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An evaluation of two adhesive media for the recovery of DNA from latent fingermarks: A preliminary study

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ABSTRACT

Dual recovery of forensic evidence is beneficial for crime scene and evidence processing as it can potentially double the evidential value of a single source, even more so in instances of DNA fingermarks. The use of adhesive liftering media has shown comparable results to swabbing when dealing with trace DNA recovery. Gelatine lifters have displayed the potential to recover DNA from latent fingermarks with minimal alteration to friction ridge detail post application, yet their ability to recover DNA has not fully been explored. The aim of this research was to compare the use of gelatine lifters with more readily available masking tape in their ability to recover cellular material from latent fingermarks. Natural (n = 120) and sebaceous (n = 120) fingermarks were deposited and aged in time frames from fresh, 1-day, 2-day, 1-week, 2-weeks, and 1 month. DiamondTM Nucleic Acid Dye was used as a visualisation method for any DNA containing cellular material. Images of the fingermarks pre and post lifting, and on the lifting media were imaged using the DSC®5 system. The media's ability to recover cellular material was assessed using fluorescent particle analysis by the employment of the free software ImageJ. Fluorescent particles could be observed on the lifting media post lifting with the use of DiamondTM Dye. Time was not seen to influence the variation in the number of fluorescent particles observed. The use of gelatine lifters was found to have a higher amount of recovered DNA containing cellular material than masking tape. Visualisation of particles on masking tape were inhibited by its porosity and absorption of the dye. Some fingermark detail could be observed in the gelatine lifters. The DSC®5 system was suitable for imaging fingermarks stained with DiamondTM Dye.

1. Introduction

When considering touch DNA within a forensic context, recovery is the initial aspect to consider, as the method of choice must collect as much of the available DNA as possible. The comparison of DNA recovery media has been considered in depth through the evaluation of the efficacy of various swabbing materials, solutions, and adhesives [1,2]. Swabbing and the use of adhesives have proved to be the most efficient and cost-effective techniques to use, with both methods displaying comparable results in relation to both the amount of DNA recovered and the quality of the resulting profile, with various types of adhesives being used and researched for use within crime scene processing [3,4].

Within this context, the element of dual recovery should also be considered due to adhesive tape being routine for recovering enhanced fingermarks and that trace DNA coexists upon touched and held items, allowing for two evidential types to be recovered simultaneously, potentially increasing the evidential value of a single exhibit [5]. Many routine fingermark recovery techniques allow for a faster and cheaper method for possible suspect identification compared to genetic analysis, which does not always guarantee a usable profile due to varying amounts of DNA transference in touch deposits and degradation [6].

Operational protocols may require scientists to target specific areas of exhibits for DNA recovery which may not possess fingermarks, or to prioritise the enhancement of fingermarks over DNA. This is mainly due to fingermark enhancement methods interfering with the DNA present by degradation, removal of DNA containing material from the surface, or results in contamination from solutions and brushes [7]. However, common methods of DNA recovery such as swabbing and strong adhesive tapes can destroy or alter latent friction ridge detail [8,9]. Recently, the research of non-destructive adhesive DNA recovery media has displayed that low tack adhesives such as gelatine lifters can be used on latent fingermarks and still allow for visualisation post-exposure [10]. Within this study, the gelatine lifters' capability to recover DNA was not explored, although

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gelatine lifters have been shown to recover DNA when using proteolytic digestion [11]. The comparison of recovery methods usually requires the extraction and isolation of the DNA to fully estimate their capability. However, this process can lead to a loss of up to 80 % of the recovered DNA, meaning that it is difficult to accurately assess [12]. The use of genetic dyes is slowly growing traction to observe DNA containing material in situ, providing a preliminary assessment of potential recoverable DNA [13]. This has been observed within both latent and enhanced fingermarks [1,14], upon various surfaces after handling [15,16], and upon both swabs and tape lifts after DNA recovery [17,18].

Diamond™ Nucleic Acid Dye (DD) has been shown to visualise latent touch DNA within fingermarks and on surfaces, displaying no adverse effects in relation to PCR amplification and fingermark enhancement when used together with a DNA extraction step [1,19]. Earlier research has used DD to look at buccal cells which had been recovered via tape lifting and displayed full profiles even a year after deposition [18]. The use of DD is a potential method to screen areas for latent DNA and to give an estimate of the potential producible profile [20]. This may also be a useful way to compare the efficiency of DNA recovery techniques [18,21]. This research aims to evaluate two forms of low adhesive media on the ability to collect touch deposits from latent fingermarks over different time periods using fluorescent particle estimations. As a result, this may help optimise dual recovery during crime scene processing and exhibit examination.

2. Material and methods

2.1. Surface preparation

Unused glass slides (Fisher Brand) were autoclaved in a PriorClave™ autoclave to sterilise the slides and to help remove the non-stick coating.

2.2. Fingermark deposition

Two male donors deposited 120 natural and sebaceous rich fingermarks each onto the sterilised glass slides, with an overall total of 240 fingermarks. The hands were rubbed together immediately before deposition to try and evenly distribute residue/cellular material across the fingertips. A researcher assisted in deposition by holding the donor's fingers during contact with the slide, to reduce the risk of minimal or excessive force.

Natural fingermarks were obtained by asking donors to refrain from hand washing, using any sanitisers and/or hand products for ~1.5 h prior to deposition. Donors were allowed to do this in their work environment throughout daily activities, which generally involved office-based tasks.

Sebaceous fingermarks were obtained by asking donors to rub the back of their necks or behind their ears, to gain sebaceous residue and to try and minimise the chance of saliva, mucus or cosmetics being transferred with the residue. Sebaceous fingermarks were used as control marks, due to the difficulty with standardising the deposition of natural touch DNA, which can result in little to no transfer.

2.3. Ageing process

Fingermarks were deposited and left for the following times periods to account for the potential difference between the time of deposition and processing. Ageing time frames consisted of fresh, 24 h, 48 h, 1 week, 2 weeks and 4 weeks, with a total of 10 fingermarks for each aging time period. Fresh samples were deposited and analysed on the same day within 2 h of deposition whilst, samples that were aged for longer periods were left within an environmentally controlled laboratory with room temperatures being recorded at 21–25 °C, access to natural light conditions. Although humidity is recognised as a factor which can contribute to changes to latent fingermarks over time, this variable was not controlled [22]. Although natural variations in ambient humidity would have been present, they were not expected to be significant since the temperature and air flow laboratories are monitored.

2.4. Adhesives

Black gelatine lifters (BVDA) and masking tape (Steris CorporationTM) were used as the methods of DNA recovery. Masking tape was considered due to it being inexpensive, widely available and the results of an alternative project had demonstrated that friction ridge detail from latent marks was available post lifting (data not shown). Black gelatine lifters were specifically chosen due to the contrast that they provided. The clear and white gelatine lifters were excluded from this study as they displayed background fluorescence when tested.

Unused gelatine lifters sheets were cut into 3 cm^2 squares before use to cover the fingermark area. The acetate sheet was removed, and the adhesive gel layer was applied to the surface. The lifter was then removed from the slide before being turning over and imaged. A glass slide was placed over the adhesive side for storage.

An unused roll of masking tape was cut into ~3 cm strips, and the adhesive layer applied to the fingermarks. After lifting the fingermark, the strip was then applied to a clean glass side, adhesive side down, and turned over for imaging purposes.

2.5. Diamond™ Dye (DD) visualisation

DD working solution was made from a stock solution (10,000x) acquired from Promega which was diluted in 75% ethanol. 10 µl of a 20x diluted working solution (30 µl of DD in 600 µl 75% ethanol) was pipetted onto all fingermarks with a coverslip being placed over the area to help evenly distribute the dye. The working solution was made fresh before being used each time to avoid variation in the concentration due to evaporation of the ethanol.

2.6. Imaging

Photographs of the fingermarks were taken using a DCS® 5 system (Foster and Freeman). The DCS® 5 system consists of a 36.3 MP camera with a tailored macro lens and a UV imaging module for fluorescent fingermark imaging. The following camera settings were used: ISO 500, shutter speed ½ second and aperture F9-F10, with illumination bandwidth 445–510 nm and filtered out at 549 nm. Unenhanced fingermarks were first imaged to determine if any fluorescent contaminates or autofluorescence was present. The fingermarks were photographed before the application of the adhesive media with the coverslip still in place. The coverslip was then removed, and the adhesive media was applied to the fingermark. Images were taken pre-recovery, post-recovery and of the adhesive lift itself. This resulted in a total of 720 images (n = 240 fingermark deposits). Controls of the microscope slides and the adhesives were treated and imaged in the same manner as the samples to assess contamination and background interferences. All control slides, coverslips and adhesive samples displayed no identifiable fluorescent particles, with only the dye itself fluorescing. In some instances, fluorescent fibres were observed, but these were easily identifiable and excluded from the data collection. Throughout the remainder of this study, any identifiable particles within the region of fingermark were therefore assumed to have been transferred to the slide during the contact between the finger and the slide, and that any particles on the adhesives were directly recovered from the surface.

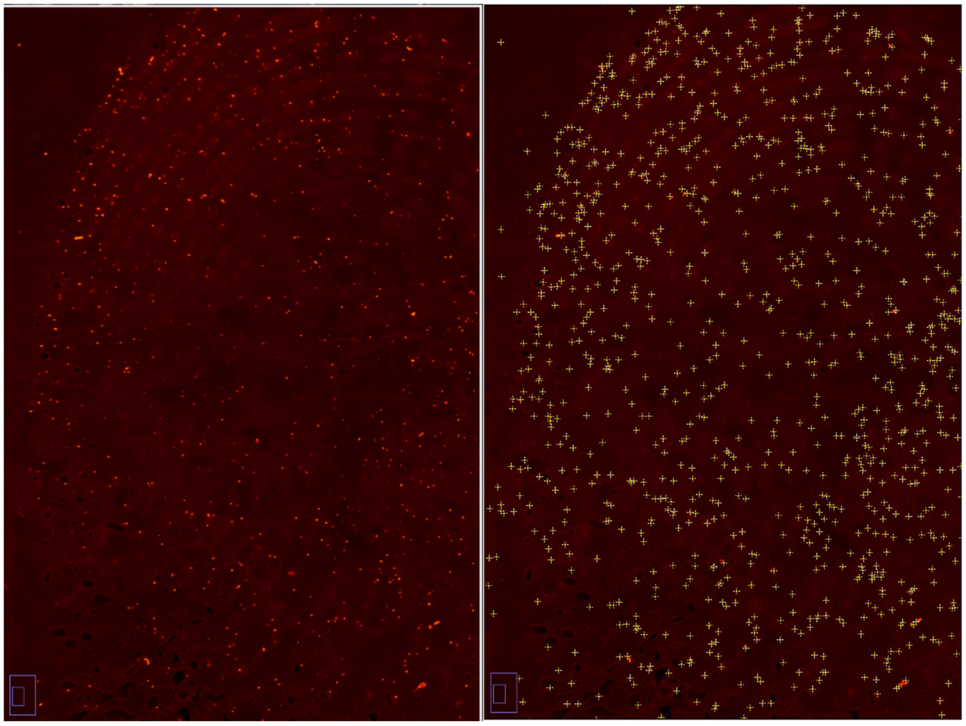

Fig. 1. Left: The original image taken with the DCS 5® system. Right: The overlaid find Maxima function applied with ImageJ to identify areas of intensity. *Images have been magnified.

2.7. Data analysis

Two researchers undertook the analysis independently by importing the images into ImageJ (https://imagej.nih.gov/ij/) which is a free to use software for image processing. The area around the fingermark was highlighted and the fluorescent particles were analysed by using the 'Find Maxima' function. The function identifies the maxima intensity of local objects from the background as outlined Grishagin [23] and is demonstrated in Fig. 1 (Fig). Due to the 'Find Maxima' function overlaying identified areas of intensity over the original image (Fig. 1), the accuracy of the points identified could be checked manually to determine if any areas of fluorescent were not registered or if background fluorescence was detected. Twenty images of naturally deposited fingermarks were manually counted and compared to the ImageJ counts, to estimate the accuracy of the software. Natural deposits were chosen due to containing observably less particles which were more discrete when compared to the sebaceous deposits. The intention was to reduce the chances of either researcher counting errors.

To assist with manual counting 20 mm × 20 mm adhesive grids (Sigma-Aldrich) were placed on the underside of the slides to avoid obscuring any particles. In addition to this, areas of the images where no fluorescent particles were observed were also analysed with the function to assess for false positives. Within the blank areas, no areas of contrast were classed as 'maxima' with the proximity threshold set to between 20.00 and 50.00, indicating that any fluorescent particles identified were of a detectable contrast from the background. Any contrast identified outside the proximity parameters was shown to be the glass background or the background fluorescence of the DD from observing the images. Values for the pre-lifted images were taken as the initial number of fluorescent particles present on the surface, and values for the post and lifted images were considered to estimate the percentage of particles still on the surface and those that have been recovered, respectively. A Kruskal-Wallis test and a pairwise comparison test was used to identify any statically significant differences. All statistical testing was carried out using SPSS (Version 27).

3. Results and discussion

Previous research by Khuu et al. [24] and Kanokwongnuwut et al. [25] have demonstrated that deposits from fingermarks stained with DD have DNA containing human cellular material, based on observations which have been verified through DNA quantification and profiling. Therefore, the fluorescent particles were not measured in this research and were assumed to be cellular in nature. Further to this, DNA was not extracted, quantified, or profiled in this instance, so the quantity or quality of DNA present on the surface cannot be commented on. Fig. 2 is a 3D rendered image taken with a DCS® 5 system illustrating distinct DD fluorescent shapes, which resemble cellular material.

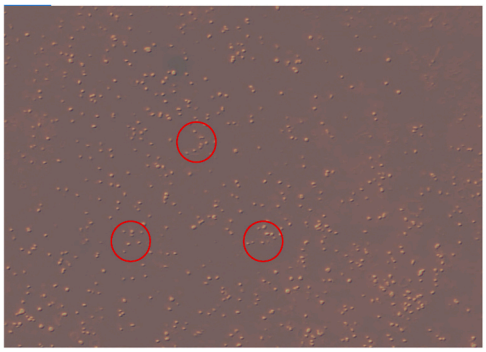

Fig. 2. A 3D rendered image using the DSC 5® illustrating the globular shapes displayed on the surface, some of which have been highlighted in red. *Image has been magnified and cropped.

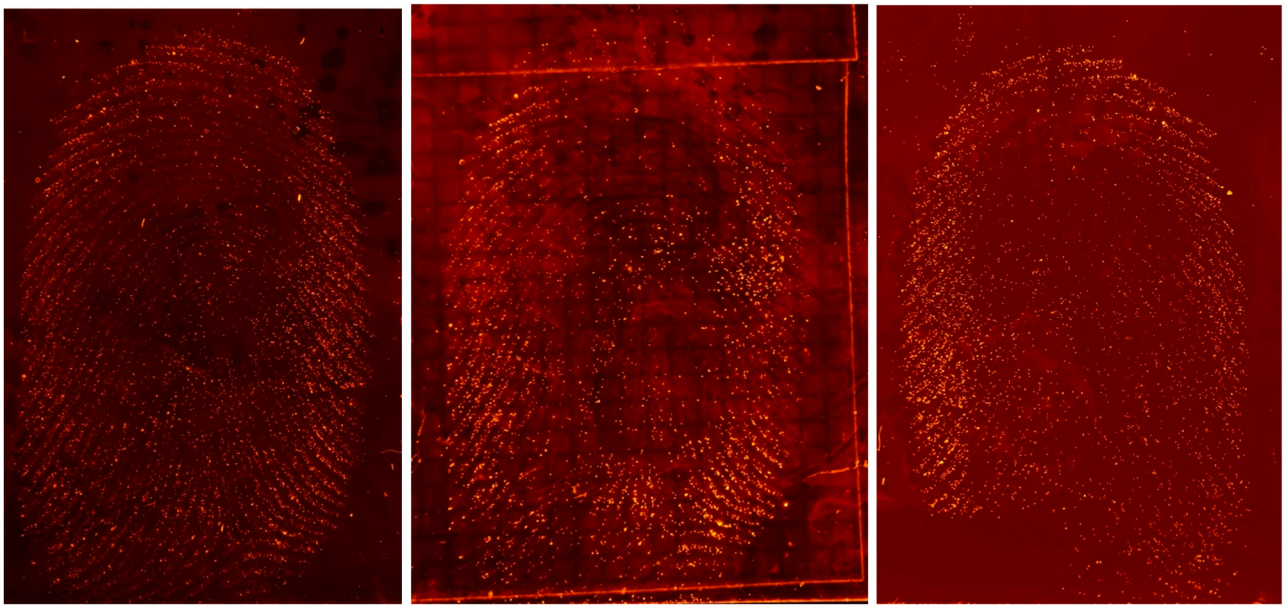

Fig. 3. A 1-week aged sebaceous fingermark enhanced with DD: From left to right 1) pre-recovery 2) post-recovery 3) the gelatine lift after recovery. *Images have been cropped.

3.1. ImageJ validation and count variation

An example of the images that were produced and counted as part of the validation pilot are displayed in Fig. 3.

To ensure that counting between researchers was consistent, 10 of each researcher's images (n = 20) were reanalysed by the second researcher independently using the ImageJ software. The images were evenly selected between the gel lifter and the masking tape samples, whilst ensuring that at least 1 image from each time frame were incorporated. This resulted in minimal differences in the counts with 5 displaying $\geq$ 10%, 2 displaying 5–10% and 13 having $\leq$ 5%, with a mean of 5% difference in scores overall. A Friedman test reported that there was no statistically significant difference between the reanalysis of the images (P = 0.251). Any counting discrepancies between researchers were not considered further.

It was found that statistically, using a paired samples T-test, that the manual counting and Image J software values were significantly different (P = 0.001) in the group of 20 compared samples. This may be a result of 16 of the samples having counts that had > 5% variation between the two methods. Fourteen of these samples were where the image J software counted a greater number of fluorescent particles than the manual method. The software could therefore be accounting for particles that are overlapping that an individual may miscount or particles that are not fluorescent enough to be manually counted. However, from the Cohen's D analysis, the effect size was found to be small (D = 0.145) indicating the statistical significance result was negligible and supporting the experimental approach.

3.2. Sebaceous fingermarks

The number of particles present in each individual finger differed considerably from each hand and between each donor with both the sebaceous and natural fingermarks. This is to be expected as natural DNA deposits have displayed both intra and inter variation between individuals [26,27]. The use of two individuals for the sample size could therefore not represent the inter variation observed in larger studies. Sebaceous counts may have varied due to uneven loading of the fingertips when rubbed against the skin, as the force and length of contact was not controlled.

Mean values were taken to compensate for the ranges. The full tables of individual particle counts can be found in the supplementary data. The mean number of fluorescent particles observed for the sebaceous fingermark deposits over all time frames is displayed in Fig. 4. Fig. 5 illustrates the mean percentages of the particles remaining on the surface and both of the lifting media.

The mean number of particles was higher for all of the pre-recovery samples before the application of the adhesive media, which was to be expected due to no interaction with the gelatine lift or masking tape. Mean values ranged from 5742 to 3269, 3545 – 1503, and 4556 – 637 for the pre, post and lift counts, respectively for both media with the 2-week depositions displaying the highest means. The standard error bars indicated a low amount of variation in the cellular material detected for all samples sets.

The mean particle counts for the pre-recovery images varied between each time frame, with an increase in particle counts being observed for the 1–2 week and 1-month samples. A Kruskal-Wallis test displayed that there was a statistical difference in the distribution of pre-sample particle values and the delay in time (p = 0.011). To establish the variation within the time delay groups a pairwise comparison was conducted. All time delays were found to be not statistically significant when comparing the time delays (p–values were adjusted using the Bonferroni correction for multiple tests) between 24 h and 1month old samples (p = > 0.05). The same was not true for fresh samples. For the comparison of fresh samples and the 48 h (p = 0.006), 1-week (p = 0.006), 2-week (p = 0.005) and 1-month (p = 0.01) samples there was a significant difference between the distribution of the sample values. However, for the comparison of fresh and 24 h ages samples the distribution of the values was shown to be the same (p = 0.391).

This indicated that the time delay did not have an influence on the particles numbers as a reasonable assumption would be that the number of particles may decrease due to DNA degradation. The variation in the number of particles pre recovery was therefore heavily influenced by the loading of the fingers and the deposition variables. There is also the possibility that over this time period debris which fluoresces under the same illumination conditions became present on the slides within the fingermark region, which was included in the counts. In extension to this, it is also possible that nonfluorescent debris may have also been present on the surface that saturated the adhesion of the media, restricting the ability to recover fluorescent particles. This may account for instances where more particles were still present on the surface, especially in

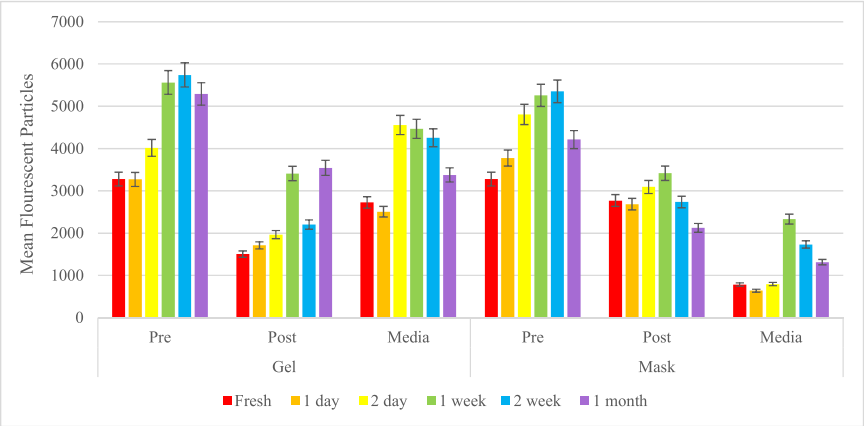

Fig. 4. Mean number of fluorescent particles observed for sebaceous fingermark deposits, overall time frames with standard error. The data is categorised in the mean number of participles observed pre- and post-recovery along with the mean number on the lift itself. Bars indicate standard error. (n = 10 fingermarks per aging time frame).

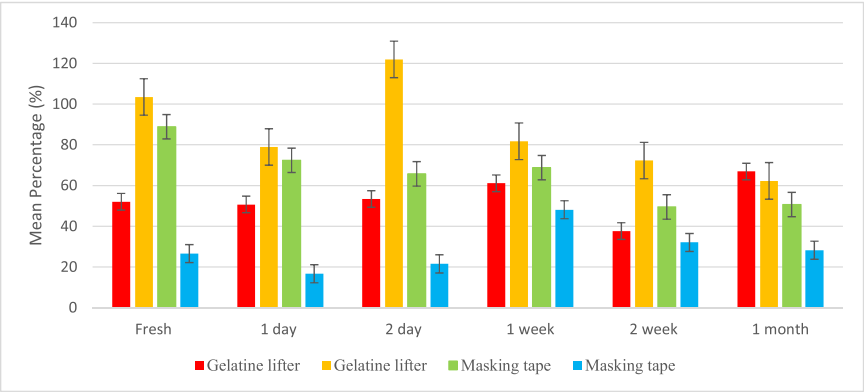

Fig. 5. Mean percentage of fluorescent particles observed on the surface post lifting for the gelatine lifter and masking tape lifts for sebaceous deposits. Bars indicate standard error.

relation to the 1-month aged samples which had a lower mean on the lift than the slide. It should also be noted that it is possible that DNA within the cells may have degraded but was still present for the DD to bind to and fluoresce, but the actual analysable amount of DNA and quality may have fragmented over this time.

Interestingly, there was a consistent increase in fluorescence observed in the sebaceous marks over time. This was not detected in the natural marks. Over time, evaporation of the aqueous content of latent residue is expected, which would be true of both types of mark in this study. Logically, this would concentrate the cellular material that was stained with the Diamond Dye™. As sebaceous rich marks age, latent residue is also expected to migrate, which may have changed the presentation of the cellular material and exposed alternative fluorescent material on the slides, as discussed.

Samples exposed to the gelatine lifter had lower mean particle estimates on the surface post-recovery with higher means being observed on the lifts themselves. This indicated that the gelatine lifts were collecting more of the particles from the surface in relation to the number of particles that remained on the surface. The masking tape, however, had higher particle mean values on the surface post-recovery than on the tape lift, thus demonstrating that it was not recovering the majority of the cellular material available on the surface. The percentage means also support the idea that the gelatine lifters were more proficient at recovering the particles due to higher means being present on the lifts than the surface. This is in contrast to the masking tape, which had higher means present on the surface images. Using a Kruskal-Wallis test statistically significant differences were present in the distribution of values for the percentage of particles present post lift on slides ($p = 0.003$), the percentage of particles present on the lifter ($p = 0.000$) and the total percentage of particles detected ($p = 0.000$) while considering the type of lift used (gel lifter and masking tape).

In some instances, the total mean percentages for the gelatine lifter exceeded 100% when the post-recovery counts and the counts on the lift were combined. This may have been a result of cellular clumping, which has been demonstrated by Farash et al. [28], who reported that when gel films were stained to view the 'bio particles', these were recovered as both individual particles and in clumps. Due to the sebaceous fingermarks being biased by rubbing the neck and behind the ear, several clumped cells could have been sloughed off during the friction and onto the finger and further transferred to the surface. The application of the DD may have reduced the adhesion between the cells which would have resulted in a single point on the pre-recovery sample being separated into two or more points either still on the surface or onto the gelatine lift. This may have been more prominent with the gelatine lift due to it being more effective in recovery when compared to the masking tape. It is also possible that the removal of the coverslip contributed to the potential splitting of the clumps resulting in more points. There is potential that some of the particles on the surface were small spots of DD that were left on the surface from the removal of the coverslip and the contact with the adhesive media. This may have arisen due to the DD being not fully dried before recovery took place to prevent cell fixation to the slide.

The masking tape however, displayed a loss of particles as 100% of the initial estimations were not accounted for in all samples except for the fresh and 1-week samples, which exceeded this value.

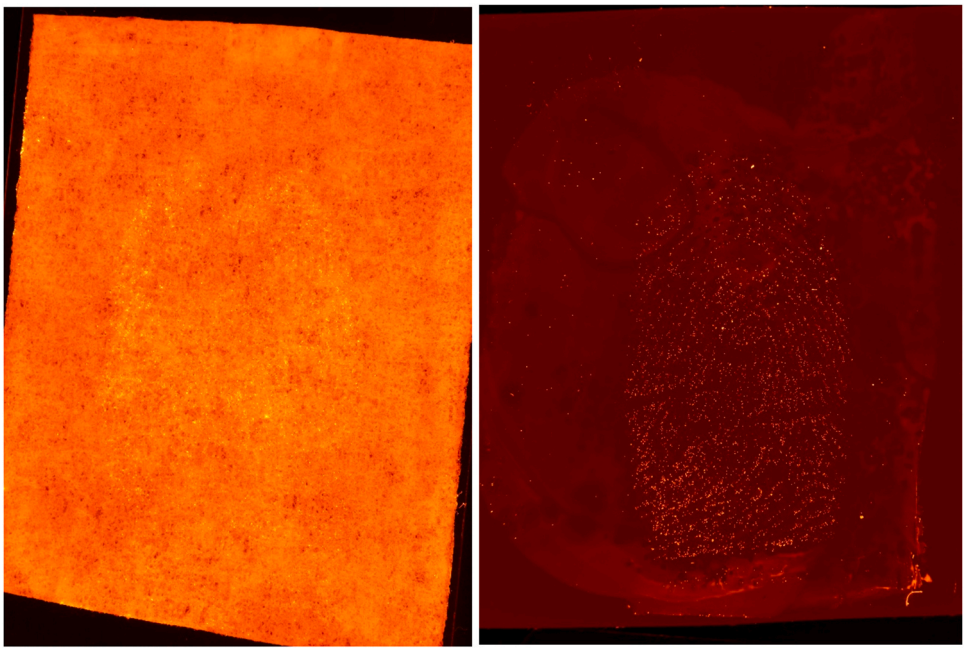

Fig. 6. Left: A 2-week aged masking tape lift from a sebaceous fingermark. Right: A 2-week aged sebaceous fingermark on a gelatine lift.

The loss of particles could have resulted from the masking tape displaying similar colouration to the fluorescent particles after being exposed to the DD. This caused discrepancies with the analysis as the points of interest which were not as discreet as was displayed with the gelatine lift (Fig. 6). A recent publication by Cook et al. [13] also reported background fluorescence being observed with DD when masking tape was used. This may have occurred due to the porosity of the tape, facilitating dye uptake when lifting. However, in nearly all instances participles could be observed potentially due to a higher concentration of DD being used within this study.

3.3. Natural fingermarks

The mean particle counts for the natural deposits are presented in Fig. 7, with the mean percentages displayed in Fig. 8.

The natural deposits had an observably lower mean number of fluorescent particles deposited when compared to the sebaceous deposits, as was expected due to the sebaceous deposits being biased intentionally. This also supports the indication that the fluorescent particles were cellular as the sebaceous fingermarks would have more DNA containing material present due to the manner of loading by rubbing the neck and ear. Furthermore, the standard errors for both the natural and sebaceous marks did not vary substantially. This was expected as the amount of cellular material deposited by a fingermark has been shown to have little intra-variation when from the same individual and time frame[14].

The natural deposits displayed more consistent means than the sebaceous fingermarks and did not exceed 2500 particle counts in either the pre, post or lift samples and ranged from 2244 to 977 (Pre lifting), 1207 – 563 (Post lifting), and 1631 – 90 (Lifts). Fig. 9 represents the differences in fluorescent participles between the natural and sebaceous fingermarks. Similar to the sebaceous deposits the pre recovered sample had higher means for the pre recovered samples than the post lifted samples and the lift samples.

The masking tape samples again displayed a higher number of particles still left on the surface post lifting than on the lift itself due to higher means and is also reflected in the percentages. This is also potentially due the background fluorescence of the masking tape, which was also observed with the sebaceous rich fingermarks. The gelatine lifter mean values were more evenly distributed between both the surface and the lifter, potentially due to the natural deposits depositing less material and limiting the number of particles

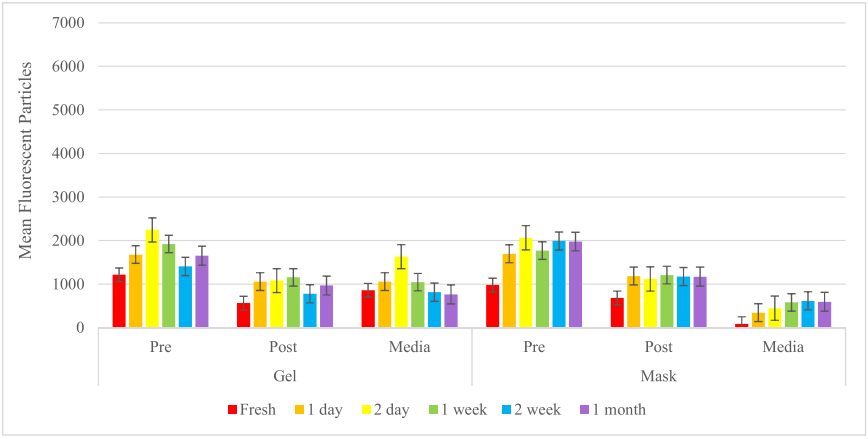

Fig. 7. The mean number of fluorescent particles observes for natural fingermark deposits over all time frames with standard error. *Graphs have been standardised.

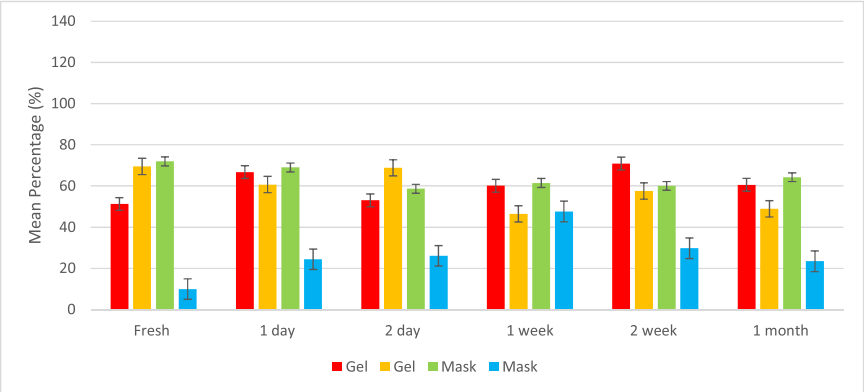

Fig. 8. The mean percentage of fluorescent particles observed on the surface post lifting and the gelatine lifter and masking tape lifts for natural deposits.

available for recovery. The fresh and 2 day samples were the exception, with higher levels of particles being present on the lift than on the surface in both the means and mean percentages. When considering the mark type (natural or sebaceous) the percentage of fluorescent particles present post lifting on the slide ($p = 0.080$) and the total percentage of particles present on the lifter and post lifted slide ($p = 0.074$) was found to have no statistical difference when using a Kruskal-Wallis test. The percentage of recovered particles on the lift was however, found to be statistically different between the mark types with a p-value of 0.006.

The natural fingermark observations corroborated the data from the sebaceous fingermarks in that the gelatine lifters were more efficient in the collection of material from fingermarks than the masking tape. This may be a result of the gelatine lifters being specifically tailored to the recovery of forensic evidence. For instance, they are routinely used for the recovery of fingermarks and footwear impressions, unlike masking tape, and therefore may present an efficacious advantage. The gelatine lifters also have the advantage of being pliable, allowing them to mould to the topography of the surface, compensating for uneven texture such as the presence of cellular clumps which may have been detrimental to the masking tape in relation to full contact with the glass slide. There is also potential that some of the adhesion of the masking tape was affected due to the DD not been fully dried before lifting. As masking tape consists of paper and adhesive, it is plausible that the DD was absorbed and reduced the level of adhesion or diluted the adhesive to prevent efficient uptake of the cellular material. This would also explain the background fluorescence of the masking tape. The gelatine lifters which are also porous in nature may have been less affected, which allowed for some absorption but with minimal loss of adhesion.

It should also be noted that there was no correlation between the quality of the fingermark and the number of fluorescent particles observed. This was more prevalent with the natural deposits due to the ridge detail being visible with the DD while only having a limited number of fluorescent particles present. The reverse was also true, in that in some instances substantial partial counts were observed with limited ridge detail clarity. There was also an uneven distribution of

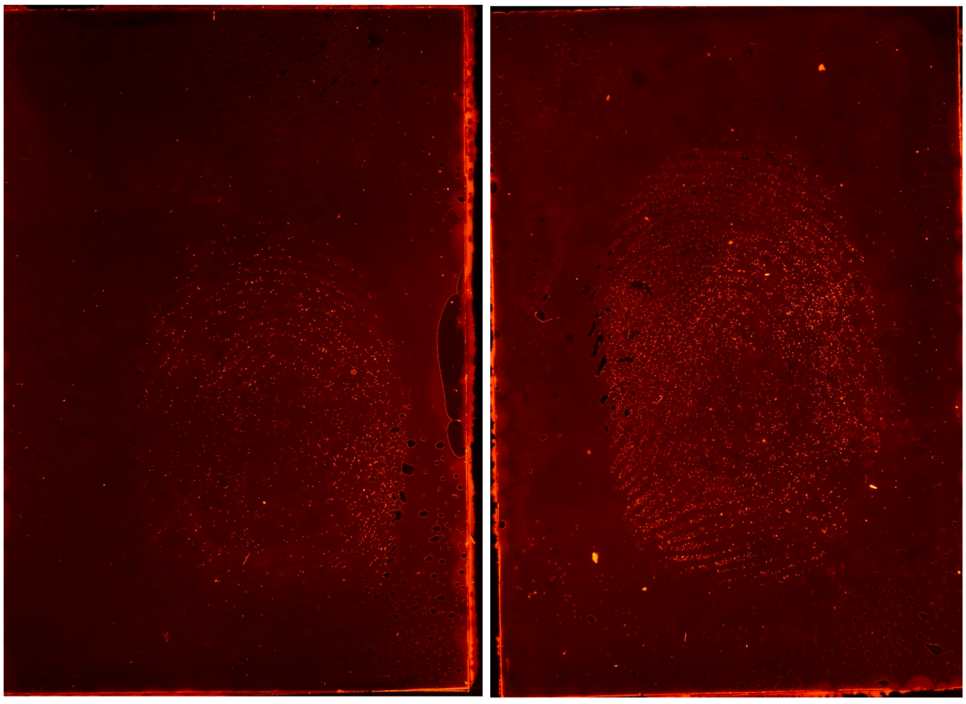

Fig. 9. Left: A 1 month aged natural fingermark. Right: A 1 month aged sebaceous fingermark. Both fingermarks are from the same donor.

Table 1
The number of samples which may produce potential profiles based on Kanokwongnuwut et al. [21] for pre-recovery and the gelatine and masking tape lifts. Samples with < 4000 particles are likely to generate no to partial profiles while samples with ≥ 4000 would likely generate partial to full profiles. N = 60 fingermarks for each variable.

Recovery Media	Pre recovery				Lift			
	< 4000 Particles		≥ 4000 Particles		< 4000 Particles		≥ 4000 Particles	
	Sebaceous	Natural	Sebaceous	Natural	Sebaceous	Natural	Sebaceous	Natural
Masking Tape	28	57	32	3	58	60	2	0
Gelatine Lifter	28	58	32	2	39	60	21	0

the fluorescent particles with both the natural and sebaceous fingermarks, with more particles being observed on the edges of the fingermarks rather than the centre, which was also observed by Khuu et al. [24]. It was suggested that the centre of fingers have a higher frequency of coming into contact with surfaces and are constantly losing cellular material as a result of this contact.

The DNA in this instance was not extracted or analysed. However, Kanokwongnuwut et al. [14] demonstrated that there was a positive correlation between the number of stained cells and the total relative fluorescent units from profiles generated. This would suggest that in this instance more fluorescent particles would likely generate profiles of a higher quality due to more cells being available for DNA extraction. Kanokwongnuwut et al. [21] expanded on this further, reporting that approximately 4000 corneocytes were required for a full DNA profile when the tape was the recovery media. In a similar model to this, the particle counts of the gelatine lifts and masking tape lifts were considered to estimate the number of samples that could potentially generate a full DNA profile, using a count of 4000 fluorescent particles as a threshold. The number of samples above and below this threshold are displayed in Table 1.

None of the natural deposits displayed 4000 or more fluorescent particles, suggesting that regardless of the lifting method the samples in this research would have potentially resulted in a partial profile. However, only 5 initial natural deposits in total displayed more than 4000 fluorescent particles, which restricts the potential for effective uptake of the lifting material. Initial sebaceous deposits had a total of 64 samples above the threshold, allowing for more opportunity of greater recovery than the natural. The masking tape had 2 lifts that displayed ≥ 4000 particle counts whereas the gelatine lifters had 21, further indicating that the gelatine lifters were more effective at collecting the cellular material. Kanokwongnuwut et al. [21] also concluded that tape lifting was not sufficient for recovery of touch DNA due to the inability to recover cell-free DNA on the surface, as only corneocytes are collected, whereas absorbent swabs will collect residues such as eccrine and sebaceous material, both of which have displayed the presence of cell-free DNA [29,30]. Gelatine lifters, however, are porous having been employed in operational casework due to their ability to recover fingermark residue and can be considered a visualisation method [8]. It is possible that due to their porosity they may also have the capability of collecting cell-free DNA in the residue during recovery which may help facilitate higher quality profiles than conventional tape lifting.

Due to DNA extraction and amplification not being conducted within this study, it does not indicate how these methods would have impacted the downstream processes. However, Diamond DyeTM has repeatedly displayed no influence during extraction, or to inhibit the PCR stage [1,17]. Gelatine lifers do have suspected PCR inhibitors present in the black and white lifts as reported by Zieger et al. [11], potentially due to the presence of metal compounds, although, this has not been confirmed. DNA profiles have been produced when clear gelatine lifters have been directly extracted after being used to recover touch deposits [11]. Black gelatine lifters were only used in this study to aid in the contrast when visualised with the DCS® 5 system. The impact that masking tape would have on the DNA extraction and amplification aspects is unclear and should be considered further.

4. Conclusions

Within this research gelatine lifters displayed greater recovery potential of DNA containing material from latent fingermarks when compared to masking tape suggesting that they are more suited for DNA recovery and should be considered further as a potential collection method within operational processing of crime scenes and from evidential item. This is potentially due to their pliable adhesive nature and being tailored to facilitate the uptake of fingermark residue. There was no observed variation of mean particles present when considering the ageing of sample after 24 h, suggesting that cellular material is not lost over time. However, this does not reflect the condition of any genetic material present. Future considerations could validate the assumptions made on potential recoverable DNA, looking at the amount and quality of the DNA present.

From the findings in this research, the DCS® 5 system coupled with the ImageJ software proved to be a complementary method in capturing and counting fingermark cellular material. Future research could look to use more sophisticated software such as RStudio and MATLAB which may account for subtleties in contrast and particle size for the inclusion or exclusion of defining cells within the samples. However, this was not the main aim of this paper and the ImageJ software allowed for user friendly pre-programmed functions and allowed for higher throughput of image analysis than manually counting. Further development of the concentration and carrier medium of the DD on other surface types will need to be explored to optimize this technique for research purposes.

Ethics

The project has been carried out in accordance with the University's policy for ethics, where an application was made and approved by the institution. All human participants gave informed consent.

CRediT authorship contribution statement

Mr. Ross Kwok: Conceptualization, Methodology, Validation, Formal analysis, Data curation Writing – original draft, Writing – review & editing, Visualisation. **Mr. Robin Parsons:** Conceptualization, Methodology, Validation, Formal analysis, Data curation Writing – original draft, Writing – review & editing, Visualisation. **Dr. Sarah Fieldhouse:** Conceptualization, Methodology, Validation, Formal analysis Writing – review & editing Supervision Visualisation, Project administration. **Dr. Laura Walton-Williams**: Conceptualization, Methodology Validation, Writing – review & editing Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.forsciint.2023.111574.

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