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TECHNICAL NOTE

CRIMINALISTICS

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Applicability of DNA Analysis on Adhesive Tape in Forensic Casework

ABSTRACT: Adhesive tape is commonly used in crimes and is often the subject of forensic evaluation. DNA analysis of adhesive tape can provide DNA profiles of suspects. The object of this study was to evaluate the applicability of DNA analysis on adhesive tape samples in forensic casework. We retrospectively reviewed all cases involving adhesive tape or similar items received by our institute for DNA analysis during the past 11 years. From 100 forensic cases reviewed, 150 adhesive tape samples were examined. A total of 98 DNA profiles were obtained from these samples. Sixty-two of the profiles provided feasible case-relevant information. In conclusion, DNA profiling of adhesive tape samples can be useful in a variety of forensic cases.

KEYWORDS: forensic science, adhesive tape, DNA analysis, forensic casework, immobilization, gagging

Adhesive tape in its various available forms is commonly used in crimes. Adhesive tape provides broad application possibilities. It can be used as a means to immobilize or silence human beings (as in immobilization or gagging), as a tool for burglary, for use in wrapping drug packets, preparing mechanical or electronic gadgets, explosive devices or simply for wrapping any desired object (1–4).

DNA analysis of adhesive tape can provide DNA profiles of potential suspects. Previous studies have shown that DNA can be found on adhesive tape or similar items. Hall and Fairley (5) and Torre and Gino (6) proved that DNA can be retrieved from adhesive tape samples used to secure gunshot residue. Their analysis concluded that the principle of DNA profiling from adhesive tape is based on adherence of epithelial cells containing nuclei as the source of DNA. Zamir et al. (7) were able to perform DNA profiling of adhesive tape samples used for taking fingerprints. The possibility of using adhesive tape to secure biological samples at crime scenes, for example from the inside of gloves or the surface of weapons, has been demonstrated (8–10). However, to our knowledge, no authors have performed DNA analysis on adhesive tape samples that were originally used in committing the crime. Therefore, the purpose of this study was to evaluate the applicability of DNA analysis to adhesive tape samples used by perpetrators in actual forensic cases.

Methods and Materials

Case Analysis

All cases involving adhesive tape or similar items (stickers on envelopes, sticky seals of envelopes) analyzed by the Institute of Forensic Medicine in Bern for DNA profiling during the period 1999–2010 were retrospectively reviewed.

Cases were classified based on the type of crime in which the tape was used. The numbers of adhesive tape samples derived from these cases were registered, and the number of DNA profiles obtained from the samples was recorded.

The DNA profiles obtained were classified as complete or incomplete single male profiles, complete or incomplete single female profiles, or complete or incomplete male-, female-, male/female-mixed profiles. Mixed profiles in which sex determination was not possible were also registered.

DNA profiles that were reported to the Swiss national DNA database EDNAIS were checked for positive matches (Hit) with a suspect or sample previously registered in the database.

DNA Analysis

The outside and the end parts of adhesive tape samples were swabbed for DNA short tandem repeat analysis using single cotton swabs with sterile distilled water as the solvent. The end parts of adhesive tape samples were cut into 1-cm-large pieces and put into Prep lysis buffer (L13).

DNA was isolated from the adhesive tape ends and cotton swabs using the Invitrogen iPrep™ Purification Instrument and the iPrep™ Charge Switch® Forensic Kit (Invitrogen Corporation, Carlsbad, CA) in accordance with the manufacturer's instructions. Samples were resuspended into a final volume of 75 μL.

Isolated DNA was quantified using the Quantifiler® Human DNA Quantification kit (Applied Biosystems, Carlsbad, CA) according to the manufacturer's protocols on an AB 7000 Sequence Detection System (Applied Biosystems). PCR amplifications were performed using the Amp*Fl*STR® SEfiler Plus™ amplification kit (Applied Biosystems), which simultaneously amplifies 11 tetranucleotide repeat STR loci (D3S1358, vWA, D15S539, D2S1338, D8S1179, SE33, D19S443, THO1, FGA, D21S11, and D18S51) and the Amelogenin locus. Some of the earlier samples

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of our data set were amplified with the Amp*Fl*STR® SGMPlus™ amplification kit (Applied Biosystems), which essentially amplifies 10 of the 11 STR loci, SE33 being excluded. Each amplification was carried out with 10 μL of the supplied reaction mix and 5 μL of the primer set. Approximately 1 ng of DNA and purified water was added to achieve a final amplification volume of 25 μL. Cycling was carried out on an AB 9700 Thermal Cycler (Applied Biosystems). Known DNA was used as positive control and DNA-free water as negative control. Cycling parameters were 95°C for 11 min followed by 30 cycles of 94°C for 20 sec, 59°C for 2 min, 72°C for 1 min, and a final extension step of 60°C for 60 min.

Electrophoretic analyses were carried out using a 3130XL Genetic Analyzer (Applied Biosystems) using the POP4 polymer and a 36-cm capillary array. For the analysis, 1 μL of the amplification product was mixed with 8.4 μL of HiDi Formamide (Applied Biosystems) and 0.6 μL of the GeneScan® 600LIZ size standard (Applied Biosystems). Electrophoresis parameters were set according to the manufacturer's recommended conditions (injection volume, 10 μL; time, 10 sec; voltage, 3000 V) and controlled by the Data Collection Software v3.0 (Applied Biosystems). Threshold for allele calling was set at 50 relative fluorescence units. The raw data were analyzed using the GeneMapper® ID Software v3.2 (Applied Biosystems).

Feasibility Definition of Obtained DNA Profiles

DNA profiles were defined as feasible when they fulfilled the requirements for submission to EDNAIS. Requirements of EDNAIS for single source DNA profiles were at least six confirmed loci that were analyzed in duplicate. Mixed DNA profiles were defined as feasible when there were only two contributors with at least eight confirmed loci for each contributor.

DNA profiles were defined as interpretable that did not fulfill the requirements for EDNAIS but could be compared to other profiles that we obtained (internal comparison).

Complete DNA profiles were defined as having confirmed alleles at all analyzable loci. Incomplete DNA profiles are defined as having confirmed alleles in a subset of all analyzable loci. Figure 1 shows an electropherogram of a complete DNA profile (all alleles labeled) from an adhesive tape sample which is suitable for storage and searching in EDNAIS. Figure 2 shows an

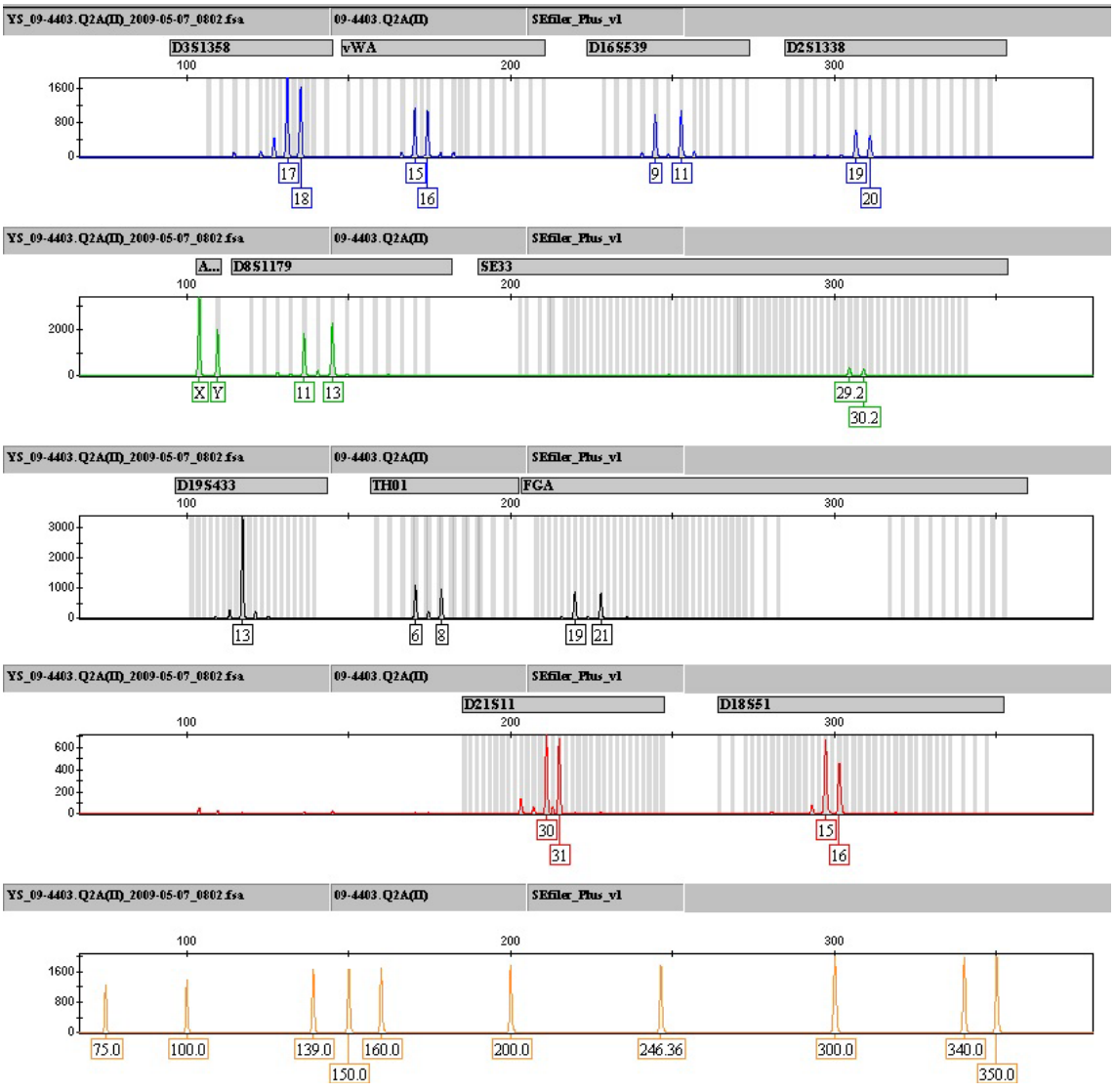

FIG. 1—*Complete profile, confirmed at all loci: DNA from adhesive tape amplified with AmpFlSTR® SEfiler Plus™ amplification kit.*

electropherogram of an incomplete DNA profile that is still feasible for EDNAIS (seven STR loci, the labeled alleles are the ones used for comparison).

Results

A total of 100 cases involving adhesive tape or similar items were received by our Institute for DNA profiling between 1999 and 2010.

Table 1 shows the different crimes and the corresponding numbers of forensic cases involving adhesive tape, as well as the numbers of adhesive tape samples retrieved from these cases. Additionally, the number of DNA profiles obtained from these samples and the feasibility of these profiles are depicted. Tables 2 and 3 show the gender distribution of mixed and single donor DNA profiles classified according to the crimes committed.

A total of 152 samples of tape were examined from 100 cases involving adhesive tape. One hundred and fifty of the samples were processed for DNA profiling and yielded a total of 98 DNA profiles. Two of the samples were not included because of a high number of other samples from the same cases that were analyzed prior and yielded feasible DNA profiles already.

Of the 98 DNA profiles obtained, eighty were male profiles, six were female profiles, and nine were mixed male/female profiles. The sex represented by three of the profiles could not be determined because of the degradation of the DNA.

Most cases and samples involved burglary cases, drug packets, and tools used with adhesive tape. DNA profiles were obtained from 74% of burglary cases and drug packets. These samples were mainly composed of incomplete mixed male profiles. DNA profiling from adhesive tape samples related to tools was successful for 35% of the samples (mainly complete male profiles). The obtained DNA profiles were feasible for 68% of the Burglary samples, 62% of the drug packets, and 36% of the tool samples.

Table 1 shows that only a few cases involved the use of adhesive tape as a gag or to immobilize (n = 17). In most of these of robberies, the victims' wrists and ankles were immobilized with adhesive tape. However, three cases involved homicide, with death

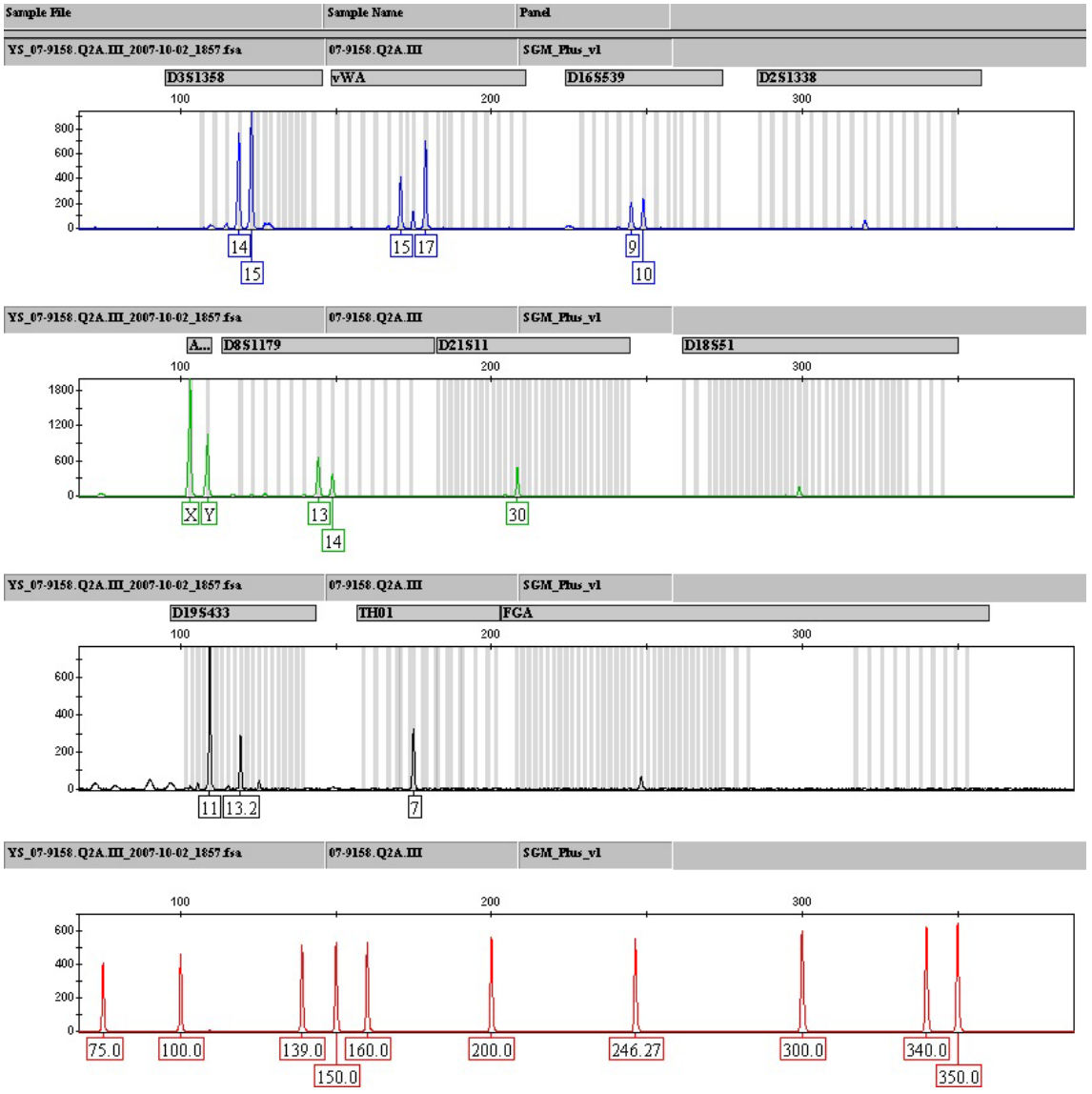

FIG. 2—*Incomplete profile: DNA from adhesive tape amplified with AmpFlSTR® SGMPlus™ amplification kit. Full typing of alleles were confirmed at only seven STR loci and is thus considered feasible for transmission to the Swiss national DNA database.*

TABLE 1—*Number and feasibility of obtained DNA profiles according to different forensic cases.*

Type of crime	Number of Cases	Number of Samples	Number of DNA Profiles Obtained from Samples	% of DNA Profiles Obtained from Samples	Samples Not Analyzed	Number of Feasible DNA Profiles	% of feasible DNA Profiles	Number of Reports to EDNAIS/Hits
Burglary	32	38	28	74	0	19	68	10/9
Drug packets	21	35	26	74	1	16	62	7/4
Tools	17	31	11	35	1	4	36	0
Immobilization	12	25	17	68	0	10	59	4/1
Envelope adhesive	7	7	4	57	0	4	100	3/1
Gagging	5	6	6	100	0	6	100	1/0
Stickers	4	5	1	20	0	1	100	0
Packages	2	5	5	100	0	2	40	2/0
Total	100	152	98	67 (mean)	2	62	71 (mean)	27/15

TABLE 2—*Gender distribution of the obtained mixed DNA profiles.*

Type of crime	Mixed Male Complete	Mixed Female Complete	Mixed Male/Female Complete	Mixed Male/Female Incomplete	Incomplete Mixed Males	Incomplete Mixed Females	Complete Mixed Sex Undetermined	Incomplete Mixed Sex Undetermined
Burglary	3	–	–	1	17	–	–	1
Drug packets	4	–	–	2	19	–	–	1
Tools	4	–	–	–	4	–	–	–
Immobilization	1	–	1	2	8	1	1	–
Envelope adhesive	2	–	–	–	1	–	–	–
Gagging	1	–	1	–	1	–	–	–
Stickers	–	–	–	–	1	–	–	–
Packages	–	1	–	2	1	–	–	–
Total = 81	15	1	2	7	52	1	1	2

TABLE 3—*Gender distribution of the obtained single donor DNA profiles.*

Type of Crime	Single Male Complete	Single Male Incomplete	Single Female Complete	Single Female Incomplete
Burglary	5	1	–	–
Drug packets	–	–	–	–
Tools	1	2	–	–
Immobilization	1	1	1	–
Envelope adhesive	1	–	–	–
Gagging	–	–	3	–
Stickers	–	–	–	–
Packages	–	1	–	–
Total = 17	8	5	4	0

caused by suffocation through gagging. In these cases, the adhesive tape was used to gag and immobilize the victims. In two cases, the perpetrator sexually assaulted women and attempted to gag them with adhesive tape. Feasible DNA profiles were obtained from all tape samples derived from cases involving gagging. Three mixed DNA profiles and three single DNA profiles were identified (Tables 2 and 3). The single profiles all matched the victims. The mixed profiles presented the victims' DNA as the major component, and the remaining DNA was mainly incomplete or too complex to interpret.

We successfully obtained DNA profiles from 68% of the immobilization case samples analyzed, with 59% of the samples presenting feasible profiles (Table 1). Most of the profiles obtained were mixed incomplete male profiles (Table 2). Of the 12 immobilization victims, six were men and six were women. A DNA profile could not be obtained in only one case. All perpetrators accused of committing the immobilizations were men. The primary DNA profiles obtained from the immobilization samples with mixed profiles were those of the victims, and the remaining DNA was mainly incomplete or too complex to interpret. The single DNA profiles obtained from immobilization samples all matched the victims.

Four feasible DNA profiles (57%) were obtained from the adhesive seal parts of seven envelopes (one sample per envelope) (Table 1).

Five samples were analyzed from four stickers with adhesive structures that were placed on envelopes. A feasible DNA profile was obtained from only one sample (Table 1).

Five samples were analyzed from two packages with stolen goods that were wrapped with adhesive tape. Only two feasible DNA profiles were obtained from these samples (Table 1).

Table 1 shows that 27 of 62 interpretable DNA profiles were reported to EDNAIS. Fifteen of the 27 reported DNA profiles represented Hits in the database (nine person Hits and six trace Hits). Ten DNA profiles obtained from the burglary samples displayed nine Hits in the database (six person Hits, three trace Hits). Seven of the reported DNA profiles from drug packet cases matched four Hits in the database (three person Hits and one trace Hit). One trace Hit was identified in both the group of four reported DNA profiles from immobilization cases and the three reported DNA profiles from cases with sticky seal parts of envelopes.

Only 27 (of 62 total feasible profiles) were reported to EDNAIS. The reason for this discrepancy is that several samples of adhesive tape were analyzed from the same case and multiple DNA profiles were obtained, but not all of the profiles were reported because they belonged to the same case. Additionally, those DNA profiles that corresponded to the victims were not reported to EDNAIS.

Two of the DNA profiles obtained from burglary cases were directly compared with DNA profiles from suspects in these cases. The DNA profiling of the suspects was also performed at our institute (local comparison). These comparisons resulted in one positive person match.

Discussion

Our data indicate that DNA profiling of adhesive tape samples that were used to commit crimes is possible in a variety of forensic cases. Our results confirm previous studies that successfully analyzed DNA from adhesive tapes. However, none of the previous studies examined samples derived from adhesive tape used in actual forensic cases. The previous studies analyzed adhesive tape samples derived from stubs used to secure gunshot residue from the skin, adhesive tape used for securing fingerprints, or tape used to secure microsamples from objects with presumptive biological samples. DNA profiling from these types of adhesive tape samples was successful in most of the analyzed samples (1–5).

We were able to obtain DNA profiles from more than half of our analyzed samples. This shows that adhesive tape samples derived from real forensic cases are potentially useful for DNA profiling. There are several possible reasons why DNA could not be detected from some samples. First, the perpetrator may have worn gloves while handling the tape and would thus not have deposited any skin cells. However, sometimes the teeth are used to rip a piece of tape from the roll, providing the possibility for detecting DNA from the perpetrator's saliva. Sticky seals of envelopes that have been licked can also contain DNA from saliva. Unsuccessful DNA profiling may also be caused by exposure of the samples to moisture or other environmental conditions causing degradation by bacterial contamination (11).

Dozens of different commercial adhesive tapes are available in Switzerland and this number rises to several thousand worldwide (1). It should be noted that different kinds of tape may display different applicability for DNA profiling. Barash et al. (8) tested four different kinds of adhesive tape and found that only one was suitable for proper DNA profiling. To our knowledge, apart from the work of Barash, no systematic study of the applicability of different kinds of adhesive tape for DNA profiling has been performed. In this study, we had no information about the particular types of tape provided by the criminal technicians who collected them from the crime scenes. Therefore, we cannot provide specific information about the applicability of different kinds of tape for DNA profiling. However, we observed that one important factor involved in the applicability of tape for DNA profiling is likely the amount of glue contained in the tape. Different types of adhesive tape contain different amounts of glue. Although tapes that contain high amounts of glue technically complicate the process of DNA profiling, tapes that contain less glue trap fewer epidermal cells when contacting human skin. Because the basic principle of deriving DNA from adhesive tape lies in the adherence of DNA-containing epidermal cells to the tape, this attribute of tape with lower glue content could handicap DNA profiling (12). To our knowledge, no research has been performed to investigate the effect of the amount of glue on the success of DNA profiling. Further research is necessary on this topic to determine the relative importance of glue content. Nevertheless, it is also possible to find DNA on the nonadhesive structures of the tape.

Our data show that DNA profiles obtained from adhesive tape samples are not always feasible. Most of the profiles identified were mixed profiles. Some of these profiles were incomplete or very complex and were therefore not suitable for a local comparison with other profiles or reporting to a DNA database. In these cases, the profiles were classified as not feasible. However, most of the identified DNA profiles were classified as feasible. The different types of crimes that used adhesive tape yielded different feasibility rates of the DNA profiles. However, the small number of cases examined for the different types of crimes did not allow for statistical interpretation.

Mixed DNA profiles were obtained from almost all samples derived from gagging and immobilization. However, DNA profiles detected from the mixed profiles were largely composed of the DNA of the victims. In most cases, the other components of the profiles were not suitable for further interpretation. Therefore, we conclude that DNA profiling of samples from adhesive tape used to assault people as a means of gagging and immobilization is generally not applicable for DNA profile identification of the suspected attacker. This finding may be due to the overload of the victims' cells masking the contribution of the perpetrator to the sample.

Most of the DNA profiles identified were male profiles. This finding is consistent with current Swiss criminal statistics which document that most crimes (over 80%) involving adhesive tape (burglary, drug offenses, and assault) are committed by men (13).

DNA profiling is only meaningful if an identified profile can be compared to other profiles. DNA profiles obtained in our department can be either reported to EDNAIS or be compared to other profiles that are related to a relevant case and were obtained in our department (local comparison). EDNAIS registers DNA profiles of crime case-relevant biological traces, unclear crime cases, and DNA profiles of suspects and perpetrators obtained from buccal swabs. A positive Hit in the EDNAIS database for each reported DNA profile obtained from the samples involving adhesive tape indicates a relatively high success rate. However, it is important to note that a positive Hit in the DNA database does not always result in a match to a suspect because Hits can also match DNA profiles performed from trace evidence retrieved from crime scenes and not from a person. However, such information can still be useful for casework.

Conclusion

DNA profiling of adhesive tape samples is possible and useful in a variety of forensic cases. However, it is important to note that, because of the nature of the adhesive tape, the potential for very few cells and possible degradation of the sample, not all profiles obtained can be interpreted. In some cases, such as immobilization or gagging, DNA profiling is not applicable owing to the overload of the victim's cells masking the perpetrator's contribution to the sample.

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