FORENSIC ANALYSIS OF IMPRINT MARKS ON SKIN UTILIZING DIGITAL PHOTOGRAMMETRIC TECHNIQUES

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ABSTRACT

This paper describes the procedures used to locate and measure imprint or impact marks on skin. This Forensic analysis covers imprints found on suspects and murder victims. The key to impact or imprint mark analysis is the ability to locate the mark that in most cases might not visible to the human eye. Several detailed analyses are described including, image acquisition techniques utilizing laser or ALS (Alternate Light Source) with the digital images. In addition the paper will describe the target or pattern generation and automated target reading of the imprint to generate a 3D model and x,y,z, coordinate data. Also discussed is the digital image matching and measurement of the object that made the mark. The paper will also discuss the part of the study using pigskin in a comparison for developing a database for anti mortem and post-mortem marks. The paper will further discuss the procedures used to model the imprints on the pig and human skin and how close the actual relationship is.

1 INTRODUCTION

The uses for photogrammetry in the areas of Forensic science has been well documented during the last decade. The term Forensic itself can be hard to describe in photogrammetric terms. Forensics covers such a broad area, think of any science or professional subject and add Forensic to it such as forensic accounting, forensic anthropology, forensic odontology, forensic pathology, forensic medicine, forensic archaeology, etc, etc. The term forensic photogrammetry is really not mentioned or listed, this is odd since a photogrammetrist role covers all areas of forensics in the areas of imaging and acquiring reliable measurements from any form of imagery. The role of the photogrammetrist in forensics should be expanding with more exposure to the legal and law enforcement agencies.

The methods and instrumentation used for forensic photogrammetry has been described (Robertson, 1990), (Robertson, 1991, 1994). The major change of course has been the use and adaptation of digital cameras and digital images. The term photograph is quickly being displaced with the term image file and the transfer to the digital domain is progressing at a rapid rate.

2 IMPACT AND IMPRINT ANALYSIS

Impact or imprint analysis, is a rather unique photogrammetric method for determination of important information or parameters of the marks. This might sound somewhat vague but you need to consider that when an object strikes another object it will leave a mark. This covers a broad range of investigation such as accident and forensic investigations as described in (Robertson, 1990). It is described how impact marks made on the ground from aircraft crashes can yield very important information such as the aircraft parameters at the time of the crash such as pitch, roll rate and speed. Even engine settings can be determined from propeller strikes on the ground surface. These can be used were flight data is not available or had been destroyed in the crash. This information has shown that it can be more accurate than analog digital information supplied by a flight data recorder

2.1 Forensic imprint analysis

For forensic imprint analysis our research and casework is related to skin imprints. This area is quit interesting since it can cover a broad range of analysis. For example the determination if the imprint is an anti mortem or post mortem mark. It can also be used to locate and measure bite marks that can be used to link suspects to a victim. Imprint marks on the body can match physical objects used by the criminal to either kill, injure or to transport the victim. The analysis is not restricted to victims but can be applied to the suspect themselves, marks such as imprints on hands can relate to the murder weapon or confirm a injury or mark on the suspect as stated by the victims or witness. Some may question are the marks really there. Just about any blow will leave a mark, for that matter any time a body is set upon a surface undoubtedly a mark will be made.

There are a couple to methods of finding, viewing, and measuring these marks. One method of course is through high-resolution imaging and sophisticated image processing techniques. This lends itself very well for dealing with historic images and crime scene images. The other method would be with alternate light that can comprise of laser or UV light and digital photography utilizing various camera filter techniques. Alternate Light is mainly used for trace evidence such as hair fibers etc. but it does provide an avenue for viewing and measuring the marks.

This paper will discuss actual homicide cases with various types of imprints on the body and a study of anti mortem and post mortem marks. We will also describe our test with pigskin and the development of a database of sample imprints to be used for human analysis. Further examples will be provided for the interpretation of imprint marks on skin using alternate light and filter combinations. This paper will only discuss in brief the examples, more detailed analysis will be broken out in separate papers and training workshops.

2.1.1 **Pig and Human Skin Imprint Analysis** The use of pigs for forensic analysis is not new they are used in various studies and training such as in forensic entomology. There appears to be limited amount of data regarding imprint marks and an imagery database of anti mortem and post mortem skin imprints. Although we have past and present case files to draw from including a limited use of cadavers, I wanted a more controlled study as to time and objects used. Presently a lot of decision's regarding imprint marks is very subjective and most pathologist do not have a good imagery database regarding imprint marks. To start with, can we use pigskin for a comparison of human skin; the answer is yes, if you can accurately model the skin parameters for human comparison. This comparison had to be made before any type of data base can be developed for post mortem marks.

2.1.2 **Skin Comparison** To begin the comparison a pig was chosen at the same weight of a human model. The pig was sedated and objects were placed under the pig for a predetermined time. For the following examples a hammer and nylon rope was used for both the pig and human model for exactly the same amount of time. Utilizing ShapeCapture software we were able to measure the skin surfaces in 3d to an accuracy of between 160 and 200 microns. Projected targets and marked targets were used on the skin surface. The ShapeCapture software uses automated target and point measurement and a bundle solution for accurate results. The following are examples of the comparison test.
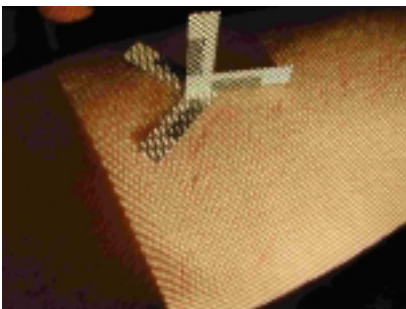
The first image row in the above example (Fig 1, Fig 2, Fig 3) illustrates the marks on the pigskin, the second row (Fig 4, Fig 5, Fig 6) illustrates the marks on the human subject all the marks are anti mortem. In addition to the determination of skin differences we also tested for the time required for the skin to return to normal that is when the imprints became invisible to the naked eye. This does not necessarily mean that the imprints had disappeared, this will be address later in the paper. The imprint marks were also viewed under various light sources such as white light and a luma-lite. The luma-lite provides light energy at the 460 nm range with a 20 nm bandwidth and is used with various filter combinations.
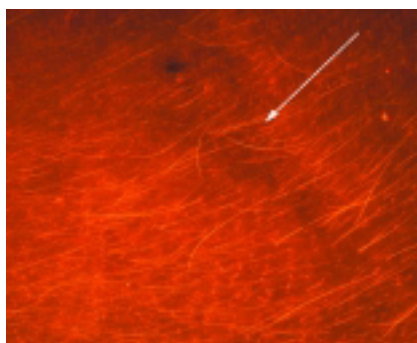
Figure 7
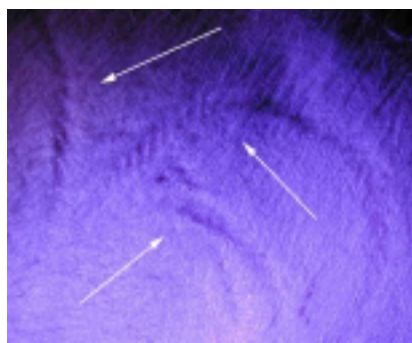
Figure 8

Figure 9

As you can see the difference between the various filter combinations the orange filter in figure 7 loses the detail but the shape is intact. Figure 9 illustrates a filter routine with no alternate light. Utilizing the ShapeCapture software 3D models can be generated of the imprint surfaces. ShapeCapture can utilize subdivision commands to generate smooth 3d surfaces as shown in the following examples. (Figure 10, 11)
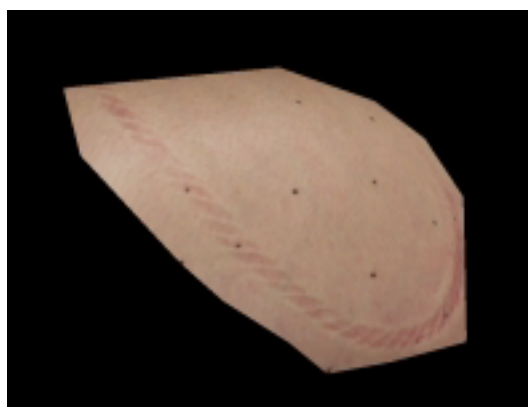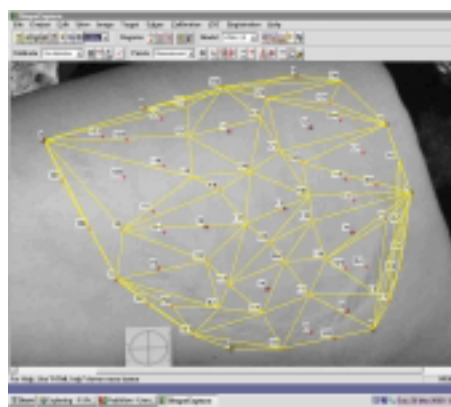

Figure 10

Figure 11

After the determination of the skin characteristics of the pig and human the second phase of the pigskin study was initiated. For these study pigs would be put down, prior to death anti mortem imprints are observed; followed by the imprint analysis of various post mortem imprints in controlled conditions and time sequence are made. In addition an analysis was made in stages up to 24 hours after death of the imprint marks. This is crossed checked with homicide cases that we have analyzed imprint marks.

3   SKIN IMPRINT ANALYSIS HOMICIDE CASES

This actual case study of imprint analysis on victims is quite interesting and covers both anti mortem and post mortem marks. One case is based on analyzing photographic images of a murder victim from 1969. This case was reopened after the convicted individual was cleared of the crime. Autopsy photographs were scanned and analyzed for imprint marks. During the analysis an anti mortem was found and determined to be a bite mark. A 3d model of the mark was made and rectified to a plane this was later used in a bit mark analysis with a suspect. An additional example test was selected of a body that was found in a shallow grave. The body was part skeletal with areas of flesh that had imprint marks that appeared to be anti-mortem and post mortem. A further example is an imprint on a leg that was created during the transport of the body. Examples will be provided on how the analysis was made of the post mortem mark on the leg.
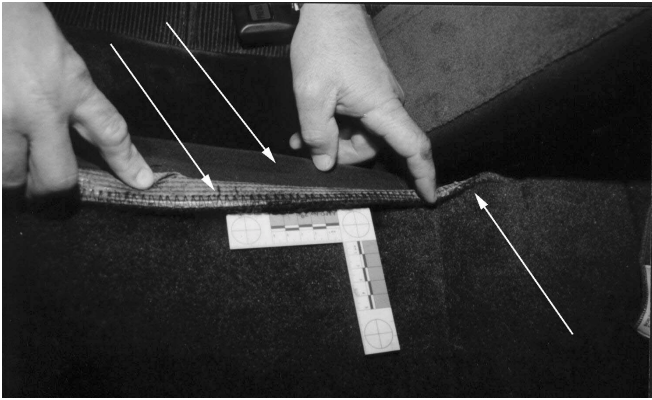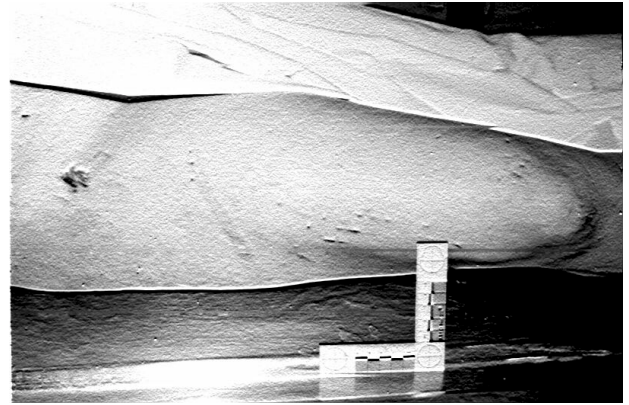
Figure 12

Figure 13

For the above example the carpet area on the back of a vehicles rear fold down passenger seat was observed for uniqueness. The following observations were made. The carpet on the back of the seat was loose which enabled it to be turned up. The edge of the carpet showed a raised form of beading in addition to the inside stitching showed a beaded surface. It was also noted at the edge of the carpet to this beading were joined by a stitching or a thread. It was also noted that the corner of the back seat carpet was more intact which means that it would only turn up one way that yielded a unique signature. In addition it was found that the upturned carpet when folded over from the corner to approximately 100 millimeters exposed surface was approximately 10 millimeters. The pattern of stitching was not regular with the length of the stitch and bead being irregular. This can be seen in the Figures 12. Figure 13 illustrates an imprint mark found on the victim's leg.

After a photogrammetric analysis utilizing several images of the leg imprint it was found that the imprint mark on the victims leg corresponded to the carpet area in the rear of the suspects vehicle. The similarities were in the dimension width and length of the upturned carpet, angular relationship and the distance and orientation of the raised carpet beading and to the imprints on the victim's leg. A further test was made, a model was placed in the suspects car and laid across the folded down rear seat the imprints on her leg were photographed and measured as shown in Figure 14, 15.
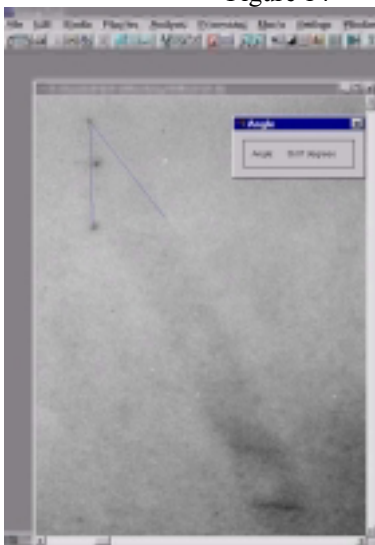

Figure 14

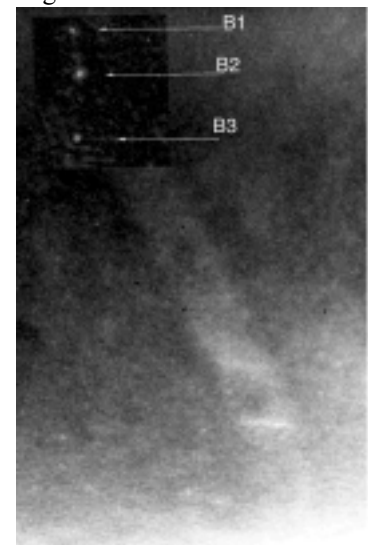Figure 15

Figure 16

Figure 17

Figure 18

Figure 16, 17 illustrate the angular relationship on the victim's leg. The angular relationship was checked on two images of the victim taken in somewhat different leg orientations. The angles on two of the victim, one of the model and the carpet itself matched to within 1 degree. The image of the imprint on the model was overlaid on the victim's imprint and the carpet beading matched illustrated in Figure 18 are the two with 35 percent opacity to illustrate the fit. Note the alignment of the beads and the angular match.

The next example shown in Figures 19, 20, 21,22 illustrate a suspected bite mark found when images where scanned relating to a homicide case that occurred more than twenty-five years previous. We scanned the images and applied our image processing techniques to the scanned images. A photogrammetric analysis was made to obtain 3d coordinate geometry that was required for the analysis. It was suspected a mark found on the body was that of a bite mark. It was important to bring out as much detail of the bite mark for matching but also to rectify it to an orthogonal plane. The mark was on an area of the breast that made this difficult but we were able to rectify the image to a plane for the forensic odontologist to review.
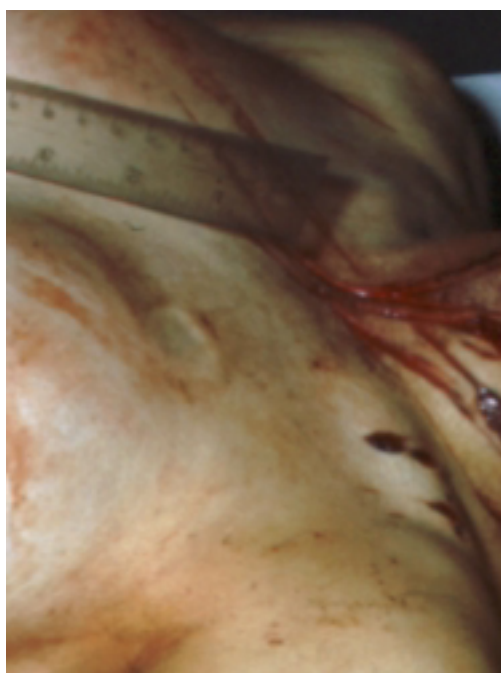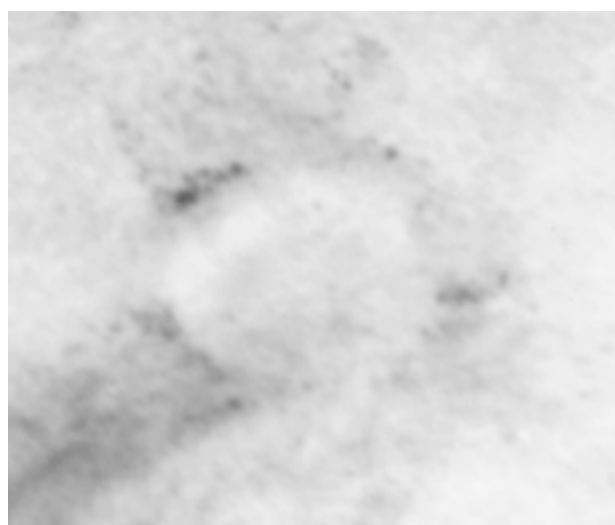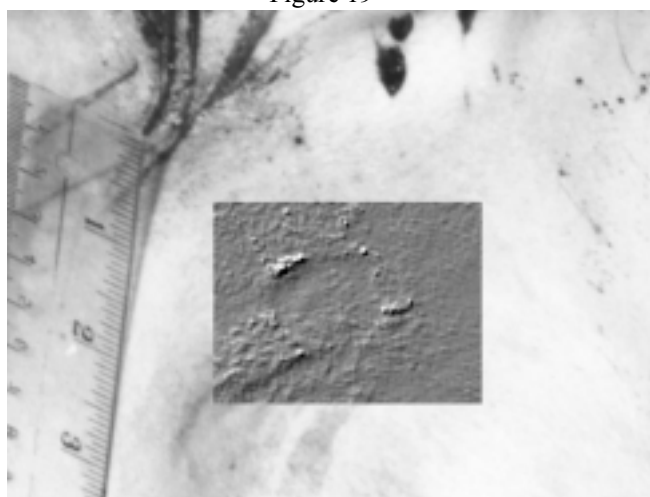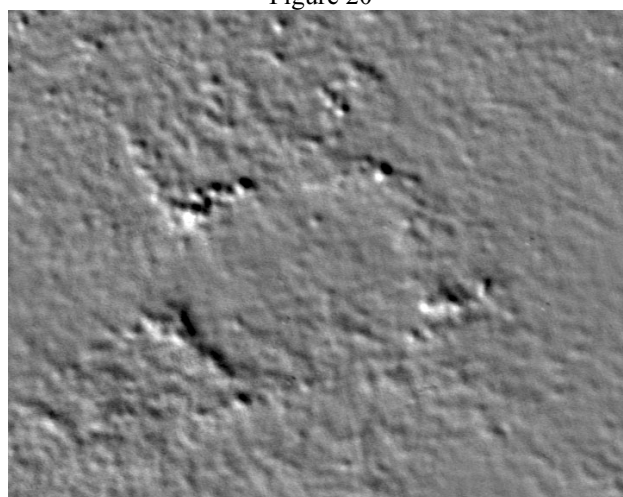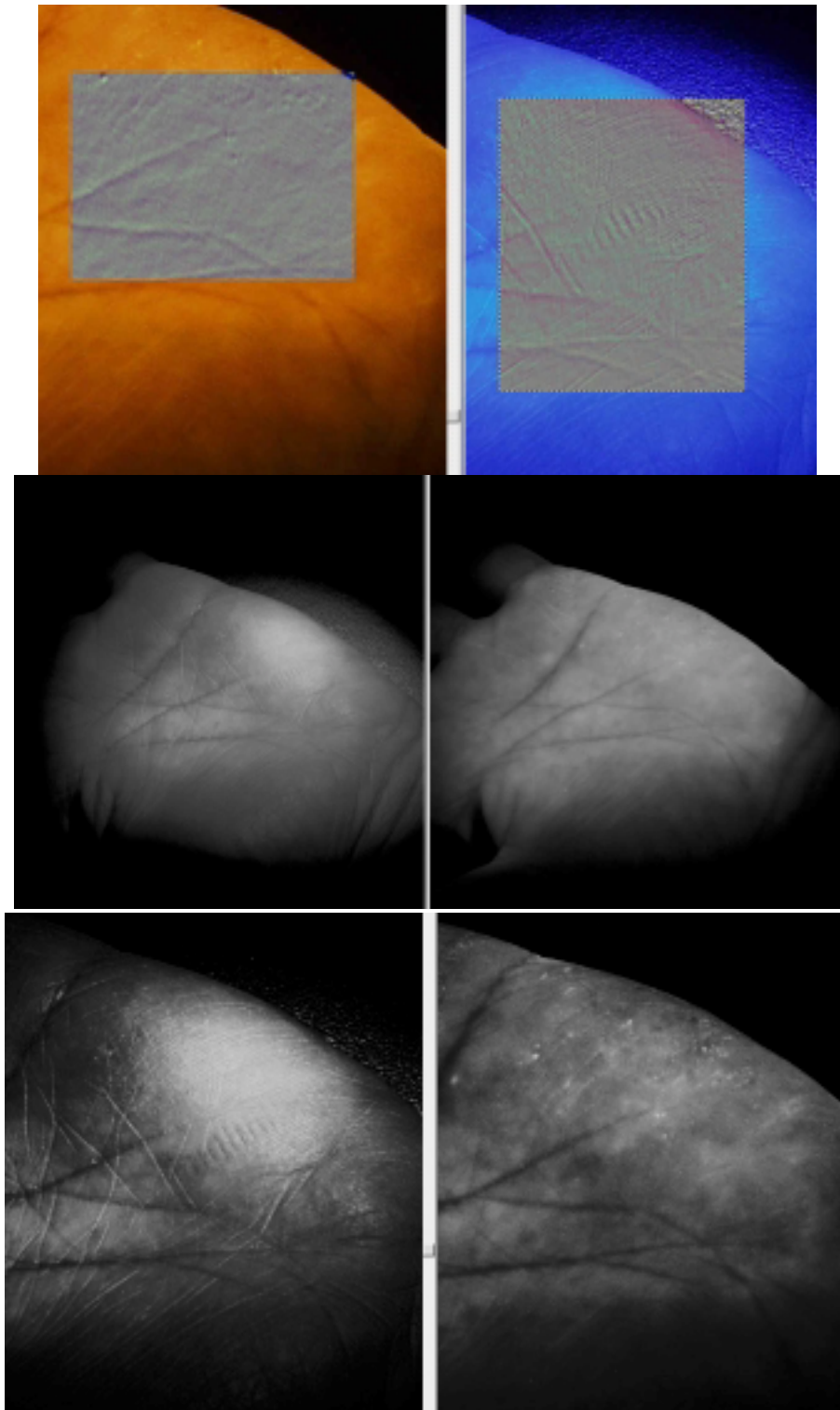

Figure 19

Figure 20

Figure 21

Figure 22

4 SKIN IMPRINT ANALYSIS OF WHITNESS MARKS

Imprint marks as described earlier are rather difficult to see. It was also explained that to the human eye an impression or mark might not exist. An example of this could be an assault where the attacker suffered scratches or cuts and over a period of time it had appeared to heal and a wound is not visible to the eye. Using Digital imaging with alternate light and filters it could be possible to show these types of wounds. It is also important to point out that it is not only important to visualize the marks but also to measure it for a comparison. Figure 23, 24, 25 are examples of an imprint on the palm of a hand the imprint was made within seconds of contact and illustrates the differences in filter routines and imaging techniques to visualize the mark. You can also see that the imprint mark is lost in some samples.
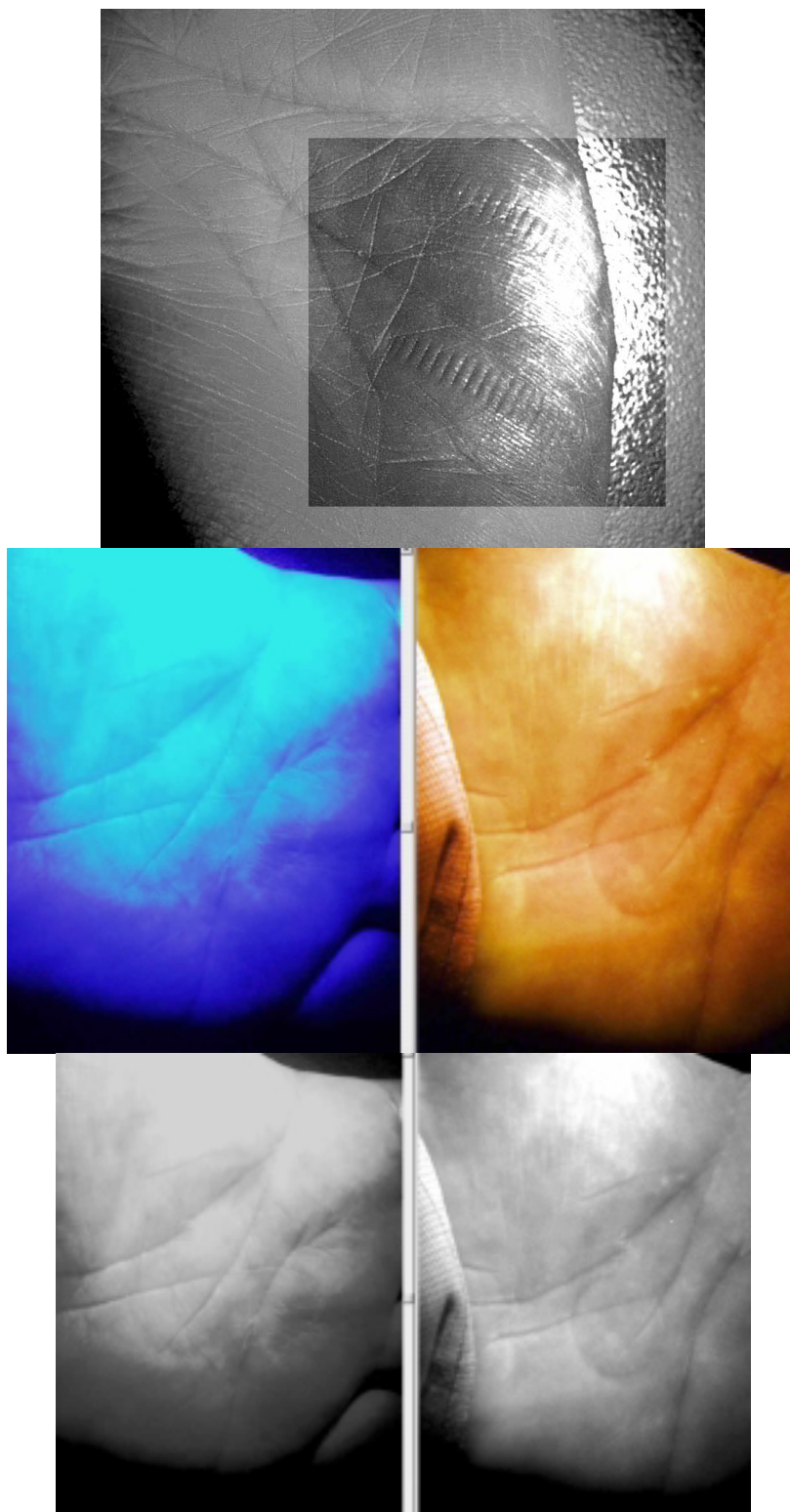
Figure 25 at top continues to illustrate the filtering and lighting of the imprint. Figures 26, 27 and Figure 28 illustrates an imprint on a hand which is a key this was positioned in the hand for less than 5 seconds. Again the various filtering effects the visibility of the mark. The above example images were acquired within the same time frame within seconds in some cases.
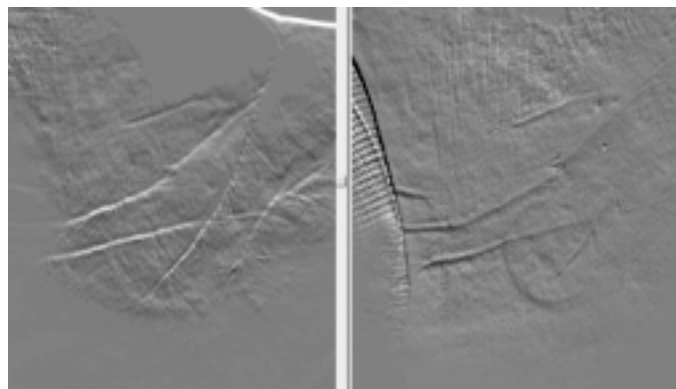
Figure 28

5 CONCLUSIONS

Throughout all the research test observations for these imprints, the time the object was placed against the skin was recorded along with the time for the mark to become not visible on the skin. It is important to note this applies only to anti mortem marks. Post mortem marks will remain on the skin, in one case the images analyzed were taken from images taken of the body after in was embalmed, and an example described earlier was that of a decomposed body. Further work will be required to expand the database of post mortem imprint marks.

This paper provides a broad overview of one interesting area of forensic photogrammetry. I think we can use this description for this area of photogrammetric analysis. Photogrammetry and photogrammetrist can provide a very important role for forensic analysis. The forensic area lacks people with strong photogrammetric backgrounds. By a strong background I am referring to knowledge of characteristics of image distortion, calibration, error analysis, digital imagery, rigorous vs. linear solution and 3D modeling. Hopefully in the future there will be more joint professional participation among the forensic and photogrammetric community.

ACKNOWLEDGMENTS

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