Visualisation of Fingermarks and Grab Impressions on Fabrics. Part 1: Gold/zinc Vacuum Metal Deposition

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Abstract

Vacuum metal deposition (VMD) is a highly sensitive technique originally introduced for detecting latent fingermarks on smooth non-porous surfaces such as carrier bags, plastics and glass. The current study explores whether VMD can be used in the examination of clothing from physical and sexual assault cases in order to visualise identifiable fingermark ridge detail and/or palmar flexion crease detail, thus allowing potential areas to be indicated for DNA swabbing and/or to determine the sequence of events. Four different fabrics were utilised during this study – nylon, polyester, polycotton and cotton, along with 15 donors who ranged in their age and propensity to leave fingermarks, from good to medium to poor as determined by results obtained from test runs using paper and plastic carrier bags processed with VMD. Once samples were collected they were kept for a determined time (1, 2, 3, 4, 5, 6, 7, 14, 21 or 28 days) and then treated using the gold/zinc metal VMD process. From the results, it appears that greater ridge detail is visible on the smoother non-porous fabrics, such as nylon whereas on rougher porous fabrics, such as cotton, only empty prints and impressions, rather than any ridge details, were visible. All fabrics did however allow the development of touch marks that could be

targeted for DNA taping thus potentially leading to a DNA profile and possible identification of a suspect.

Keywords: Fingermark detection; Vacuum metal deposition; Fabrics; Nylon; Polyester; Polycotton; Cotton

1. Introduction

VMD is a highly sensitive technique for detecting latent fingermarks on smooth non-porous surfaces, such as plastics, and is especially useful if the sample is old or has been weathered [1] VMD works by thermally evaporating metals, such as gold and zinc, under vacuum causing a thin layer of the metals to be deposited onto the sample. With gold and zinc, the former is deposited first and adheres to the whole surface of the sample. These gold atoms cluster together forming agglomerates, which may penetrate some constituents of the fingermark residues [2]. Zinc is then evaporated, which preferentially deposits on the exposed gold agglomerates rather than on areas where these are embedded in the latent fingermark deposit [Fig. 1], which in turn means the zinc is binding to the fingermark valleys not the ridges of the print [3]. Generally, the resulting fingermark is a negative with ridges that appear as the background colour of the sample and valleys covered by the gold and zinc appearing grey [2, 4].

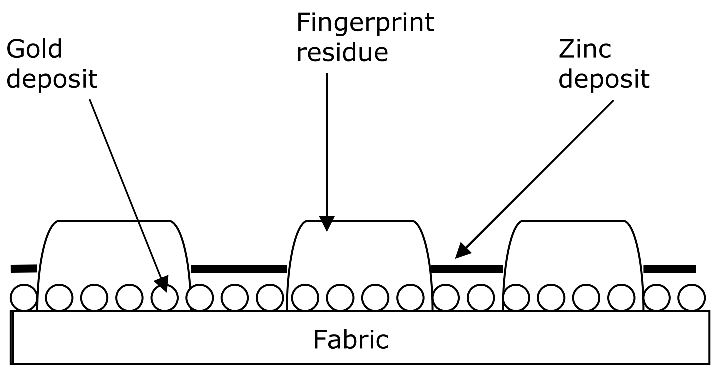

Fig. 1. VMD deposition of gold and zinc onto fabric (adapted from [5]).

Research into the use of VMD on clothing and fabrics began in the 1970s [6], however was discontinued when it was found that radioactive sulphur dioxide was a more effective technique for visualisation of fingermarks on such surfaces. Recently, there has been some resurgence in VMD research [7] to investigate how the technique can be utilised in the visualisation of fingermark and handmark impressions on clothing collected from cases of sexual and/or physical attacks. This reinvestigation of VMD has been prompted by the discontinuation of the radioactive sulphur dioxide technique at all laboratories where it was previously available [1]. Enhanced visualisation of these marks could potentially help in the identification of those involved in incidents through the development of ridge detail and palmar flexion creases; in visualising areas that could be targeted for DNA; and helping to corroborate a sequence of events. For example, a consensual encounter is less likely to involve marks that indicate the complainant was grabbed from behind; or a person who committed suicide would be unlikely to have hand or finger marks on the back of their clothing.

Traditionally, VMD is employed for the development of fingermarks on non-porous materials, such as plastics rather than on fabrics due to the nature of the surface [8]. The openness of the weave, as well as the absorbency/adsorbency of the fabric can affect how well the fingermark residues adhere to the fabric surface or pass through the weave to the surface below. The fibre type (natural or synthetic) also affects whether the fingermark residues penetrate into the fabric or evaporate from the surface. All these factors influence how well these techniques visualise marks on the surface of a fabric. Additionally, once a mark has been visualised the weave pattern can cause interference when recording the ridge detail using photography or digital scanning, thus making it harder to interpret the mark and compare it to known fingermarks.

The manual of fingermark development techniques [1] states that with fabrics there is no “proven process” for latent fingermark visualisation. The recommended method to be followed for visualising fingermarks on fabric is either superglue or radioactive sulphur dioxide. The preconditions for both of these methods are that the fabric must not have been exposed to rain, must have a minimum thread count of three per millimetre and must not be underwear that has been worn for longer than two hours [1]. Previous studies have investigated the use of VMD in visualising fingermarks on plastics, such as polyethylene, which have a smooth surface [2,7] whereas this current study used four different fabric types with a range of surface smoothness. The aim of this work was to determine whether it is possible to recover fingermark ridge detail on fabric using VMD along with determining the effect of different fabric types, different fingermark donors and the age of the impression on fingermark recovery.

2. Materials and methods

The fabric types used in this study were cotton, nylon, polyester and polycotton and were all white in colour. These fabric types are commonly used in the manufacture of clothing and all complied with the Home Office requirement of a minimum of 3 threads per mm. The fabrics were prepared for deposit collection by cutting 23 cm x 16 cm sized samples which were labelled with the fabric type, hand position (F – fingers, P – palm), donor number and process day. This sample size was chosen to minimise cost but was large enough to accommodate a full hand impression. However, much larger samples can be processed using commercial equipment.

The 15 donors used in this study were a mix of males and females who ranged in age (35 to 60) and their potential to leave fingermark deposits (ascertained using VMD processing of paper and plastic bags). Prior to collection, the donors had not washed their hands for at least 30 minutes and had not been loaded with extra sebaceous deposits, therefore the deposits left were "normal" and contained only the deposits naturally found on the donors' hands. The deposition collection was carried out by the fabric swatch being laid on the collector's arm and the donor "grabbing" the sample firmly for 10 seconds. After acquisition, the samples were kept in plastic wallets, in the dark, at room temperature for 1, 2, 3, 4, 5, 6, 7, 14, 21 or 28 days and were then processed. In total there were 150 samples of each fabric (15 donors and 10 different ages).

The VMD equipment used in this study was an Edwards 24" Metal Deposition Unit, and was operated as described in the Home Office Scientific Development Branch documentation [1]. Gold (0.002g) was placed in the centre filament and zinc pieces (1g) in the other two filaments. The chamber pressure was reduced to $3x10^{-4}$ mbar, the gold filament current was switched on allowing the gold to evaporate for about 5 sec. The zinc filament was then turned on until sufficient zinc was deposited and fingermark detail could be seen, by directly observing the sample throughout the deposition process. Normally a mark was observed within a few minutes but some samples required longer exposure. To ensure that the process was working properly, test pieces of paper with fingermarks were placed next to the fabrics in the VMD chamber. The VMD chamber was brought back up to atmospheric pressure, the sample removed, labelled with details of the fabric type, donor and test day and then photographed.

The visualised marks were then graded, from "No development" to "Excellent", depending on the amount of ridge detail observed.

(0) No development - no visible or recognisable marks on fabric

(1) "Empty" prints - where the donor had touched the fabric could be seen but no ridge detail observed on fingertips or palm.

(2) Fair – Pattern and ridge flow and/or palmar flexion creases visible, but not enough detail for identification.

(3) Good - Ridge characteristics (Galton details) visible on some fingermarks.

(4) Excellent - good ridge detail on **all** fingertips and palm with visible pores, ridge edge detail and ridge flow.

3. Results and discussion

There were 150 samples of each fabric type (15 donors and 10 different ages of the impressions) and developed marks were graded from 0 to 4, after visual examination, as shown in Fig. 2. The majority of the samples (72%) were graded as 1 and below, 18% were graded 2, 8% graded 3 and 2% graded 4.

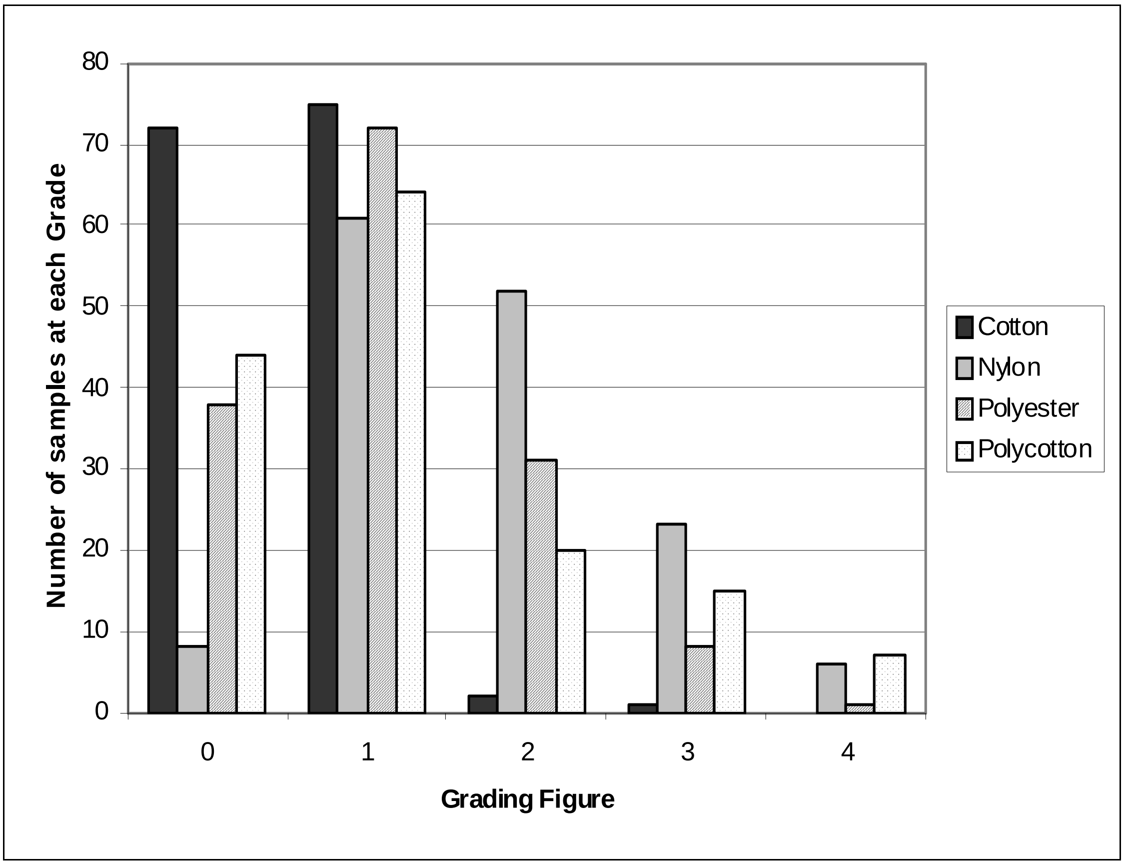

Fig. 2. Distribution of gradings on all visualised marks

Cotton gave mainly grades 0-1 (indicating no development or empty prints) while the other fabrics ranged between 1 and 4. Interestingly, the profile of polycotton and polyester was very similar though nylon had by far the highest number of grade 2. In order to try and quantify the results each grading was given a value from 0-4 and this was multiplied by the number of samples which fell into that grading. The average value for each fabric was then calculated and this showed that, overall, nylon was the highest ranked (1.72), followed by polycotton (1.18), polyester (1.08) and finally cotton (0.54).

When comparing the fabric surface and the surfaces of substrates that traditionally led to good detail visualisation (glass and plastics), these results are not unexpected. The nylon used in this study was smooth, shiny, non-porous and of a tight weave with the polyester being similar but not as shiny. Neither polycotton nor cotton were shiny, and had rougher surfaces, therefore some lack of visualisation of detail might be expected although the closeness of the average values for polycotton and polyester indicates that the influence of surface characteristics may be more complex. This reinforces the findings of the study carried out by Misner in 1993 [9], who found that the fabric surface needed to be fine and smooth, such as with silk and nylon. Thus the surface of the fibres forming the fabric should also be considered. For example, nylon is smooth and non-porous on the microscopic level, whilst cotton is rough and porous. Thus both the microscopic and macroscopic features need to be taken into consideration.

The level of palmar flexion creases detail and ridge detail is illustrated graphically in Fig. 3 and 4 and an example of nylon with excellent palmar flexion creases are shown in Fig 5. It can be seen that every fabric can show visible palmar flexion creases but not all donors produced a visible mark each time. Generally, nylon ranked highest for palmar flexion creases consistently showing the most detail. Polycotton was next in the ranking, though there were variations in results between polycotton and polyester. Overall, cotton generally performed worst, with 3 or less samples per age category (out of 15 samples) producing visible palmar flexion creases, with these samples corresponding to good donors. This further illustrates the ability of the donor to leave a good impression and also impacts on the ability of VMD to visualise impressions.

Generally, the age of the sample does appear to have some effect on the number of impressions showing palmar flexion creases particularly for nylon and polyester after 7 days. Regularly, less detail is visualised as the samples age, though occasionally a fabric will have more detail later in the timeline.

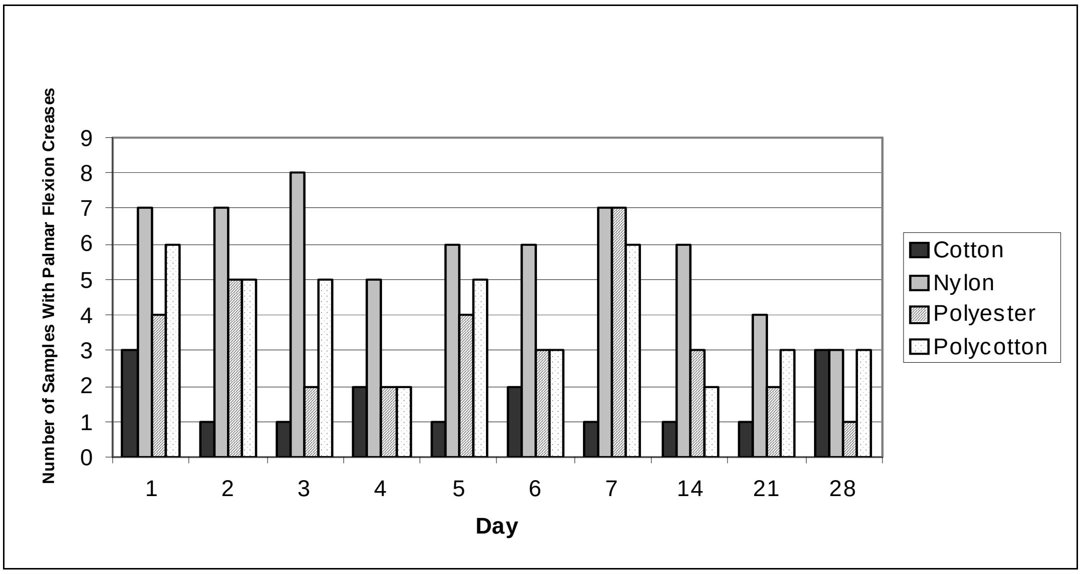

Fig. 3. Number samples containing palmar flexion creases.

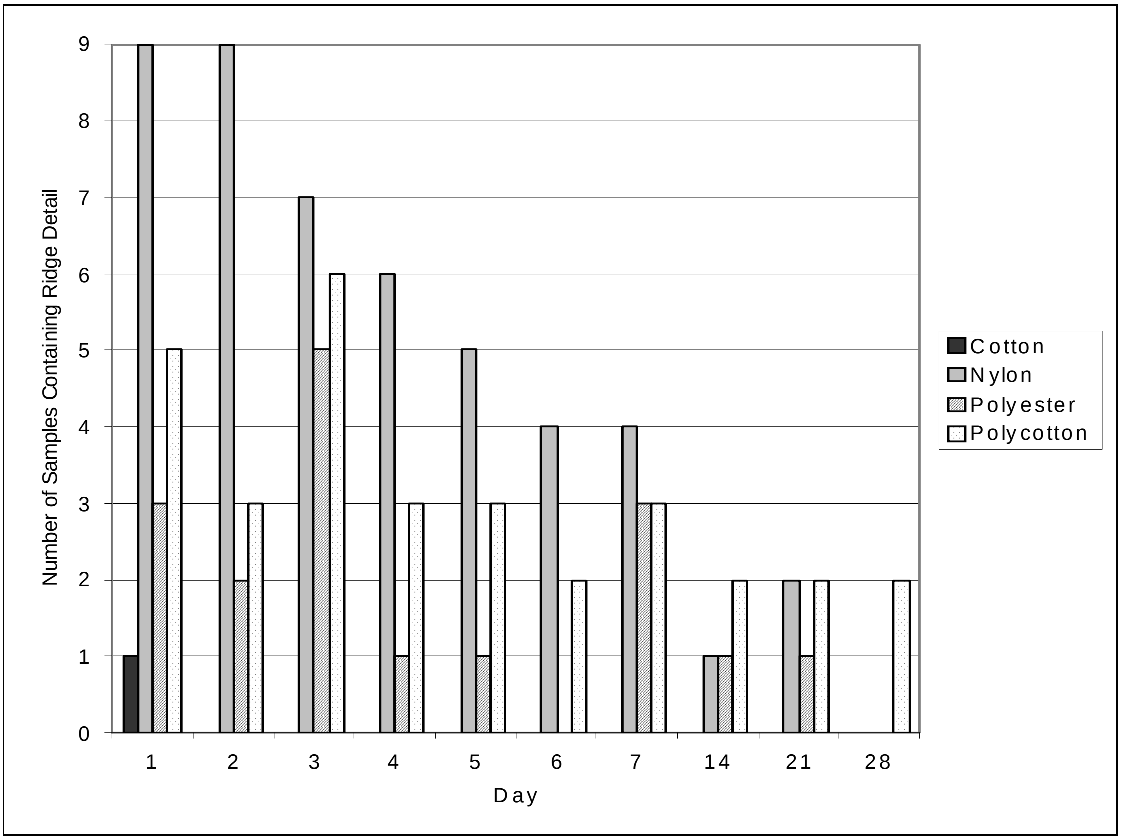

Fig. 4. Number of samples containing ridge detail.

Fig. 5. A 21 day sample on nylon demonstrating palmar flexion creases

The number of samples with observable ridge detail was less than that seen for palmar flexion creases. It was found that polycotton showed ridge detail everyday, nylon and polyester on all of the days except day 28, whilst cotton only showed one mark with ridge detail on day 1 (Fig 4). All of the above samples contained ridge detail rated 2 and higher with no empty impressions, though some samples contained more ridge detail than others and would be more useful for identification purposes. This is illustrated for nylon in Fig 6 where excellent (grade 4) ridge detail along with good palmar flexion creases can be seen.

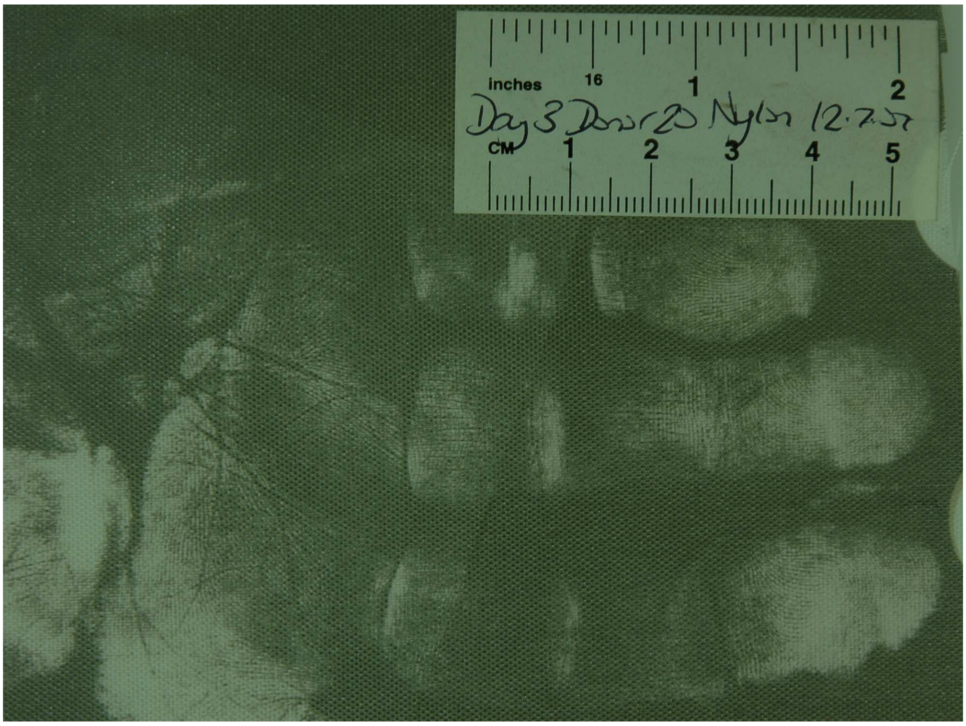

Fig. 6. Three day sample on nylon demonstrating excellent ridge detail.

When looking at the nylon samples as a whole the most detail was seen on days 1 and 2 ,with nine samples, with the least detail on days 14, 21 and none on day 28, which shows that the fresher samples (day 1 and 2) allowed more detail to develop and that detail declines over time. The level of ridge detail observed on all fabrics correlates well with the freshness of the samples as seen at day 3 where seven nylon, five polyester and six polycotton donors all left some form of ridge detail. Also, the number of donors leaving ridge detail reduces over time until day 21 when there are only two impressions with ridge detail on nylon and polycotton and one on polyester and on day 28 there are only two impressions on polycotton that exhibit ridge detail. This reinforces the view that nylon, followed by polycotton, are the better fabrics when it comes to allowing the development of ridge detail by VMD.

The ability of the donor to deposit marks does have an effect on the level of both ridge and palmar flexion crease detail visualised by the VMD process. The best donors will leave marks that lead to good to excellent ridge detail and palmar flexion creases, whereas poor donors may only leave touch marks, but no detail.

The samples graded 0 and 1 could, however, still be used in certain operational circumstances. There may not be ridge detail or palmar flexion creases visible, but there could be an indication of a certain area of the fabric having being touched or grabbed which could then be targeted for DNA. Bowman [1] states that VMD treatment prior to DNA collection does not affect the development of subsequent profiles that could lead to identification. As seen in Fig. 7, nylon was generally the best surface for the development of target areas across all age categories, with a combined average success rate of 95%. The lowest number of donors to leave target areas on nylon is on day 28 but, even then, the figure is 80%. On average, the fabric showing the least target areas was cotton with the highest number of donors to leave target areas being on day 1 (87%) but this number falls to 60% by day 2 and reaches a minimum of 40%. This information again reinforces the opinion that nylon gives more information than cotton. Neither polyester nor polycotton had a day where all the samples contained visible target areas though both have days where fourteen (93%) donors produced a target area – polyester on day 3 and polycotton on day 2 and 3. The rest of the days ranged from a high of 87% (polyester day 2 and polycotton day 1) and a low of 60% (polyester day 4 and 21 and polycotton day 28).

The results indicate that nylon has a greater ability to retain fingermark residues on the surface and therefore allow more ridge detail to be developed by treatment with VMD. However, all the fabrics showed a range of developed impressions, from possible target areas in the form of faint finger marks to full hand print grab marks [Fig. 8], which could be utilised as target areas for DNA. These impressions could also help determine the possible sequence of events and may indicate:

- a struggle (grab marks with bent fingers),
- a shove (straight fingers),
- no impressions (no detectable contact)

For example, if an individual has reported a sexual assault whereas the suspect is stating the encounter was consensual, the type of impressions developed on clothing may provide evidence supporting a particular account, though this point is subject to further research. The type of impression (or absence) left on clothing can help corroborate certain assertions even if there are no ridge details or palmar flexion creases visualised. Further work will be carried out to identify which palmar shapes are associated with different types of contact.

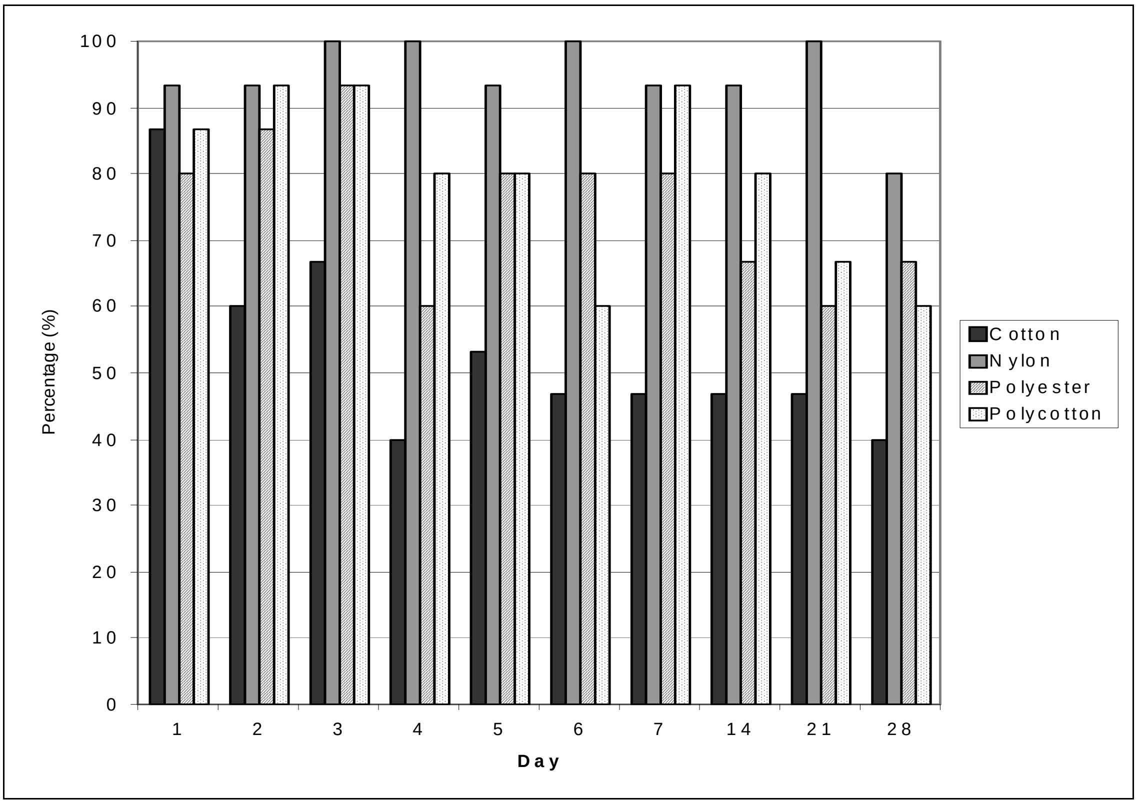

Fig.7. Percentage of samples having target areas rendered visible by VMD

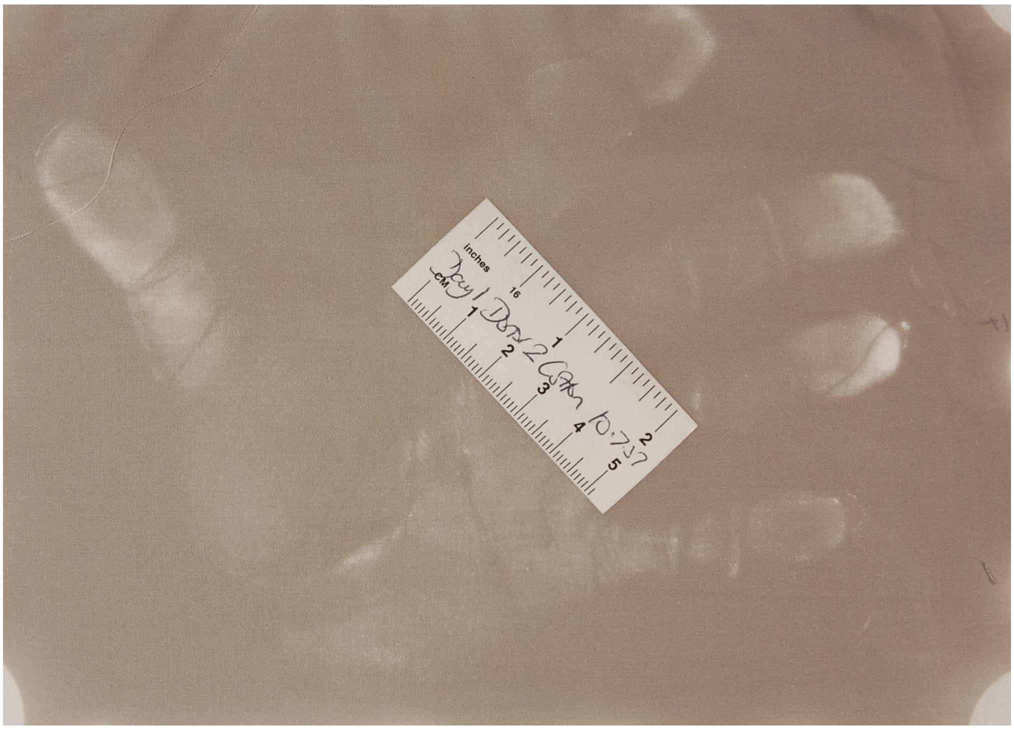

Fig. 8. One day sample on cotton demonstrating full hand print target area grab mark.

4. Conclusions

Of the fabrics tested it appears that there was consistently greater ridge detail identified on the shinier tighter weave non-porous textiles, such as nylon, whereas duller more porous fabrics, such as cotton showed only empty prints with no fingermark ridge detail or just grab-impressions. Lack of either ridge detail or palmar flexion creases, does not however mean the VMD process cannot help in investigations as impressions can lead to a "picture of events" or visualise an area to target for DNA.

The age of the sample does appear to have an effect on the amount of ridge detail produced. Therefore samples developed earlier may allow visualisation of better detail and as most assault cases are generally reported within the first few days after the event this is a positive aspect of this study. Delay in reporting assaults does not necessarily invalidate the technique as older samples gave some visualisation of detail (ridge or palmar flexion creases) along with target areas for DNA collection.

The major influence on the ability to retrieve a fingermark from a fabric is the donor. A good donor will consistently leave prints that show good to excellent ridge detail, palmar flexion creases and target areas for DNA collection due to the presence high levels of secretions. However, certain donors will secrete less because of drier skin which in turn leads to ineffective visualisation using VMD. Therefore secretion levels do impact on the deposits and visualisation. However, poor donors who did not have samples with good detail did still show target areas, which could lead to identification from DNA procured from these impressions. Work is currently being carried out on DNA acquisition and will be reported in due course.

Thus, the use of VMD in the visualisation of a fingermark, palmar flexion crease or just an indication of an area on clothing where DNA may be acquired should be seen as an effective tool in the examination of clothing from potential assault cases. Further work is ongoing to determine the effect that "dirty or worn" clothing can have on the acquisition of fingermark detail utilising VMD.

Acknowledgements

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