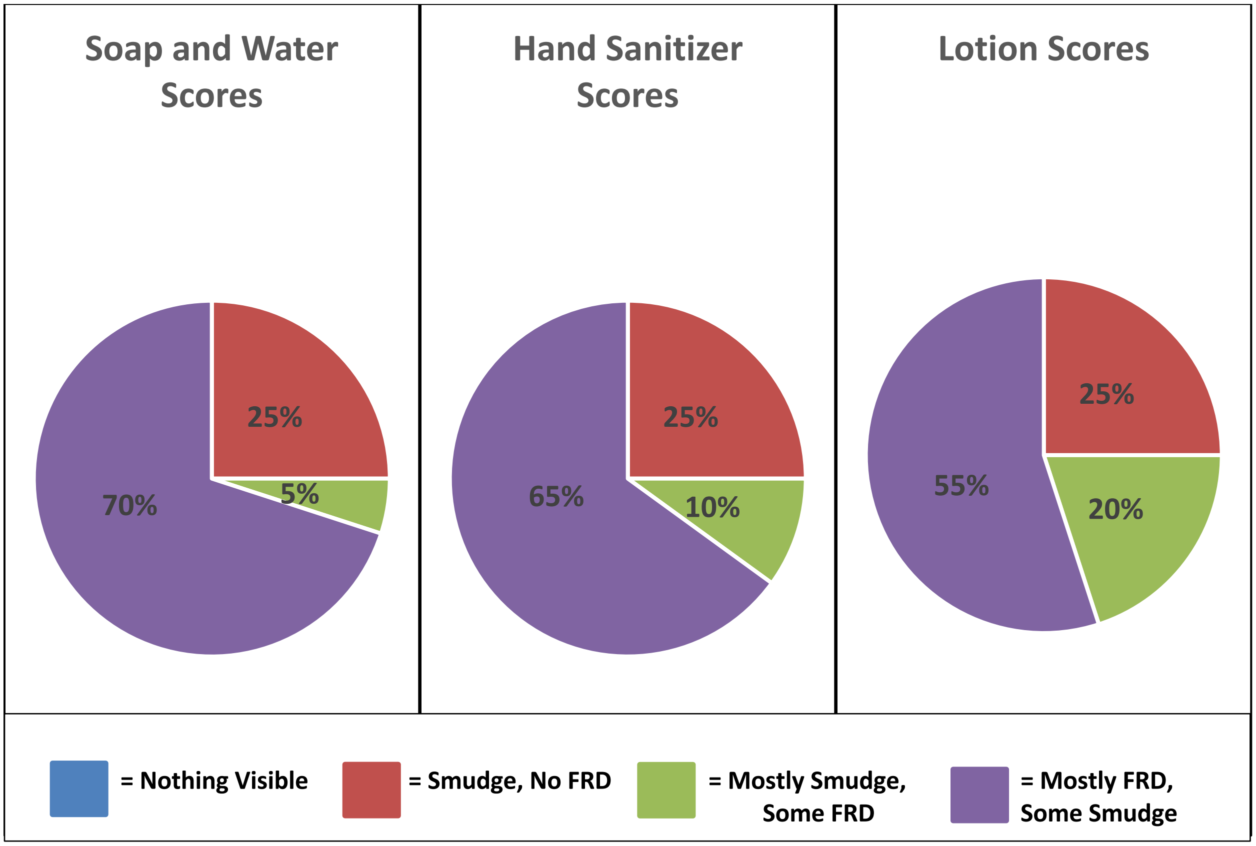

Figure 13, *Pie chart representation of scores given after processing with fingerprint powder. Note the changes in the amount of friction ridge detail present as the hand condition variable changes.*

Research Results and Discussion

Using an ordinal logistic regression, aimed to determine which, if any, of the independent variables (hand condition and glove size/number) had a statistically significant impact on the dependent variable (friction ridge detail score). As a reminder, the hypothesis of the researcher addressed the following: There is a correlation between friction ridge detail transfer and glove size, number, or hand condition. Furthermore; the smaller the glove size, the higher the amount of friction ridge detail transfer. Additionally, when wearing two pairs of gloves, the amount of friction ridge detail transferred will decrease. Lastly, when lotion is applied prior to donning gloves, the amount of friction ridge detail transferred will be higher than that of hand sanitizer or soap and water. Therefore, for statistical purposes, the null hypothesis was the following: there is no correlation between friction ridge detail transfer and glove size, number, or hand condition.

A test of parallel lines was performed, which yielded the following results:

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	20.445			
General	19.162	1.283	5	.937

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

Table 1, *Test of parallel lines, as generated by ordinal logistic regression in IBM® SPSS®.*

Based on the above information, the following interpretation was made: because there was a non-statistically significant result on the test of parallel lines (.937), the assumption of proportional odds was met. This means the relationship between the independent variable was the same across all possible comparisons involving the dependent variable.

Based on model fit information, the full model containing all independent variables showed significant improvement over the null. More specifically however, glove size/number was determined to have a statistically significant effect on the model, while hand condition was not (Table 2). The interpretation of this test is as follows: The glove size/number has a statistically significant effect on the transfer of friction ridge detail through gloves, Wald $\chi 2(3) = 19.565$, $p = .000$. The hand condition does not have a statistically significant effect on the transfer of friction ridge detail through gloves, Wald $\chi 2(2) = 1.358$, $p = .507$.

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
GloveSize	19.565	3	.000
HandCondition	1.358	2	.507

Dependent Variable: PowderedScore
Model: (Threshold), GloveSize, HandCondition

Table 2, *Test of model effects, as generated by ordinal logistic regression in IBM® SPSS®.*

Because hand condition was determined not to have a statistically significant effect on the friction ridge score, the following statistical interpretation was made solely on the independent variable of glove size/number. In order to conduct the appropriate statistical testing, all nominal variables had to be converted to those with numerical value. For this reason, glove size/number was categorized in the following manner: Small = 0, Medium = 1, Large = 2, and Double-Gloved = 3. Double-Gloved became the reference category once dichotomous cumulative categories were created.

Parameter Estimates					
		Hypothesis Test			
Parameter		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[PowderedScore=1]	6.859	1	.009	30.292
	[PowderedScore=2]	12.474	1	.000	405.522
[GloveSize=0]		.000	1	.998	3.698E+11
[GloveSize=1]		19.175	1	.000	3325.390
[GloveSize=2]		14.215	1	.000	311.017
[GloveSize=3]		.	.	.	1
[HandCondition=0]		1.341	1	.247	3.575
[HandCondition=1]		.444	1	.505	2.002
[HandCondition=2]		.	.	.	1
(Scale)					

Table 3, *Parameter estimates, as generated by ordinal logistic regression in IBM® SPSS®, with medium-size glove statistics highlighted.*

The highlighted portion of the figure above conveys the following information: The odds of transferring friction ridge detail while wearing one pair of properly fitting gloves is 3325.390, 95% CI [88.203, 125372.076] times that of wearing two pairs of properly fitting gloves, a statistically significant effect, Wald $\chi2(1) = 19.175$, $p = .000$. In other words, it is 3325.39 times more likely that you will transfer friction ridge detail through one pair of properly fitting nitrile gloves than if you are wearing two pairs.

Based on the data collected, initial impressions, and conclusions supported by statistical analysis, this research established with certainty that given the thickness of the nitrile gloves used in this study, the best way to prevent friction ridge transfer is to wear two pairs of gloves. This has long-standing been a recommendation amongst the forensic and crime scene community, but the results garnered through this study prove that double-gloving should be the commonplace procedure of crime scene personnel. Given the goal to minimize the effects of Locard's exchange principle; it is absolutely vital that crime scene personnel enter each scene equipped with the best information regarding how to stop transposition of themselves onto the scene.

These results came as a shock, seeing as gloves are considered vital personal protective equipment not only to protect the crime scene personnel from hazards at the scene, but to protect the scene from cross-contamination by the crime scene personnel. So, it is only natural to question how the results of this study are possible. How can an item of personal protective equipment the community holds in such high regard be so ineffective at preventing scene contamination? First and foremost, it is important to note that although the forensic community tends to hold this expectation, the gloves often used by the forensic community are not intended specifically for the purpose of minimizing cross contamination at crime scenes. More often than not, they are manufactured for medical or chemical purposes, and have a particular rating to avoid permeation of certain chemicals, therefore supporting the idea that the matrices on the fingers at the time of deposition are not actually permeating through the surface of the glove, but rather there is another explanation for the transfer of friction ridge detail. This hypothesized explanation has two major components: 1) the ability of friction ridge detail to adhere to surfaces and 2) the powder compounds left on the outer surface of the glove during manufacturing.

According to the National Institute of Justice's *Fingerprint Sourcebook* (2016), "the outer morphology of the friction ridge skin is a direct reflection of its function. The ridges and sweat pores allow the hands and feet to grasp surfaces firmly, and the creases allow the skin to flex" (p. 2-3). One could surmise that as a function of the friction ridge morphology, the skin on the fingertips flexed and grasped firmly onto the inner surface of the glove. If you take your finger and place it into the finger of a nitrile glove, pulling the glove away from the direction of the finger, the friction ridge detail can even be seen through the glove because the glove is thinly stretched while the friction ridge detail is pressed against the inner surface of the glove material, making the ridges and furrows clearly visible. The same concept applies to deposition even if the glove surface is not stretched thinly. As the tip of the finger touches the substrate with the rubber glove as a barrier, the ridges form to the inside surface of the glove, which forms this same shape on the surface of the substrate, leaving behind a mark from the glove itself, but with the pattern of the depositor's friction ridge detail.

This theory begs the question: what is the material in which the friction ridge detail is being deposited? The gloves used in this study were powder-free. After further research on the production and manufacturing of gloves, it was discovered that there is residual powder left on medical gloves post-manufacturing. In fact, the American Society of Testing and Materials - who sets the permeation standards for the aforementioned chemicals – has a document dedicated to testing for the residual powder. This document indicated that on average, 0.2 milligrams of powder are left behind on powder-free latex exam gloves, and 0.63 milligrams of powder are left behind on powder-free synthetic exam gloves (American Society of Testing and Materials, 2017). This particular document does not address nitrile exam gloves specifically, but as indicated by this document, there are tolerable levels of powder left on "powder-free" gloves through the manufacturing process. From this discovery, one can hypothesize that the matrix in which the friction ridge detail was deposited in this study was the powder on the outside surface of the glove, which was left over by the manufacturing process. The powder particles are then deposited in the pattern of the delivering friction ridge detail, much like a stamp where the fingerprints pressed against the inner surface of the glove acts as the rubber die and the fine powder particles left on the outer surface of the glove serve as the ink.

Based on the analysis of the researcher accompanied by a consultation with a laboratory latent fingerprint examiner, the friction ridge detail presented in this study is just that: ridge detail. Ridges and furrows are present in a ridged pattern, indicating Level 1 detail, but there are not visible ridge endings, bifurcations, or pores, indicating an overall lack of Level 2 or Level 3 detail. This means that with a reasonable degree of certainty, these prints are present, yet likely unidentifiable. As with any latent print at a crime scene,

> "it may be difficult to determine whether the latent print contains sufficient quality and quantity of detail for comparison. The LPE [latent print examiner] generally cannot perform a critical analysis until the photographs and lifts are examined in the proper setting at the laboratory. Latent prints that are of sufficient value may later be deemed insufficient for comparison. This is to be expected in a conservative approach that ensures all possible evidence is preserved" (National Institute of Justice, 2016, p. 10-6).

This means if deposition of friction ridge detail by crime scene personnel has been an ongoing issue in the forensic community, it is unlikely anyone would have been able to trace the source of the problem. If all ridge detail deposited by these crime scene technicians ends up being deemed unidentifiable; it is never traced back to them and they are none the wiser, meaning processes to mitigate this issue are not thought to be put in place. Based on the conclusions in this research; it is pivotal that agencies change their policies to require a double-gloving technique in order to avoid cross-contamination of their crime scenes. Furthermore, this saves invaluable agency time, manpower, and funding spent on developing, processing, and examining unidentifiable latent fingerprints left behind by their own crime scene personnel.

Conclusion

In terms of further directions within the forensic community, there have been discussions regarding the development of a crime scene-specific glove. Take for example the "Forensic Glove", a patent by Anthony Coombs published in 2015. This invention is a glove with distinct geometric texture on the palm and fingertip area of the glove hand (See Figure 14). The idea being that although crime scene personnel would leave a pattern behind at their scene, it would be a very distinguishable pattern, and would save the time and resources of developing, lifting, and examining the print in a laboratory setting. Based on open source research; it appears this invention (or something very similar) is in production and available for use, but is not widely known or purchased (Coombs, 2015).

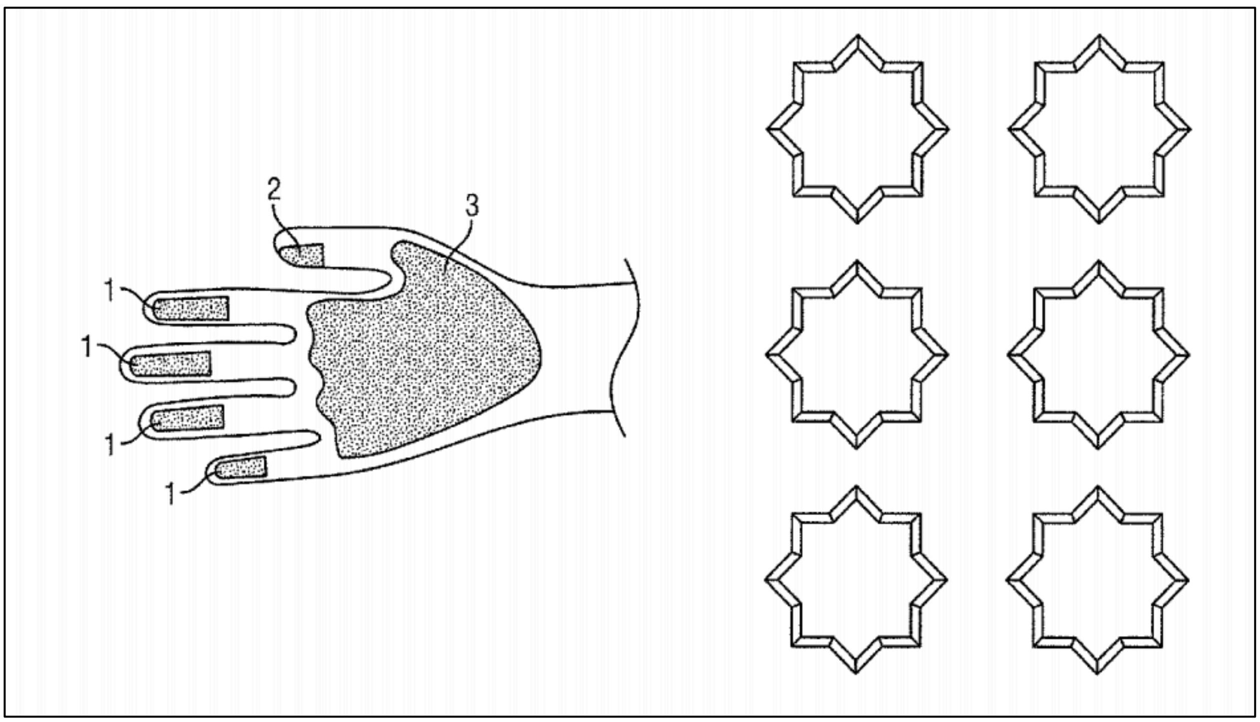

Figure 14, *Diagram of "Forensic Glove" (Patent # US 8,985,469 B2) by Anthony Coombs (2015)*

This study alone should be enough to make agencies responsible for crime scene processing consider adopting a double-gloving standard at all scenes. However, there are significant further directions to be taken. Because of the preliminary nature of this study, a thin glove was used to deposit fingerprints on arguably one of the easiest surfaces to deposit and visualize friction ridge detail. Further testing assessing the effects of various brands, thicknesses, and materials of gloves would be extremely beneficial to the forensic community. Different brands or manufacturers have different standards regarding the amount of powder residue on their gloves, the thickness of both the palmar and fingertip surface, and the texture (or lack thereof) printed on the fingers of the glove. As previously mentioned, the gloves used in this study were examination quality gloves, but exploring the difference in thickness given a surgical glove would be of interest. Though nitrile generally seems to be the glove of choice amongst the forensic community, it is of value to determine if the results found in this study hold true given other materials.

The substrate is also a point of further possibility. Even with the same gloves used in this study, it would benefit the community to be aware if the same results apply when depositing fingerprints on a variety of surfaces. Further research could be done on semi-porous surfaces such as waxy surfaces or glossy cardboard, as well as porous surfaces such as fabric or paper. Also of importance are oddly shaped surfaces such as bottles, car door handles, and doorknobs. It would be valuable to also test varying amounts of pressure. This study in particular aimed to create a baseline for this type of research by depositing fingerprints using a pressure consistent with ink fingerprinting. But realistically people do not handle items with this amount of pressure, so replicating this study with pressure consistent with typical handling of an object would be beneficial.

Based on the lack of statistically significant results garnered from the “hand condition” variable in this study, further research is not necessarily recommended in that area, but significant variations to the gloves and substrates, then additional testing involving the glove size/number variable would be of significant benefit to the forensic community. Another variable of interest would be post-transfer conditions. Though friction ridge detail was proven to transfer to a surface even with a glove barrier, this research did not further explore the durability of this detail. One could further explore the hypothesis that the friction ridge detail is comprised of residual powder on the outside of the glove by exposing the deposited fingermarks to air flow or wind. Even without active forces such as these, the longevity of this ridge detail could be tested by leaving it untouched for given periods of time. The stability of the ridge detail could be examined through tests that disturb the detail like depositing an overlapping fingerprint or attempting the clean the surface.

In conclusion, the findings of this research present great significance to the forensic community as a whole and more specifically, the crime scene community. The data shows a need to change current standard operating procedures across the board. As impactful as this research has the potential to be, there is much more that needs to be explored on this topic. As longstanding as its basic concept is in the teachings of forensic science, the community should have a better scientific understanding of the phenomenon that friction ridge detail can transfer through gloves. This research provides a baseline of data for this topic, and leaves room for exploration by the forensic scientists who it directly impacts.

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