

Evaluation of DNA Recovery from Fingernails Post-Hair Washing

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Introduction

Historically, DNA evidence has primarily been used to address questions related to the source of the DNA and help the factfinder answer the “who?” question. However, advances in the sensitivity of analysis have shifted lawyers’ questions at trial to *how* the DNA got to the crime scene. Questions concerning activity level analysis have caused a need to focus on the quality of profiles under various conditions associated with an activity rather than the mere recovery of DNA. The need for empirical data focused on the quality of DNA profiles in practical conditions is highlighted in current literature. One area specifically understudied is how hygienic activities affect persistence and prevalence of DNA.

Fingernail evidence may raise questions regarding physical contact. Understanding background levels of foreign DNA is therefore essential for activity-level interpretation of evidence, particularly when evaluating the effects of common hygienic activities on both self and foreign DNA.

Sample Collection

All samples were collected according to the Institutional Review Board (IRB) approval [IRB-2024-343].

Participants: Twelve adult volunteers were recruited for this study. Each submitted buccal swabs as reference samples to assess self contribution to profiles from their nails.

Study Design: Volunteers self-sampled swabs from underneath their fingernails before and after three categorized hygiene events as they habitually perform.

- Showering only
- Hair washing only
- Showering with hair washing

Volunteers then answered survey questions related to time elapsed since their last shower, handwashing, hair length, nail length, and cohabitant information.

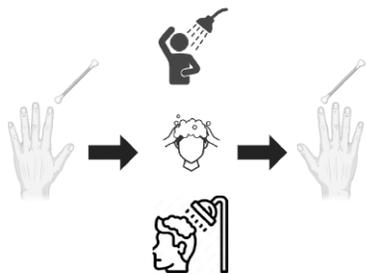
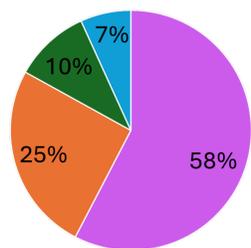


Figure 1: Representation of pre and post event sample collection by volunteers.

RESULTS & DISCUSSION

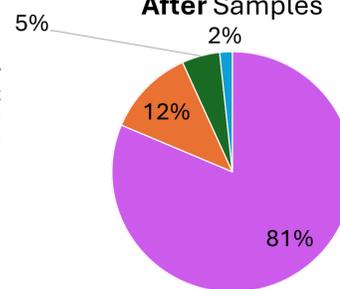
Foreign Allele Distribution in Before Samples



■ 0 Alleles ■ 1 to 3 Alleles ■ 4 to 6 Alleles ■ 7+ Alleles

Figure 2: Categorized number of foreign alleles in pre-event samples (n=59) representing background foreign DNA with majority having **no foreign alleles** (n=34), **1 to 3 foreign alleles** (n=15), **4 to 6 foreign alleles** (n=6), and **7 or more foreign alleles** (n=4).

Foreign Allele Distribution in After Samples



■ 0 Alleles ■ 1 to 3 Alleles ■ 4 to 6 Alleles ■ 7+ Alleles

Figure 3: Categorized number of foreign alleles in post-event samples (n=59) with an increase in the number of samples having **no foreign alleles** (n=48), **1 to 3 foreign alleles** (n=7), **4 to 6 foreign alleles** (n=3) and **11 foreign alleles** (n=1)

- All foreign profiles were low-level, partial profiles consisting of 16 alleles or less. The highest foreign donor contribution across the study was 31%.
- Foreign DNA was detected in 42% of pre-event fingernail samples, most commonly consisting of one to three foreign alleles.
- Following showering and/or hair-washing events, both the proportion of samples containing foreign DNA and the number of foreign alleles decreased; when foreign DNA persisted, it was typically low-level, consisting of few foreign alleles.
- Hair washing and showering events were effective at reducing both self and foreign DNA presence
- There were four instances where the after hand contained more foreign alleles than the before hand, with one event representing an extreme outlier. This may be an artifact of sampling strategy using alternating hands as before and after.
- These counts of foreign alleles compare favorably with previous work by [1-3], even though the DNA profiling kit used is different. The increase in proportion of samples with foreign alleles may be a result increased sensitivity in kit technology, although foreign profile quality is similar.

Volunteer (self) Profile Completeness

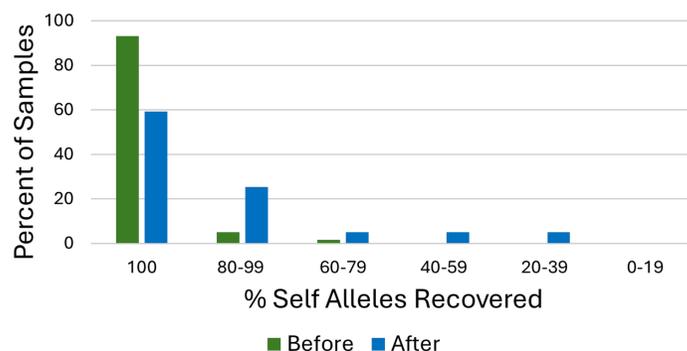


Figure 4: Profile completeness of self DNA contributions from pre-event samples and post-event samples (n=59 events). Overall, there is a decrease in the profile completeness of self contributing DNA from pre-event to post-event samples. All samples had presence of self DNA in both pre and post event samples.

Classification of Foreign Allele Change from Before to After Sample

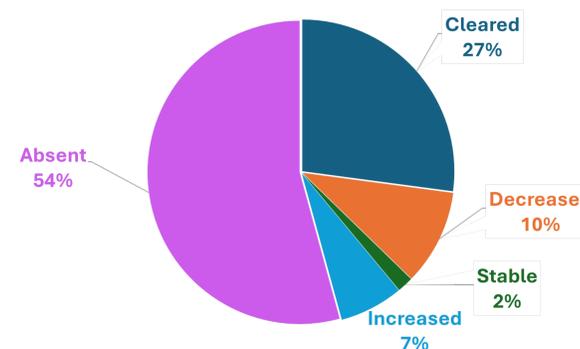


Figure 5: Distribution of foreign allele changes by event for 59 sample sets. Category counts are **ABSENT** (no foreign alleles in both pre and post event samples), **CLEARED** (all foreign alleles present in pre event are absent in post event), **DECREASED**, **STABLE** (same foreign alleles in pre and post event) and **INCREASED**

MATERIALS & METHODS

Sample Processing:

- Extraction: EZ1/EZ2 Investigator® Kit (Qiagen, Georgetown, MA)
- Quantitation: Quantiplex® Pro Kit (Qiagen,Georgetown, MA)
- Amplification: Investigator® 24plex QS Kit (0.5 ng target input) (Qiagen, Georgetown, MA)
- Capillary electrophoresis: Applied Biosystems 3500 Genetic Analyzer (Applied Biosystems, Carlsbad, CA)

Analysis and Interpretation:

- ArmedXpert™ version 3.1.14 used for allele calling and profile editing.
- STRmix® version 2.12: used for donor ratios and degradation assessment.

Foreign allele counts: 0 foreign alleles, 1 – 3 foreign alleles, 4 – 6 foreign alleles, 7+ foreign alleles

Before and after comparison: Pre-event samples were compared to corresponding post-event samples to assess changes in self-profile completeness and foreign allele counts. For each event, volunteers swabbed one hand before and the opposite hand after the hygiene activity. Events were repeated to account for natural variability in background foreign DNA, and the pre- and post-event assignment of dominant and non-dominant hands was alternated across events. DNA levels cannot be assumed to match across time or between hands.

CONCLUSIONS

- The proportion of samples with foreign DNA was higher than [1-3] (15-41%) but had similar number of foreign alleles when foreign DNA was present.
- Showering and hair washing, reduced or cleared foreign DNA under fingernails in the majority of samples, suggesting that these activities impact DNA persistence.
- These findings contribute to activity-level interpretation by characterizing background DNA, helping to contextualize low-level foreign DNA detected under fingernails following routine daily activities.

ACKNOWLEDGEMENTS

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