Article

Evaluation of Full Spectrum (IR/UV) Photography to Visualize Latent Fingerprints on Difficult Surfaces

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Abstract: Full-spectrum (IR/UV) photography has the potential to capture and visualize infrared (IR) and ultraviolet (UV) light that traditional digital-single-lens-reflex (DSLR) photography cannot capture. The purpose of this study was to determine if IR/UV photography could visualize latent fingerprints on difficult surfaces better than traditionally used DSLR photography. IR/UV photography has been used in various subfields including forensic pathology, odontology, and anthropology with recent uses in fingerprint visualization. This study is the first of its kind to look at the efficacy of visualizing latent fingerprints using IR/UV photography on stainless steel, soft plastic, and pig skin. Four donors aged 16 to 56 years deposited six fingerprints onto three substrates; stainless steel, soft plastic, pig skin. Each fingerprint was photographed with five different camera-light combinations before processing and after processing with UV-fluorescent fingerprint powder creating a total sample size of 360 fingerprint photographs. Each photograph was individually graded using the Bandey Scale (Home Office fingerprint evaluation scale) and results were analyzed using Kruskal Wallis and Mann-Whitney U tests. The tests showed no statistical significance in fingerprint grading between the various camera-light combinations both with and without processing.

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Introduction

Friction ridge impressions have routinely been used to identify people since the early 1900's, making them an extremely useful tool for law enforcement [1]. Questioned friction ridge impressions are typically composed of organic and inorganic substances [2]. Questioned friction ridge impressions can be classified into three categories based on their visibility and surface; patent (visible) prints, plastic (impression) prints, and latent (invisible or less visible) prints [3]. Latent prints are the most common type of print found in forensic scenes, and often require the use of chemicals, powder, or forensic light sources (FLS) to visualize [2, 3]. Furthermore, surfaces (sometimes refered to as 'substrates') will influence the process used to visualize a print [3]. Porous surfaces (e.g., paper, leather, and fabric) allow substances to be absorbed [3]. Non-porous surfaces (e.g., plastic, glass, and tile) have a tighter cell structure, causing the residue to remain exposed on the surface [3]. The use of chemical and physical processing methods to reveal latent prints can be costly and timely due to the number of steps that are needed to process prints on different surfaces, which can increase the possibility of error [4, 5].

Forensic practitioners often use digital-single-lens-reflex (DSLR) cameras to photograph prints after they have been visualized [4, 5]. Recent research has found that full spectrum photography, also known as infrared/ultraviolet (IR/UV) photography, can detect latent prints with little additional processing [6, 7]. IR/UV cameras can capture more wavelengths of light compared to DSLR cameras, including visible, IR, and UV light [8]. Infrared (IR) light is composed of long electromagnetic wavelengths and spans from 700-900 nanometers (nm) [6, 9]. Ultraviolet (UV) light is composed of short electromagnetic wavelengths and spans from 200-375 nm [7,10]. These wavelengths can provide additional contrast that DSLR cameras would not be able to achieve and can also make special powders fluoresce if additional processing is needed.

One of the greatest challenges when developing prints using conventional powders is selecting a powder that strongly contrasts with the surface [11]. Contrast is generated due to the diverse reflective properties of UV and IR radiation waves, and the relative amounts of light that are reflected off the different materials found in latent prints [7, 13]. In cases where latent print deposits have little or no inherent contrast or visibility, fluorescent powders can be used to provide further contrast.

Fluorescent powders work by absorbing light of one colour which excites the atoms in the powder causing the powder to re-emit light of a different colour [14, 15]. These powders can provide additional contrast compared to white or black granular powder by dampening unnecessary background information such as surface texture or colour [16].

Stainless steel is a commonly encountered surface at crime scenes (e.g., garbage cans, knives, and door handles) and can be difficult to photograph using traditional methods (DSLR cameras) due to its reflective properties, which IR/UV cameras may help eliminate. Soft plastic is a versatile and commonly used material (e.g., garbage bag, zip-top bag, and disposable shopping bags) which may also be encountered at crime scenes. Stainless steel and soft plastic, which are non-porous, can pose a challenge for investigators as they may not hold oils and dirt as well as porous materials [16]. Previous studies have found that a sequence of cyanoacrylate fuming, fluorescent dye staining, and vacuum metal deposition is the ideal sequence to recover latent prints on soft plastic; however, this process is time-consuming and costly as multiple steps and pieces of equipment are needed to reveal quality latent prints [16].

Some studies have found success in using gel lifters and/or IR fluorescent powder [11,16]. IR fluorescent powder works to suppress background interference by displaying high contrast prints and offers ease of access and fast processing time [16]. Skin presents unique challenges with respect to latent print development due to factors such as skin elasticity, decomposition, environment, and print longevity on skin [18]. Latent print development on skin is important to research due to its implications in criminal investigations, as perpetrators may leave their prints behind on their victims. The three surfaces used in this study were identified by latent print examiners from a police service as surfaces that are often difficult to photograph. These surfaces were also selected to fill a gap in the literature on latent print visualization using IR/UV photography. This research may help enhance the recovery of latent prints by improving recovery techniques and evidence collection [19].

The purpose of this research was to determine if IR/UV photography can visualize latent prints on difficult surfaces better than traditionally used DSLR photography. This research is significant as IR/UV photography may capture additional information on stainless steel, soft plastic, and skin that DSLR photography cannot capture.

Materials and Methods

The stainless steel surface used in this study was a Fox Run™ baking sheet sourced online from Amazon Canada and measured 36.2 x 42.5 x 0.1 cm. The sheet was cut into four identical 18 x 14.5 x 0.1 cm pieces using tin snips. The stainless steel was then washed with Dial antibacterial soap and water, before it was further divided into six 5.5 x 6.5 x 0.1 cm sections. The stainless steel was then wiped down with 70% Medicare® alcohol before lines were drawn across with a permanent sharpie marker to create six sections. The soft plastic bags (clear zip-top Ziploc® bags) were sourced from a local No Frills®; they were cleaned using 70% Medicare® alcohol before being divided into six 8 x 5 x 0.1 cm sections with permanent marker.

The pig skin used in this study was sourced from a local Toronto, ON butcher and was kept refrigerated at 4°C for 24 hours until donor latent prints were deposited. On the day donors deposited latent prints, the pig skin was taken out of the refrigerator and allowed to acclimate to room temperature (21 °C) as recommended by previous pig skin studies [19, 20]. The average room temperature was 22°C ± 2°C while humidity averaged 20% ± 5%. The skin was wiped using 70% Medicare® alcohol before it was divided into six 8 x 5 x 1 cm sections with permanent marker. All surfaces were handled with latex gloves after cleaning to minimize the possibility of contamination.

Volunteer donor participants were recruited by the lead researcher. The study used four donors consisting of two males and two females aged 16-56 years old. Environmental variables were recorded to minimize extraneous variables affecting the research including; temperature, humidity, duration of fingerprint aging, lighting conditions, and camera angles. A copy stand was used to hold each camera 25 cm above the counter surface. All photography equipment and specifications are listed in Table 1.

Photography Equipment Used in this Study
Nikon Z5 IR/UV Camera (Modified camera with removed hot mirror filter, which allows IR and UV light to pass through)
Nikon AF Micro NIKKOR 60mm f/2.8D
72 mm 720 nm Kolari Pro Gen 3 Infrared Lens Filter
72 mm 850 nm Kolari Pro Gen 3 Infrared Lens Filter
77 mm 365 nm UV filter
7 pc 49-77 mm adapters to adapt Macro lens to UV/IR, UV and zoom to UV
Infrared Light
Ultraviolet light
Nikon DSLR D7100 Camera
Nikon AF-S Micro NIKKOR 60mm f/2.8G ED
Kaiser Reprokid Copy Stand with Light Kit

Table 1

Photographic equipment used in this study.

Donors were provided with a consent form to fill out prior to print deposition which outlined researcher and donor responsibilities. Donors were then instructed on how to deposit natural/ungroomed latent prints, as natural/ungroomed latent prints are more likely to mimic prints found from crime scenes and are recommended by International Fingerprint Research Group (IFRG) guidelines [21]. Donors were instructed to go about their daily routine, and were instructed to not deliberately touch their nose, face, or hair, or wash their hands 30 minutes prior to depositing their prints to mimic the average chemical composition found in ungroomed latent fingerprints [3, 21].

Donors deposited their prints in a University of Toronto Mississauga (UTM) laboratory room under restricted access. They were instructed to deposit six impressions from the same finger in a row per surface to create a depletion series. No finger was used on more than one surface to ensure that an even number of ungroomed latent prints were deposited onto each surface. Each participant deposited 18 latent prints (one finger three substrates six depletion series), creating a total of 72 latent print deposits. For each depletion series, only the first, third, and

sixth latent prints were analyzed to make the sample size more manageable for latent print examiners, creating a total 36 latent print deposits. Donor information was manually recorded in a table which included donor age and sex with no other identifying information to keep donor identity confidential. After donors finished depositing latent prints, they were instructed to wash their hands thoroughly with soap and water before leaving to ensure any pig skin residue was washed off. As an incentive to donate prints and as a thank-you to participants who deposited their fingerprints, donors received a $20 gift card.

Following deposition, the stainless steel and soft plastic samples bearing the latent prints were aged in a locked room with restricted access for 14 days, while the pig skin samples bearing latent prints were aged for 24 hours. This time frame was chosen to mimic crime scene conditions [19, 20, 21]. The latent prints were then photographed under five different camera-light conditions with a DSLR camera (Nikon D7100) and a modified IR/UV camera (Nikon Z5); all photography equipment used is listed in Table 1.

The camera-light combinations allowed a comparison of DSLR photography under regular light conditions to IR/UV photography under various light conditions including regular white light, IR light, and UV light. After initial photographs were taken, the latent prints were lightly dusted with a Lightning Powder® Zephyr fiberglass fingerprint brush and UV fluorescent powder (Pure Yellow Chameleon Colors UV Color Powder), before they were photographed again with the same camera-light combinations. This created a total sample size of 360 latent print images. All images were then uploaded to a secure Dropbox™ file and shared with a latent print examiner, who graded the latent prints using the Bandey Scale as shown in Table 2 [22].

Grade	Comments
0	No development
1	No continuous ridges. All discontinuous or dotty
2	1/3 of mark continuous ridges. (Rest no development, dotty, smudge or infill)
3	2/3 of mark continuous ridges. (Rest no development, dotty, smudge or infill)
4	Full development. Whole mark continuous ridges.

Table 2

Bandey Scale (Home Office fingerprint evaluation scale).

A set of descriptive statistics and the various camera-light combinations used to photograph the latent prints is shown in

Table 3. These grades were input into an excel file and were statistically analyzed using Kruskal-Wallis and Mann-Whitney *U* tests.

	DSLR (white light)	IR/UV (white light)	IR/UV (IR 720nm)	IR/UV (IR 850nm)	IR/UV (UV)	Total
n	72	72	72	72	72	360
Min	0	0	0	0	0	0
Max	3	3	3	3	3	3
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Mean	0.666667	0.658889	0.597222	0.525558	0.652778	0.616667

Table 3

Descriptive statistics of latent print grades taken with DSLR and IR/UV cameras.

Ethics

An ethics review form was submitted and approved by the University of Toronto Mississauga's Forensic Science Program, and a partnered police agency. Volunteers were given consent forms to fill out prior to latent print deposition. The consent form outlined the purpose of the study along with researcher and donor responsibilities. No donors or animals were harmed in this study.

Results

After the latent print images were examined and categorized (*n*=360) using the Bandey Scale, a basic set of descriptive statistics was created in Excel as presented in Table 3. Next, a comparison of grades by camera-light categories was completed as presented in Figure 1. Most latent prints were graded as a zero across all categories with a total of two hundred and forty-five latent prints (68%) being graded as zero. Forty-four latent prints (12%) were graded as one. Thirty-five latent prints (10%) were graded as two. Thirty-six latent prints (10%) were graded as three. Zero latent prints were graded as four (0%). The camera

type and camera-light combination did not impact the grade each latent print was given (Figure 1).
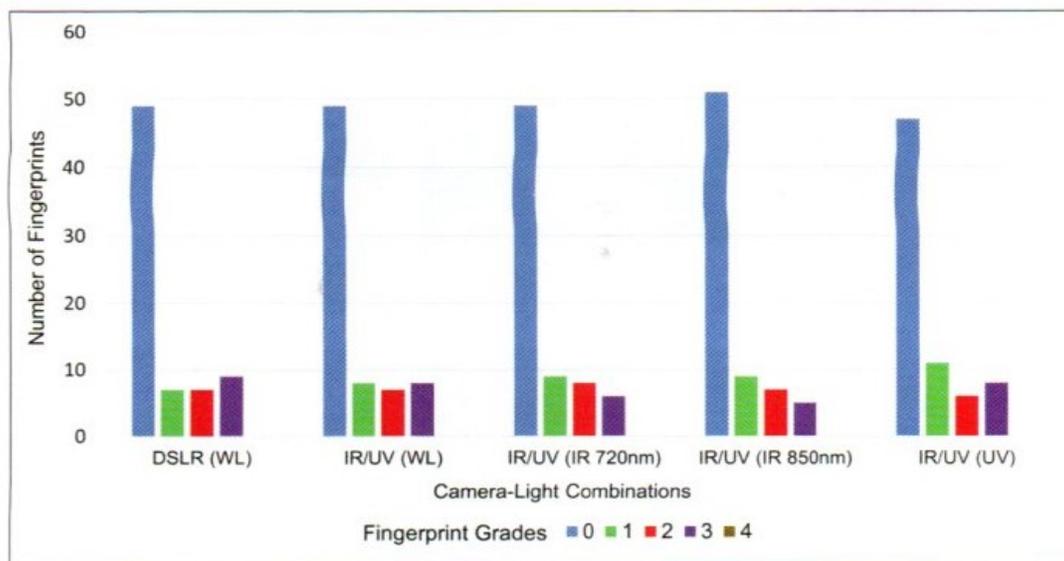

Figure 1

A comparison of latent print grades per camera-light category.
WL = White Light; IR = Infrared; UV = Ultraviolet.

Additionally, processing the latent prints with UV powder did not impact their grades in a substantial way as presented in Figure 2.
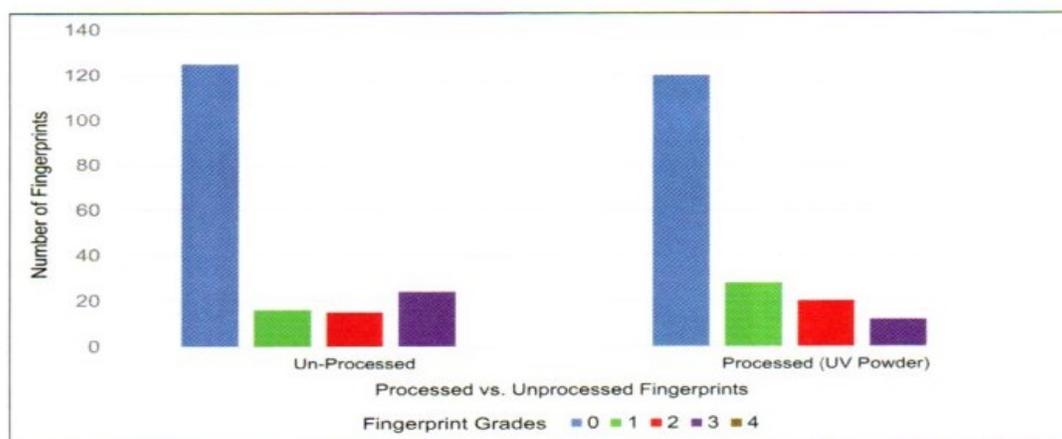

Figure 2

Comparison of latent print grades with and without UV powder processing.

Figure 3, Figure 4, and Figure 5 show the various camera-light combinations and their effect on latent print visualization across the three surfaces. A Kruskal-Wallis test was used to compare all camera-light combinations on each surface [22, 23].

These grades created a non-parametric set of data. This test was used to see if one or more camera-light combinations performed better than the others.
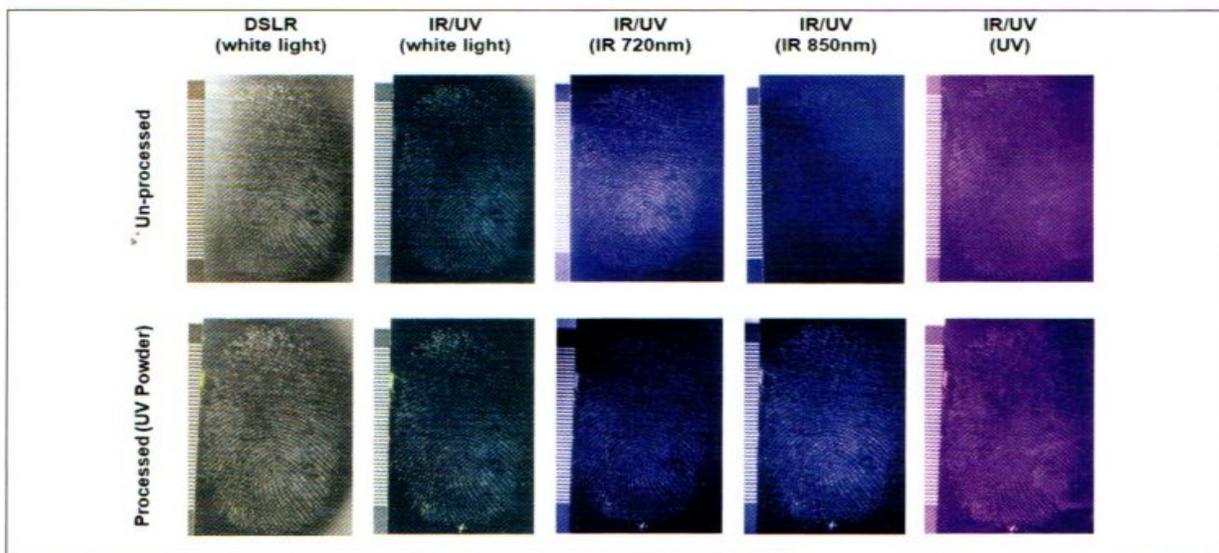
Figure 3

Camera-light combinations for latent prints developed on stainless steel with and without UV powder processing.
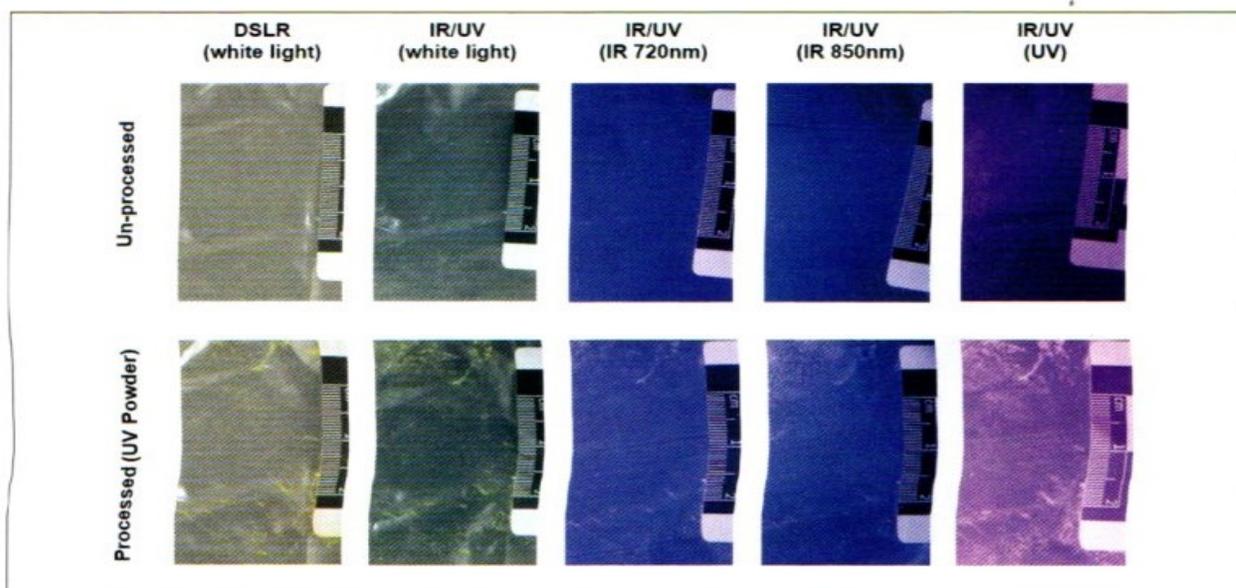

Figure 4

Camera-light combinations for latent prints developed on clear, zip-top plastic bags with and without UV powder processing.
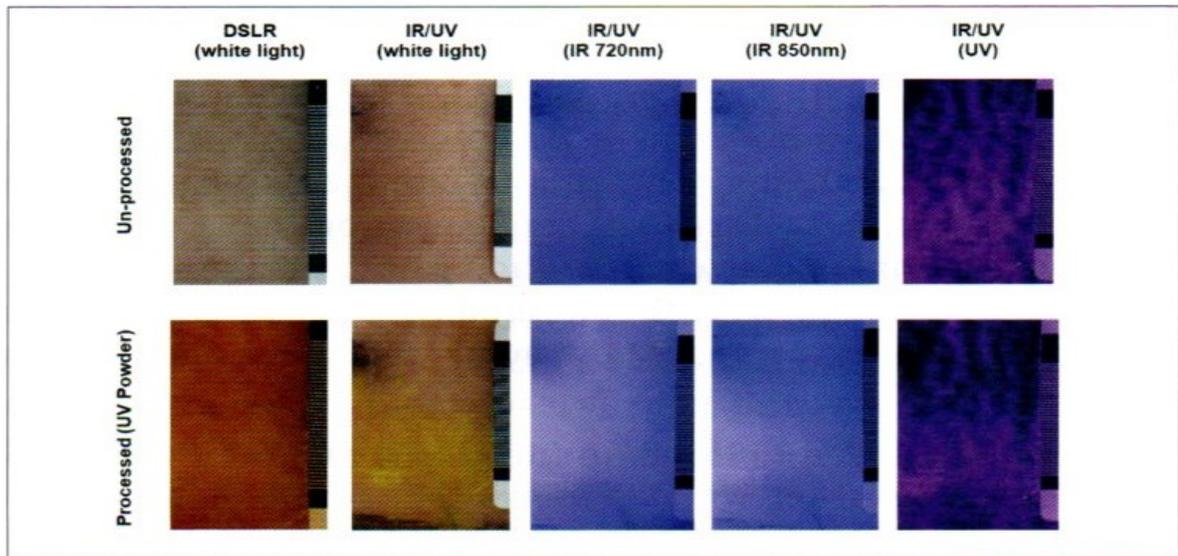
Figure 5

Camera-light combinations for latent prints developed on pig skin with and without UV powder processing.

The Kruskal-Wallis test revealed no statistical significance between different camera-light combinations, $H(4) = 0.4184$, p $= 0.96$, meaning that IR/UV photography did not reveal more ridge detail than DSLR photography on stainless steel, soft plastic, or pig skin in this study. A Mann-Whitney U test was also performed to compare un-processed latent print grades to processed latent print grades. This test was used to evaluate if powder processing had any effect on the grades of the latent prints. The results indicate that there was no significant difference between the grades of unprocessed latent prints and processed latent prints, $U = 16190$; $P = 0.99$, meaning that processing the latent prints with UV fluorescent powder had no effect on ridge detail visibility in this study. The Kruskal-Wallis test and Mann-Whitney U test were both performed with PAST 4.09 (PAleontological STatistics, a scientific data analysis software).

Discussion

This study was the first of its kind to use IR/UV photography to detect latent prints on stainless steel, soft plastic, and pig skin. These surfaces were chosen in conjunction with a partnered police agency to cover a gap in the literature to promote best practices in crime scene photography. While IR/UV photography has the demonstrated capability to capture more information than DLSR photography on surfaces such as bone, metal, and

certain plastics, this study identified the limited applicability of IR/UV photography when photographing latent prints on stainless steel, soft plastic, and pig skin [7,11,16]. The quality of a developed latent impression is dependent on several factors: the surface touched, environmental factors, composition of the residue, deposition factors (e.g., movement on the surface), and individual factors (e.g sweat secretion rates, age, sex etc.) [24]. These factors, along with the methods chosen to develop and recover latent prints, impact how much quality or detail can be captured [24].

The powder used to develop the latent prints in this study was chosen based on its IR fluorescent properties to allow for the use of an IR/UV camera to capture these wavelengths. Previous research used the Chameleon Colors UV Color powder in a sandblaster to visualize latent prints, whereas the current research used a traditional dusting method with a fiberglass brush which may account for the difference in latent print visualization success [25]. The Chameleon Colors UV Color powder is an FDA (Food and Drug Administration) approved, safe, and inexpensive alternative to leading commercial fingerprint powders which can be important when used in large quantities, such as with the sandblaster technique, but is of limited use with a traditional fingerprint dusting technique.

Kruskal-Wallis test results indicated that IR/UV photography did not reveal more ridge detail than DSLR photography on stainless steel, soft plastic, or pig skin used in this study. Various camera-light combinations were used to compare the different settings/capabilities of the IR/UV camera; however, all photographs taken by the IR/UV camera under various camera-light combinations had grades equivalent to those of the DSLR photographs taken under white light. The various camera-light combinations had a limited/no effect on the amount of ridge detail a latent print examiner could observe allowing similar scoring regardless of camera-light combination. The Mann-Whitney U test results indicated that processing latent prints on stainless steel, soft plastic, and pig skin with pure yellow Chameleon Colors UV color powder had no effect on ridge detail visibility compared to unprocessed latent prints in this study.

Limitations and Future Research

The researchers of this study recognize study design limitations. First, the use of pig skin as a proxy for human skin. Future research should utilize human cadavers to more closely approximate crime scene applicability in the field. Second, although a total of 360 latent print images were examined and provided robust statistical results, the actual donor sample size consisted of only four donors which should be expanded upon in further research. Additionally, a second latent print examiner would be beneficial to record inter-observer variability in grading. Third, the various camera-light combinations and powders chosen here were based on practicality and availability; different camera-light combinations and powders should be studied in future research to investigate the effect of different light wavelengths.

Future research using IR/UV photography is recommended on high contrast materials or highly reflective surfaces where IR and UV light combinations may be useful in isolating latent prints while blocking out background colours. IR and UV fluorescent powders can be useful on these surfaces as the IR/UV powder and camera should allow for a better contrast than what would be regularly achieved with traditional fingerprint powders. Further study should also be completed on latent print visualization on bone, as prior research has shown that latent prints can be detected on human bone when visualized under both IR and UV light [7]. Lastly, additional research should be completed on the use of IR/UV photography in cases with blunt force trauma. Previous studies have suggested that that IR/UV photography can be highly effective in visualizing year-old bitemarks and in documenting bruises on people with dark/pigmented skin [6, 26].

Conclusion

IR/UV photography did not reveal more ridge detail than DSLR photography on the stainless steel, soft plastic, or pig skin in this study. Latent prints were graded similarly across all three substrates regardless of camera-light combination or being processed with a powder. These results indicate a limited use for IR/UV cameras over DSLR camera when photographing these three surfaces. Additionally, the results of this study indicate that the Chameleon Colors UV Color powder is not recommended as a brush-on powder for development of latent prints on stainless steel, soft plastic, or pig skin, but may be useful in other capacities.

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Disclaimers/ Conflict of Interest

This information has not been presented anywhere prior to this paper's submission. The authors declare no conflict of interest and have no disclaimers.

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