DNA from Fingerprints: Attempting dual recovery

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1. Abstract

DNA and Fingerprints are highly prioritised evidence types as they are considered reliable when distinguishing between individuals within a population. Attempts have been documented on recovering both forms of evidence from a single source, but were met with varying success. These studies have however highlighted issues concerning interferences resulting from the methods used to either recover or visualise, with a significant issue lying with contamination or destruction of the DNA by fingerprint enhancement techniques. The aim of the research was to recover DNA prior to enhancement to determine the extent of recovery and damage of both the ridge detail and DNA. Fingerprints were deposited on textured plastic, carrier bags, glass, stainless steel and paper. DNA was recovered by the use of nylon flocked swabs (Copan™), minitapes (Scenesafe™) or gelatine lifts (Crime Scene Investigation Limited™). Extraction was conducted with QIAmp DNA micro kit™ (QIAGEN®), with Qubit® fluorometry being used for DNA quantification and NGM Select™ (AmpFISTR®) determining the quality. For fingerprint enhancement; cyanoacrylate, aluminium powder and DFO were used to visualise the prints which were scored using the Centre of Applied Science and Technology (CAST) grading scheme. The gelatine lifts displayed higher detectable levels of DNA along with recovering more donor alleles. The lifts also resulted in the least amount of damage to ridge detail. Minitapes followed in both DNA levels and ridge damage. The nylons swabs displayed a low affinity for collecting DNA while removing all traces of the fingerprints.

2. Introduction

The recovery of DNA from fingerprints is not a new concept (Van Oorshot & Jones, 1997) but further advancement has allowed for increased preference, more complete profiles and smaller amounts of DNA to be analysed (Quinones et al, 2012; Aditya et al, 2011). In addition to this, research has highlighted the issues associated with attempting to recover both the DNA that has been transferred and the friction ridge skin detail of the fingerprint. The recovery is approached with several considerations based on multiple variables which include the surface type, the enhancement method needed and which evidence type will be more valuable (Murray et al, 2001). The current protocol is to first identify an area that has or may have fingermarks present and then use the required enhancement technique for the surface type (Balough et al 2003b) in order to evaluate the quality of the fingermarks. If the fingermark is intact the priority lies with the ridge detail and the DNA recovered after the comparative analysis. If the fingermark is smudged or damaged, then DNA is given precedent as the techniques employed to recovery the DNA can destroy or alter the ridge detail (Soltyszeski et al, 2006). The most successful attempts of recovering both evidence types were when the fingermarks were enhanced and collected with the use of tape, with DNA analysis being conducted by direct extraction of the tape (Zamir, 2000). However research has displayed certain issues in regards as to how the enhancement chemicals and mechanisms can destroy DNA (Bahlough et al 2003), remove the cellular material from the surface (Raymond et al, 2004) and contaminate the DNA via the fingerprint brushes, powders and solutions that the surfaces are washed in (Proff et al, 2006; Bhoelai et al, 2011). To avoid some of the concerns, it has been suggested to avoid using certain chemicals along with applying the use of disposable brushes with small aliquots of the powders and solutions (Van Oorschot et al, 2005). The latter however does not eliminate the mechanism of removal by the physical interactions of the enhancement equipment. Another suggestion would be to

recover the DNA prior to enhancement which would allow for the full recovery of the DNA without any exposure to chemicals or physical intervention. It is acknowledged that it would be beneficial to employ methods which can efficiently recover DNA while causing no to little alteration to the ridge detail. Three different forms of recovery methods, relating to both DNA and fingerprint recovery, were used over five different surfaces to investigate their ability to collect DNA and assess their effect on the fingerprint quality.

3. Experimental

3.1 Experimental Set up

A participant was asked to deposit fingerprints on five different surfaces which were chosen based on the CAST's list of most frequently tested surfaces (as of September 2015) and in order to simulate common surfaces encountered at crimes scenes. These included stainless steel, glass microscope slides (FisherBrand™), textured plastic, smooth plastic in the form of carrier bags, and white copier paper (Pukka Pad, 80gsm). All non-porous surfaces were sterilised by the use of 2% virkon and 70% methylated spirits. Paper was irradiated with ultraviolet light (UV) (5 minutes each side) before use. Blanks were taken for the surfaces, all of which were negative for DNA.

Before depositing fingerprints the participant washed their hands and wrists with antibacterial soap. They were then asked to refrain from any activity for 5 minutes, after which they charged their index, middle and third fingers of both hands with eccrine sweat from behind the ears. After a further 5 minutes, the participant was asked to deposit fingerprints upon the surfaces, using mild pressure.

3.2 Deposition

A depletion series of 10 fingerprints were split between two halves of a single surface. One half of the series was taken and used as a control while the other was stored in a sealed pre-cleaned container for approximately a 24 hour period. After this period the fingerprints were removed and the DNA recovered.

3.3 DNA Recovery & Extraction

Nylon flocked swabs (Copan™), minitapes (Scenesafe™) and gelatine lifts (Crime Scene Investigation Ltd™) were used to recover the DNA. These were chosen in extension to previous research which indicated minimal alterations to fingerprint ridge detail (Oravocá, 2013). Each depletion series of prints were pooled together per repeat of the DNA recovery methods. This resulted in a total of three repeats for each method over each surface.

The nylon swabs were first dipped into a pot of sterile water and the pressed against the side to remove any excess water. The swab was then swabbed down a depletion series with light pressure while being turned along its longitudinal axis. The end was then broken off at its breaking point in to a sterile 1.5ml eppendorf. A single minitape was used down a depletion series twice before being placed into a sterile 1.5ml eppendorf. The gelatine lifts were provided in 13cmX18cm sheets. A single sheet was cut into 1cmx1cm squares big enough for a single fingertip. The plastic covering was removed from a square then used twice down a depletion series before being further cut into thin strips by the use of sterile dissection scissors, and placed in a sterile 1.5ml eppendorf.

Once recovered the DNA was extracted by the use of the Qiagen QIAmp DNA micro kit™ (QIAGEN®) using the standard operating procedures (SOP) provided with the kit, and quantified by the use of a Qubit fluorometer™ (Qubit®) with a limit of detection set at 0.50ng/ml. Readings from the fluorometer were multiplied by 20 in order to account for dilution factors. DNA was then amplified using a mycycler™ thermal cycler with a final volume of 15ml using the NGM SElect™ (AmpFISTR®) requirements. The product was then typed on an ABI 3500 genetic analyser (Applied Biosystems®) using a POP6 buffer with a

peak amplitude threshold of 50 relative fluorescent units (RFU). DNA profiles were compared to buccal references samples of both the participant and the researcher.

3.4 Fingerprint enhancement and examination

Both the control fingerprints and the fingerprints in the depletions series were subjected to the same enhancement methods based on the surfaces they were deposited on. For the glass and the stainless steel surfaces the fingerprints were enhanced by aluminium powder. Cyanoacrylate fuming with basic yellow staining was used for both textured and smooth plastic, while ninhydrin was used for paper. Once enhanced the control fingerprints and those exposed to the recovery methods were compared on a video spectral comparator (VSC) (Foster & Freeman™) with illumination settings ranging from visible-infrared to ultraviolet and filters from visible to 365nm. The fingerprints were graded using the CAST grading system of 0-4 with 0 being no ridge detail and 4 being full ridge detail.

4. Results and Discussion

4.1 Experimental Issues

During the experimental procedure there were a number of issues that arose. Some of these issues were more prevalent with the textured plastic and the stainless steel. One of these was a potential contamination of the gelatine lifts and minitapes which were not in any form of sterile packaging, allowing them to be exposed to potential contaminates. A further complication was that the participant needed to be changed after the textured plastic and stainless steel surfaces. Both of these issues will be discussed in detail later. There were also some problems during extraction when processing the gelatine lifts and minitapes. During the early stages of the extraction all of the minitapes eppendorfs had a tendency to leak lysate from the lids, even after ensuring all were secure. This caused some of the sample and potentially DNA to be lost. The gelatine lifts caused complications in the Qiagen columns as they melted when exposed to heat. This resulted in a viscous lysate that repeatedly blocked the columns requiring intervention with a pipette tip which risked damage to the filter. These issues have been considered when interpreting the results of this study.

4.2 Quantification

Table 1: Qubit quantification results of all techniques over all surfaces

	Minitapes		Gelatine Lifts		Nylon Swabs	
	Average DNA (ng/ml)	Standard Deviation (ng/ml)	Average DNA (ng/ml)	Standard Deviation (ng/ml)	Average DNA (ng/ml)	Standard Deviation (ng/ml)
Textured Plastic	88.73	17.73	753.47	931.94	54.27	25.87
Stainless Steel	61.31	6.20	2024.33	432.75	25.07	6.22
Glass	114.24	28.70	390.93	545.14	25.07	6.22
Smooth Plastic	49.31	36.04	120.78	26.64	43.58	6.94
Paper	35.69	16.46	584.53	493.52	54.47	12.30

From the quantification results in table 1 it can be seen that the gelatine lifts displayed more affinity for collecting DNA, but were also the most inconsistent between each of the repeats, as identified by their large standard deviations. As mentioned previously, only three repeats were conducted for each surface, which made outliers difficult to identify. The minitapes displayed lower DNA levels than the gelatine lifts yet outperformed the nylon swabs, with the exception of paper, as the adhesion on the minitapes tore and removed the top layer of paper fibres. The nylon swabs recovered the least amount of DNA and in some cases were either close to or below the limit of detection of the Qubit device.

The poor results of the swabs in comparison to adhesive techniques is expected as previous research by Hanasson (2009) and LI & Harris (2003) illustrated that minitapes recovered more material than swabbing due to the adhesion properties. Although gelatine lifts were not considered in these studies it is suggested that the moderate adhesion of the gelatine lifts is a contributing factor to recovering DNA. There is however, a potential issue as demonstrated by Verdon et al (2014) in that adhesive mediums can redistribute material back to the surface if repeatedly used over the same sample area, although this is dependent on the level of adhesion of the medium and the number of repeated uses. Due to the repeated use down the depletion series there is potential that some cellular material may have been transferred back to the surfaces and account for some of the inconsistencies between the repeats. This may have been more prevalent for the gelatine lifts as they were less adhesive, resulting in the cells being less secure and more susceptible to being displaced. In regards to the nylon swabs, the lower DNA yields may have resulted from a large surface area being swabbed, allowing for cellular material to become spread over the entire area and not recovered efficiently (Van Oorschot, 2010). Another possible explanation could be due to the variation in fingerprint quality as some of the control prints displayed less ridge detail resulting from insufficient pressure and contact with the surface. This may have resulted in limited transference of cellular material than other fingerprints and depletion series. In addition to this, some of the fingerprints were not split equally between the two halves of the surface. This resulted in variable amounts of ridge detail, and in extension the amount of DNA transferred, to not only differ between different depletion series but also within a single series. Using a Kruskal-Wallis test (α=0.05) a statistical difference was observed between the recovery methods. A Wilcoxon test (α=0.05) was used to determine that a significant difference was observed with the gelatine lifts when compared to the minitapes and nylon swabs ($p<0.05$).

When considering the surfaces, the gelatine lifts highest yield was from the textured plastic. This may be due to the rough texture of the plastic encouraging sloughing off of skin cells, which become trapped within the indentations and allowing for greater availability (Wickenheiser, 2001; Daly et al, 2012). This in combination with the gelatine lifts pliability, allowed for greater recovery, as the gelatine lifts may have moulded to the texture and collected cells in the indentations. The minitapes highest yields were from the glass surface and may be due to an explanation provided by Pesaresi et al (2003) who suggests that there is an increase in perspiration when skin comes into contact with glass. This stimulates the sloughing off of skin cells and facilitates the transportation of cells to the substrate via sweat, which also contains cell free DNA (Quinones et al, 2012). Such actions may also relate to why glass is a good substrate for fingerprints as more eccrine and sebaceous materials are secreted when the finger comes into contact with the surface (Barbaro et al, 2006; Kita et al, 2008). Tozzo et al (2015) also found that glass was a good substrate for the recovery of DNA due to a higher number of complete profiles. Such recovery may be credited to the cellular material remaining on top of the surface (Van Oorschot, 2014) and not becoming trapped within the surfaces matrix. This allows for the cellular material to be readily collected yet vulnerable to being dislodged by physical intervention and may also explain as to why such surfaces facilitate high quality fingerprints (Murray et al, 2001; Goray et al, 2009). The highest yield for the nylon swabs was recovered from the paper. Paper as a surface should be an ideal substrate for cellular material as it is porous and abrasive, which encourages transfer and retention; due to the cells becoming trapped in the paper fibres (Raymond et al, 2004). This could have contributed to recovery as the water from the swabs altered the fibrous structure of the paper, therefore loosening the cells and absorbing them via capillary action (Balogh et al, 2003b; Plaza et al, 2015). A Kruskal-Wallis test (α =0.05) was conducted to test for statistical significance. No statistical difference was observed between the surfaces used ($p=>0.05$).

These levels of DNA are considerably higher than what was approximated by Goray (2010) and Bright (2004) who found than a whole hand print can result in an average range of 0.16-53ng of DNA,

considerably lower than some of the values displayed in this study, especially taking into account that only half fingerprints were used. Due to the splitting of the fingerprint, it not only halved the ridge detail but also the initial amount of DNA available of recovery due to the majority of the DNA being deposited on the initial contact (Alessandrini et al, 2003; Van Oorshot et al, 2003). This limited the amount of recoverable DNA from a single series, to levels which are expected to be lower than the estimated values of Goray (2010) and Bright (2004). The higher levels may have resulted from potential contamination and interferences. One area that may have contributed to such contamination was that the gelatine lifts and minitapes were not in sterile packaging as previously mentioned. This was further prevalent with the gelatine lifts as they required cutting, on more than one occasion, to usable sizes before recovery and extraction. This therefore caused excess handling in comparison to the minitapes and nylon swab (Poy et al 2006; Van Oorschot, 2010) increasing the likelihood of contamination. For the glass, smooth plastic and paper the gelatine lifts were treated with 70% methylated spirits, however this was not done for textured plastic and stainless steel due to this issue only being identified after the surfaces were analysed. Due to time constraints these surfaces could not be retested. Another issue with the gelatine lifts is that they contain a gelatine layer which was protein based, specifically bovine, which may have caused an interference with the Qubit system as it is not human specific. If possible equipment such as the Quantifiler human DNA quantification kit (Van Oorschot, 2010) should be used instead as it is specific for human DNA.

An aspect that also has an impact upon the amounts of recoverable DNA is the shedder variation between a person's hands (Haines et al, 2013). This was demonstrated by Phipps et al (2007) who identified that a person's dominant hand can yield more DNA than the non-dominant hand as it used more frequently therefore transferring more material and so consequently has a greater need for cellular regeneration. Such variation between hands has also been illustrated by Alessandrini et al (2003) and Meakin et al (2013), however the variation between people is more significant (Lowe et al, 2002, Kumar et al, 2015) and may have also been an issue throughout the study. As mentioned previously, the participant needed to be changed after the textured plastic and stainless steel. The shedder status of both participants was not determined prior to the study. Although this adds some realistic context, due to the shedder status of an offender would also be unknown (De Bruin et al, 2010), it does however potentially affect the results if one of the participants was a better shedder than the other.

4.3 DNA Profiles

When analysing the DNA profiles, all homozygous regions in the participant's reference samples were treated as heterozygous due to the known homozygous peaks in the sample profiles were either less or equal to adjacent peaks (Gill et al, 2000) and therefore not being identifiable as homozygous. Using this, the reference profile of participant A (textured plastic and stainless steel) had a total of 31 alleles out of 32, and participant B (glass, smooth plastic and paper) had a total of 29 alleles. Shared alleles were declared when they were present in both the participant's and researcher's reference profiles at the same loci, which would make it unclear as to whom it originated from. The amelogenin was only considered when identifying possible contamination as both participants were female, whereas the researcher was male. Spurious alleles were declared when they were visually recognisable from background noise and could not be associated to either the participants or the researcher (Alessandrini et al, 2003). Figure 2 presents the number of donor specific alleles recovered for each technique and surface.

When first looking at the profiles it was observed that no full profiles were produced for any recovery methods. Initial observations also displayed obvious allele drop out and heterozygous imbalances. There were rare instances in which the participant's alleles were present with spurious alleles but had equal peak heights allowing for the donors genotype to be inferred at that loci. However the majority of the participant's alleles suffered imbalances, or were equal to peaks resulting from contamination.

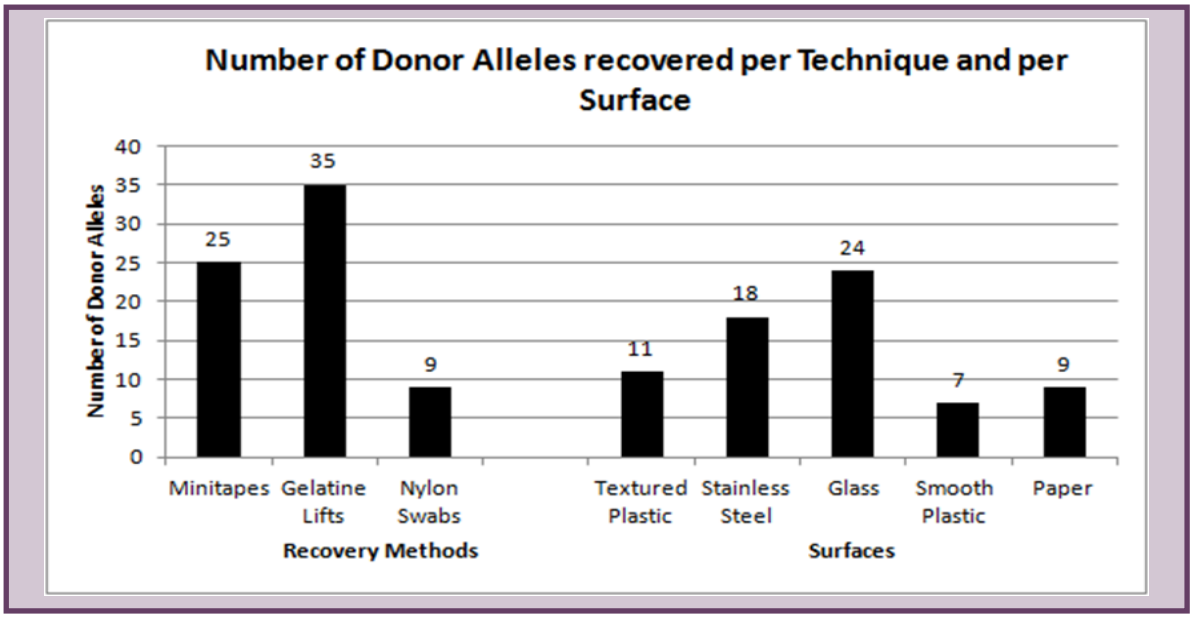

Figure 2: Number of donor specific alleles recovered per technique and per surface

Some of the donor's alleles may have resulted from being an increased stutter peak due to being one base pair less than a prominent spurious peak and being close to the peak amplitude threshold. For the donor specific alleles, 21 profiles resulted in *no profile* yet when considering the shared alleles, 17 *no profiles* were produced.

The gelatine lifts however recovered more of the donor alleles with 35 out of a possible 149 being recovered from over 15 profiles (figure 2), whereas the minitapes displayed 25 alleles and the nylon swabs 9 alleles. There is a considerable loss of DNA between the expected amount of alleles and those observed. This could be attributed to poor recovery, little available cellular material or issues with extraction. Shared alleles were also observed over all profiles but were expected, as there was a considerable overlap between the reference samples of the researcher and both participants which caused difficulties during interpretation.

The number of recovered donor alleles confirms the quantification results; gelatine lifts recovered the most, and nylon swabs recovered the least. This again may have resulted due to the adhesion properties of the gelatine lifts. When considering the surface type, the gelatine lifts had more effective recovery from the glass and paper surfaces whereas the minitapes recovered the most donor DNA from the stainless steel and textured plastic. This contradicts the quantification as the gelatine lifts displayed higher levels of DNA than the minitapes. The gelatine lifts however did result in the greatest range of peak heights (52-1800 RFU) showing elevated but sporadic recovery, which was previously displayed in the quantification results. Surprisingly, the minitapes resulted in the lowest range peaks heights (52-880 RFU) of all the methods, although the nylon swabs only resulted in one profile with substantial peak heights (1200 RFU) but was determined to be considerably contaminated from the researcher. Such contamination was also identified in the gelatine lift profiles in regards to the researcher and spurious alleles to a greater degree than both the swabs and minitapes. In some instances, for all of the methods, the amount of contaminating alleles dominated the profiles not only by the amount of alleles present but also in regards to peak heights. As the negative controls displayed no DNA it can be determined that the contamination did not occur during the extraction or amplification, but may have originated during deposition, storage or collection stages.

When looking at the surfaces specifically, the glass surface resulted in the most donor alleles being recovered along with having the greatest peak heights of all surfaces, as seen in Kumar et al (2015) and Tozzo et al's (2015) work. In general, the hard non-porous surfaces provided the better results not only with the amount of donor DNA but also peak heights. The smooth plastic however is non-porous yet is not a hard surface as it is relatively malleable which is potentially problematic when retaining cellular

material as it may remain upon the surface and be easily dislodged or transferred with movement (Verdon et al 2013; Goray et al, 2010). This would explain not only the least amount of detectable DNA but also the least amount of donor DNA. The porous substrate, paper, provided limited recovery of any material as displayed in the quantity of donor alleles and the peak heights which were the lowest of all the surfaces. Paper has previously shown to be a considerably challenging surface for recovering many forms of DNA, not just touch DNA (Thamnurak et al, 2011; Balough et al, 2003).

A possible contribution to the poor profile quality may be from the inclusion of hand washing. Phipps et al (2007) demonstrated that there is a significant difference between the DNA yield and profile quality when the hands are washed or unwashed. The washing process removes DNA containing material such as skin cells and sweat (Meakin et al, 2013) leaving the hands devoid of moisture. Due to this removal, a time lapse is required for such materials to regenerate. Lowe et al (2002) deemed that a 15 minute period can be sufficient time lapse for some people but was irrelevant after 2 hours. Here the study only used a 10 minute period which may have been insufficient for adequate renewal. This would have affected the deposition for the textured plastic and stainless steel, as only the index finger was used repeatedly. However this was rectified for the remaining surfaces as the middle and index fingers were included in sampling, resulting in fresher samples. The paper surface may have also been affected by this as the glass, smooth plastic and paper were all deposited in the same time frame with the paper being last, and therefore the effect of limited renewal could have potentially been greater for the paper. Although the effect of the surfaces themselves should not be dismissed entirely.

4.4 Fingerprint Quality

Initial observations of the surfaces indicated that there were visible fingerprint traces on the glass and stainless steel for both the gelatine lifts and minitapes, but very little could be seen for the swabbed depletion series, signifying little residue left. When viewed under the Visual Spectral Comparator (VSC), the majority of the other surfaces also had limited residue remaining. This is illustrated in table 2.

Surface	Minitapes			Gelatine Lifts			Nylon Swabs		
	Control	Recovered	Change	Control	Recovered	Change	Control	Recovered	Change
Textured Plastic	2.0	1.4	0.6	2.5	1.0	1.5	1.4	0.0	1.4
Stainless Steel	2.0	1.8	0.2	2.5	1.8	0.7	2.3	0.0	2.3
Glass	3.1	2.2	0.9	3.1	1.2	1.9	2.8	0.0	2.8
Smooth Plastic	1.7	1.2	0.5	1.9	0.7	1.2	1.8	0.0	1.8
Paper	1.7	1.2	0.5	1.8	0.6	1.2	1.7	0.0	1.7
Average change			0.5			1.3			2

Table 2: Mean fingerprint scores for the control, recovered and the overall average (mean) change.

The nylon swabs completely eradicated the ridge detail of the fingerprints leaving little to no trace of residue. The only instance where detail was still present was when the swab did not pass through the entirety of the fingerprint. This could be attributed to the water from the swab washing away the secretions of the fingerprint. It may have been more beneficial to have used the swabs dry to lessen the damage to the ridge detail (Plaza et al, 2015, Oravcová, 2013).The gel lifts did display some alteration to

the fingerprint quality; however this was in the form of slight distortion to the ridge detail rather than removal of the ridges. This distortion may have resulted from ineffective brushing techniques, as over powdering the ridge detail on a smooth surface resulted in poor quality fingerprints. It may be expected that gelatine lifts would have higher fingerprint scores for the recovered samples compared to minitapes, as they are specifically tailored to recover fingerprints and are made from porous gelatine which can allow for the absorption of sebaceous and eccrine secretions, whereas minitapes are non-porous plastic, which can prevent the absorption of secretions. Minitapes did display some limited distortion but this was mainly due to the transference of ridge detail from other fingerprints within the depletion series when repeatedly used, causing overlapping ridges to be seen. The fingerprints on paper which were exposed to the minitapes were interpreted with care as the tapes adhesive side become saturated with paper fibres after the first initial use, preventing the remainder of the depletion series to be effectively exposed to the adhesion.

The reduction in recovered fingerprints compared to the control may be dependent upon the surface on which the fingerprints were deposited on. For example, the porous nature of paper allows for some of the ridge detail to be lost within the pores of the surfaces matrix. This was also displayed with the textured plastic as the ridge detail did not extend within the recesses. Issues also arose with developing the fingerprints on the smooth plastic. The smooth plastic first had to be mounted onto robust pieces of plastic in order for deposition to occur. This proved a limitation during the development as some of the basic yellow solution became trapped between the plastics hindering analysis. The fingerprints that were detectable were of a very poor quality and may relate back to malleability of the plastic material. The smooth, non-porous qualities of the glass and stainless steel samples were beneficial. These surfaces have been noted for their ability to provide high quality ridge detail (Van Oorschot et al, 2010; Pesaresi et al, 2003), and have been confirmed as being able to provide better quality marks in this study, as seen in table 2. Due to these surfaces also supplying higher amounts of donor DNA, it may suggest that there is a potential link between the fingerprint score and DNA profile quality. The grading system however was only conducted by one individual and can be subjective in its interpretation especially when there may only be small nuances between the details. A series of Wilcoxon tests ($\alpha = 0.05$) were conducted and displayed that there was a significant difference ($p<0.05$) between the control fingerprints and those exposed to the recovery methods, for all surfaces apart from smooth plastic which showed no significant difference ($p>0.05$). This could be attributed to both the control and recovered fingerprint on smooth being of a low quality and influenced by the basic yellow solution obstructing detail.

5 Conclusion

The purpose of this study was to determine if it was possible to recover DNA from a fingerprint while keeping the ridge detail intact. From the recovery methods used, only the minitapes and gelatine lifts left any ridge detail that could be analysed albeit slightly altered. The nylon swabs removed all traces of the fingerprint from all surfaces. Although some of the methods left sufficient fingerprint detail for comparative purposes, there was a significant difference ($p<0.05$) between the controls and the recovered fingerprints for all recovery methods on all surfaces apart from smooth plastic. In terms of DNA recovery the minitapes and gelatine lifts displayed more affinity for DNA recovery than the nylon swabs in both the amount of DNA recovered and the quality of the profiles produced. In addition to this, the gelatine lifts also displayed a significant difference ($p<0.05$) when compared to the other methods, indicating greater propensity for collecting DNA, however they were more susceptible to contamination. This study has highlighted the issues associated with the use of trace DNA from fingerprints and provides a starting point for further research in recovery methods.

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