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Evaluating the prevalence of DNA mixtures found in fingernail samples from victims and suspects in homicide cases

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ABSTRACT

An important aspect of homicide investigations is the identification of the persons that had the last contact with the victim prior to death. Violent crimes are frequently characterized by a struggle between the victim and the perpetrator where biological material can be expected to be exchanged between them.

Forensic DNA typing enables the generation of genetic profiles by extraction and amplification of cellular material found under fingernails. The evidential value of these samples may be critical if the secondary contributor found in a DNA mixture, can be matched with a potential suspect, or through a DNA database search.

The amount of biological material transferred under the fingernails during "casual" activities is not sufficient to genotype reportable mixtures. This may not be the case with homicide victims that may have struggled and died under violent circumstances.

The aim of this study was to evaluate the prevalence of DNA mixtures found under the fingernails of both victims and suspected perpetrators of violent deaths.

We present a retrospective study of 137 DNA profiles genotyped from fingernail samples of homicide victims and suspects, collected at the Israeli National Center of Forensic Medicine. The majority of the samples produced single source profiles (n = 107, 78%) that matched those of the donor's. DNA mixtures (n = 30, 22%) were found in increased frequency among victims (n = 25/100, 25%) compared to suspects (n = 5/37, 13.5%). Mixtures were sub-divided into high level (n = 15, 50%), low level (n = 9, 30%) and residual (n = 6, 20%), according to the number of the foreign contributors' alleles. Thus, this distinctive group of homicide victims was found to express both elevated frequency of DNA mixtures together with highly informative value of the secondary foreign profiles, as compared to other studied populations. These findings support an important aspect for the criminal investigation in murder cases, where a struggle may have ensued and the identification of an additional profile found in a mixture from a fingernail sample may point to a possible perpetrator of the crime.

1. Introduction

Finding foreign biological material under the fingernails of a victim and/or a suspect in a homicide case can be a valuable evidence in a criminal investigation [1,2]. A DNA mixture originating from the donor's cells combined with a secondary source implies that physical contact occurred, in which biological material was transferred between these individuals [3–7].

Recent studies have shown that even though casual physical activities may leave traces of biological material under the fingernails, the background level of this cellular debris is not usually sufficient to produce detectable DNA mixtures in the majority of samples [8,9]. Most DNA profiles (80%) originating from swab samples taken from under the fingernails of individuals of the general population are characterized as a single source, typed only by the donors' cells [8]. In some cases low level DNA mixtures can be found under the fingernails of volunteers of the general population. Similar results are presented by Cerri et al. [9] after characterization of fingernail swabs collected from individuals who died in non-violent death.

The study of Dowlman et al. [10] which tested the effect of cohabiting interactions on DNA mixtures, presented higher prevalence of DNA mixtures from fingernail samples of volunteers compared to general population volunteers.

These studies demonstrate that the foreign biological material accumulated under the fingernails during every day activities, is usually not sufficient to allow detection of high level DNA mixtures. In fact, finding a high level of DNA mixture under one's fingernails is a relatively rare occurrence and is not correlated with "casual" everyday activities [10].

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In contrast to daily activity, violent crimes can often be associated with intense physical contact between victim and perpetrator, due to struggling at the scene of the crime. The assumed struggle is expected to facilitate the transference of biological materials between two (or more), individuals [1–7]. As a result of the criminal act, blood, semen, epithelial cells or any other biological material is transferred from the perpetrator to the victim's body. This material would be expected to remain on the victim's body, since the fatal consequences of the event precluded him from disposing of this evidence. Hence, fingernail samples are routinely collected during autopsies of homicide victims at the Israel National Center of Forensic Medicine. Suspects may also be sampled if their arrest takes place a short time after the assault, usually, within 24 h.

In criminal cases investigated between the years 2005 and 2010, dozens of fingernail swab samples were routinely collected from murder victims and/or suspects for further DNA analysis by the Forensic Biology Laboratory of the National Center of Forensic Medicine.

The aim of this study is to evaluate the occurrence of DNA mixtures from under the fingernails of murder victims, a distinctive population in which DNA mixtures would be expected to be more prevalent.

2. Materials and methods

2.1. Data collection

The data presented in this study was retrospectively analyzed from 137 DNA profiles genotyped from fingernail samples collected at the Israeli National Center of Forensic Medicine between 2005 and 2010. The majority of the profiles originated from homicide victims ($n = 100$), the remainder from suspects ($n = 37$) (Fig. 1). The cases included in the study were only those where reportable DNA profiles were achieved, being either single source or a mixture. Those containing DNA mixtures were limited to those with two contributors since peak height ratio (PHR) analysis is not possible for three or more contributors.

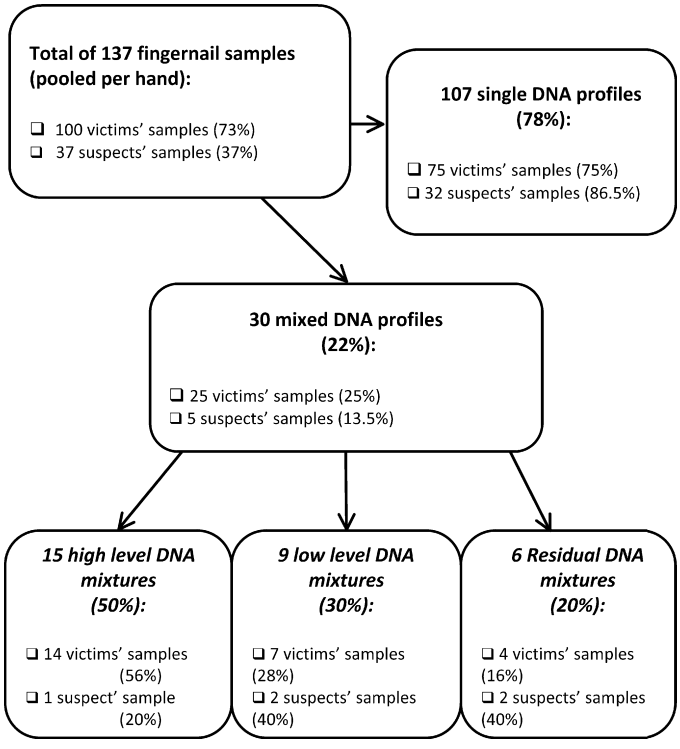

Fig. 1. Distribution of samples and genetic profile types generated from victims and suspects of homicide cases fingernails.

The primary criteria of which victim's fingernails were sampled was determined by the medical examiner, based on the circumstances known at the time of the autopsy. In general, gunshot victims were the only type of homicide cases that were disqualified for fingernail examination, under the assumption that a physical struggle may not have taken place before the victim's death.

2.2. Sample collection

The majority of the bodies submitted to the mortuary had their hands protected by bags. Samples from a victim's fingernails were taken at the beginning of the external examination of the body by one of the following techniques (according to the methods in use at the time): clipping was primarily used from 2005 to 2007, substituted later by fingernail swabbing with a slightly wet cotton swab due to the practical aspects: easier collection of the debris from all 5 fingers on a single swab promote an easier DNA extraction, without the need of pre-wash stage which is carried out on nail clippings. According to the Biology Lab procedures, the swabs were dried for 24 h prior to storage (−20 °C).

Blood samples were routinely taken from all victims during the autopsy to use as a reference sample.

The debris collected from under five fingernails from each hand was referred to as a single, independent sample.

Samples from suspects were collected, either as clippings, or by swabbing of the fingernails (as described above). For suspects, buccal swabs were taken to serve as a reference sample.

2.3. DNA extraction and quantification

Both types of fingernail samples, clippings or swabs were extracted using Chelex-100 procedure [11]. The primary wash of the fingernail clippings was carried out with double distilled, UV-irradiated water, for 30 min at 37 °C. Only washing liquid served for the DNA extraction. For DNA extractions performed between the years 2005 and 2008 quantification was carried out using the QuantiFiler Human DNA Quantification kit (Applied Biosystems, USA). DUO QuantiFiler was employed on samples extracted from 2009 onwards. Real-time PCR was performed on an ABI 7500 Sequence Detection System according to the manufacturer's protocols.

2.4. SGM-Plus PCR amplification kit

Samples were amplified using the AMPFlSTR SGM Plus kit (cat no. 4307133 Applied Biosystems, USA). The optimal DNA amount for samples was 1.5 ng, according to our lab's internal validation sensitivity test. Each DNA sample was amplified in a total reaction volume of 25 μl, on a 9700 thermal cycler (Applied Biosystems, USA) following standard PCR conditions as recommended by the manufacturer. A positive PCR control (AMPFlSTR control DNA 007) and a negative control (no DNA) were included in each set of amplifications.

2.5. Capillary electrophoresis

A loading mix was prepared with 10 μl Hi-Di formamide (Applied Biosystems, USA) and 0.5 μl GeneScan 500 ROX size standard (P/N 401734 Applied Biosystems, USA). Loading mix was added to 1.1 μl of PCR product and analyzed on 96 well reaction plates (Applied Biosystems, USA). Duplicate allelic ladder samples (1.1 μl) were included in each run. Samples were denatured at 95 °C for 3 min before being run on either ABI's 3100 or 3130xl Genetic Analyzers (Applied Biosystems, USA).