Detection of Bodily Fluids in Fingermarks Using Raman Hyperspectroscopy

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Abstract
Fingermarks are among the most common forms of forensic evidence, and their value extends beyond ridge pattern analysis to encompass chemical information such as drug residues, traces of explosives, personal care products, and others. Advances in analytical chemistry have greatly expanded the investigative potential of fingermarks, enabling the detection of these substances and linking individuals to specific activities or environments1. Such developments open new avenues for casework resolution and highlight the growing importance of chemical profiling in forensic practice. Among emerging techniques, Raman spectroscopy has received considerable attention in the forensic field due to its rapid, selective, and non-destructive nature.
This study highlights the application of Raman hyperspectroscopy for the detection of trace amounts of oral fluid (OF) within the fingermark (FM) matrix. The averaged spectra of natural FMs and OF-contaminated FMs exhibited characteristic vibrational bands associated with proteins, lipids, peptides, and nucleic acids, which originate from eccrine and sebaceous gland secretions. Notably, the phenylalanine band was more prominent in the OF-contaminated FMs. Principal component analysis (PCA) demonstrated separation between FMs and OF-contaminated FMs; however, partial overlap was observed, likely due to the contribution of endogenous fingermark components. To further enhance classification performance, three supervised machine learning algorithms were developed to distinguish between the two sample classes. Linear discriminant analysis (LDA) and k-nearest neighbors (KNN) achieved satisfactory discrimination based on cross validation test, whereas partial least squares discriminant analysis (PLS-DA) provided superior classification performance. Overall, this proof-of-concept study demonstrates the potential of Raman hyperspectroscopy combined with machine learning algorithms for the detection of traces oral fluid in fingermark samples.