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Investigating Touch DNA Success Rates in Vehicle Sites for Hit-and-Run Casework

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ABSTRACT: This study evaluated the effectiveness of Touch DNA recovery from four key vehicle contact points—steering wheel (SW), gear shift (GS), interior door handle (IDH), and exterior door handle (EDH)—in the context of hit-and-run forensic casework. 1769 samples were collected from 359 vehicles processed between 2020 and 2023. Statistically significant differences were observed in the quantity and quality of DNA recovered across these sites ($p < 0.05$). The steering wheel yielded the highest DNA success rates, followed by the gear shift, whereas the exterior and interior door handles demonstrated substantially lower recovery efficiency. These findings underscore the critical role of strategic sampling site selection in maximizing evidentiary outcomes. The results support prioritizing the steering wheel and gear shift as primary targets for DNA collection in vehicle-based investigations. The study highlights the practical utility of Touch DNA in linking individuals to vehicular crimes and calls for further research into alternative sampling techniques and contamination control measures to optimize forensic DNA recovery protocols in real-world hit-and-run scenarios.

Keywords: Forensic genetics; Forensic science; DNA profiling; Trace DNA; Touch DNA; DNA recovery; Hit-and-run casework; Vehicle DNA collection; Forensic casework; DNA success rate

1. Introduction

Touch DNA, also called trace DNA, represents a significant form of genetic material frequently encountered at crime scenes and serves as a powerful tool in forensic investigations for linking suspects to criminal activity [1–6]. It is typically transferred through incidental contact with commonly handled surfaces and objects such as tools, door handles, or clothing [2,7–9]. Unlike conventional biological evidence, Touch DNA poses specific challenges due to several factors affecting both the amount and quality of DNA that can be recovered. These include the physical nature of the surface material [10,11], environmental exposure conditions [12–14], and inconsistencies introduced by collection methods [10,11,15–18], particularly regarding the application of wetting agents or the number of adhesive lifts performed [19–25]. In addition, differences in DNA extraction and quantification procedures [2,4,12,26–30], risks of contamination, and variability in DNA shedding rates among individuals further complicate analysis [31–38].

The effectiveness of DNA recovery is strongly influenced by the sampling technique used. Research has consistently emphasized the importance of selecting appropriate tools—such as cotton swabs, nylon swabs, or adhesive tapes—based on the surface type [10,11]. Cotton and nylon swabs are generally more effective on smooth, non-porous surfaces like plastic or glass [10,20]. At the same time, adhesive-based tapelifting techniques are better suited for porous materials such as textiles [39–44]. Several recent developments have been introduced to improve DNA recovery from challenging substrates to overcome traditional methods' limitations. These include hybrid approaches using cotton and microFLOQ® swabs for direct amplification, microbial wet-vacuum systems, and the application of enhanced decontaminating agents [23,44–46]. Together, these innovations underscore the rapid advancement in forensic DNA

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sampling technologies. Moreover, the significant variability in Touch DNA yields depending on surface type and environmental exposure conditions highlights the necessity for tailored, site-specific collection strategies [47–50].

The integration of real casework findings with flexible forensic methodologies is crucial to adapting practices to evolving criminal patterns. This reinforces the need to embrace technological innovation and adaptive sampling techniques to address the demands of modern forensic science [51,52].

Conventional DNA extraction workflows, especially those based on silica column purification, are known to result in DNA loss, which can be particularly problematic when working with low-copy or degraded samples [1,53]. To address these limitations, direct amplification protocols—which bypass traditional extraction and quantification steps—have attracted interest for their ability to conserve sample material and streamline analysis in forensic workflows [17,22,54].

Between 2019 and 2021, the Biology and DNA Section at the General Department of Forensic Science and Criminology processed 6277 forensic cases, from which 14,552 DNA samples were collected [51]. Given the frequency with which vehicles are involved in criminal activity, they are often subjected to forensic DNA sampling. This study evaluates the success rates of Touch DNA recovery from four key sites within vehicles: the steering wheel, gear shift, interior door handle, and exterior door handle. Using casework samples from hit-and-run incidents handled by the Dubai Police, the goal is to determine which of these sites most consistently yields useful DNA profiles that can assist in identifying and linking suspects to vehicular crimes.

According to UAE Ministry of Interior statistics, the country recorded 4391 road accidents in 2023 (352 fatalities, 5568 injuries), with increases in 2024 to 4748 accidents, 384 fatalities, and 6032 injuries. With a population of around 10 million, this accident rate reflects a significant public safety challenge [55].

Although detailed national figures on hit-and-run incidents are limited, internal data from the Dubai Police suggest that hit-and-run cases represent a substantial portion of forensic vehicle investigations, underscoring the relevance of optimizing Touch DNA recovery in such contexts. This operational demand provided the foundation for the present study, which systematically evaluated forensic sampling strategies in large set of real-world hit-and-run cases, as described in Section 2.1.

2. Materials and Methods

2.1. DNA Recovery

This study systematically examined 359 vehicles linked to hit-and-run cases occurring between 2020 and 2023. DNA sampling targeted four key locations commonly relevant in vehicular forensic analysis: the entire steering wheel, the gear shift knob, and both the interior and exterior surfaces of the driver's door handle.

Copan cotton swabs (150C) were used for sample collection, selected for their effectiveness on smooth, non-porous surfaces [10]. Before use, the swabs were pre-moistened with approximately 100–150 µL of sterile distilled water, dispensed using a plastic spray bottle—a technique shown to enhance Touch DNA collection efficiency [2]. Swabbing was conducted using medium pressure, and swabs were rotated to maximize coverage of each sampling area.

Immediately after collection, all swabs were frozen to preserve the Touch DNA's stability and reduce the risk of degradation or contamination before laboratory processing [19]. This controlled sample collection and storage protocol was intended to maintain both the quality and quantity of recoverable DNA, ensuring reliability in the downstream DNA profiling and analytical phases.

2.2. DNA Extraction and Quantification

All collected samples were processed using the PrepFiler Express™ Forensic DNA Extraction Kit (Thermo Fisher Scientific, Waltham, MA, USA) with a Hamilton Automated Liquid Handler, strictly adhering to the manufacturer's recommended protocols. The entire swab head was used for each sample to maximize DNA yield, with a final elution volume of 50 µL.

DNA quantification was conducted using the Qiagen Investigator Quantiplex Pro Quantification Kit, integrated with the QuantStudio 5 Real-Time PCR system (qPCR) and analyzed using HID Real-Time PCR Analysis Software v1.3 (Thermo Fisher Scientific), in accordance with the prescribed guidelines.

2.3. Amplification, Electrophoresis, and Data Analysis

DNA amplification was performed using the GlobalFiler™ PCR Amplification Kit on an ABI GeneAmp® 9700 PCR System (Thermo Fisher Scientific), applying 29 amplification cycles per the manufacturer's protocol. The resulting

amplicons were subsequently separated and analyzed via capillary electrophoresis on the ABI 3500 Genetic Analyzer (Thermo Fisher Scientific).

For the analysis, each sample contained a reaction mixture comprising 1 µL of PCR product, 9.6 µL of Hi-Di™ formamide, and 0.4 µL of GeneScan™ 600 LIZ® Size Standard v2.0. Additionally, at least 1 µL of allelic ladder was included in each 96-well plate injection to ensure proper allele calling and calibration.

Capillary electrophoresis was carried out using a 36-cm capillary array filled with POP-4™ polymer (Life Technologies, Carlsbad, CA, USA), under standard injection conditions of 1.2 kV for 24 s. The output, which included short tandem repeat (STR) data, was analyzed using GeneMapper® ID-X Software Version 1.5, following the interpretation thresholds and guidelines defined for the GlobalFiler™ kit. A minimum detection threshold of 75 RFUs was applied to ensure analytical consistency.

To assess statistically significant differences in DNA yield and profile quality across sample sites, factorial analysis of variance (ANOVA) was performed using RStudio, while Microsoft Excel was used for supplementary data processing and visualization.

3. Results

3.1. Sample Collection and DNA Profile Recovery

1769 Touch DNA samples were collected from 359 vehicles involved in hit-and-run incidents between 2020 and 2023. Of these, 1436 samples were obtained from four pre-selected vehicle surfaces of forensic interest: the steering wheel (SW), gear shift (GS), interior door handle (IDH), and exterior door handle (EDH). Upon completion of DNA profiling, 970 of the samples (67.5%) yielded interpretable DNA profiles. A result was considered positive if the DNA profile exhibited either homozygous or heterozygous alleles across at least eight of the 13 CODIS core loci and met the statistical rarity threshold comparable to a single match within the NDIS database.

3.2. DNA Yield across Sampling Sites

Quantitative analysis of DNA concentration revealed statistically significant differences among the four sampled vehicle sites ($p < 0.05$). The highest mean DNA concentration was recovered from the steering wheel, which yielded an average of 0.56 ng/µL. The gear shift followed with an average of 0.19 ng/µL, while the interior and exterior door handles produced lower yields, with mean concentrations of 0.075 ng/µL and 0.027 ng/µL, respectively. These findings indicate that the steering wheel was the most productive site for Touch DNA recovery, both in quantity and consistency. When examining the rate of positive DNA profiles by location, the steering wheel again led with a 42% success rate. The gear shift at 28% followed this, the interior door handle at 19%, and the exterior door handle at 11%. These results support the conclusion that the steering wheel and gear shift are the most reliable targets for Touch DNA collection in vehicle-related forensic investigations (Figure 1).

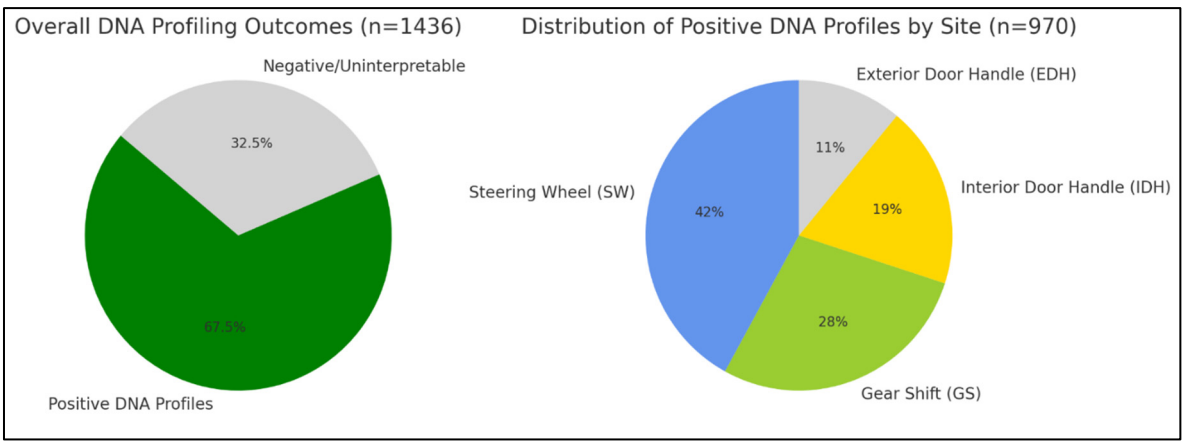

Figure 1. Distribution of Touch DNA recovery outcomes from vehicle sampling sites across 359 hit-and-run cases processed between 2020 and 2023. The left pie chart illustrates the overall success rate of DNA profiling from a total of 1436 samples collected from four vehicle sites: steering wheel (SW), gear shift (GS), interior door handle (IDH), and exterior door handle (EDH). Of these, 970 samples (67.5%) yielded interpretable DNA profiles. The right pie chart presents the distribution of those positive DNA profiles by sampling site, with the steering wheel contributing 42% of all successful profiles, followed by the gear shift (28%), interior door

handle (19%), and exterior door handle (11%). These findings emphasize the evidentiary value of the steering wheel and gear shift as primary sampling targets in vehicle-based forensic investigations.

3.3. Profile Types and Allelic Composition

In addition to variation in DNA yield, significant differences were observed in the types and complexity of DNA profiles recovered from each sampling site ($p < 0.05$). Full single (FS) and mixed (FM) DNA profiles were more commonly recovered from the steering wheel and gear shift. Conversely, the interior and exterior door handles were less likely to yield complete profiles and more frequently produced partial results with lower allelic content. The steering wheel generated the richest allelic data among the full mixed profiles, with an average of 109 alleles per profile. This was followed by the gear shift with 83 alleles, the interior door handle with 65 alleles, and the exterior door handle with 57 alleles.

Importantly, a clearly identifiable major contributor was observed in 92% of full mixed DNA profiles recovered from the steering wheel and 84% of those from the gear shift. In contrast, none of the full mixed profiles obtained from the interior or exterior door handles yielded a distinguishable major contributor. These findings further support the forensic value of the steering wheel and gear shift as primary targets—not only for higher DNA yields and richer allelic content, but also for producing profiles that are more likely to enable suspect identification through dominant contributor analysis (Figure 2).

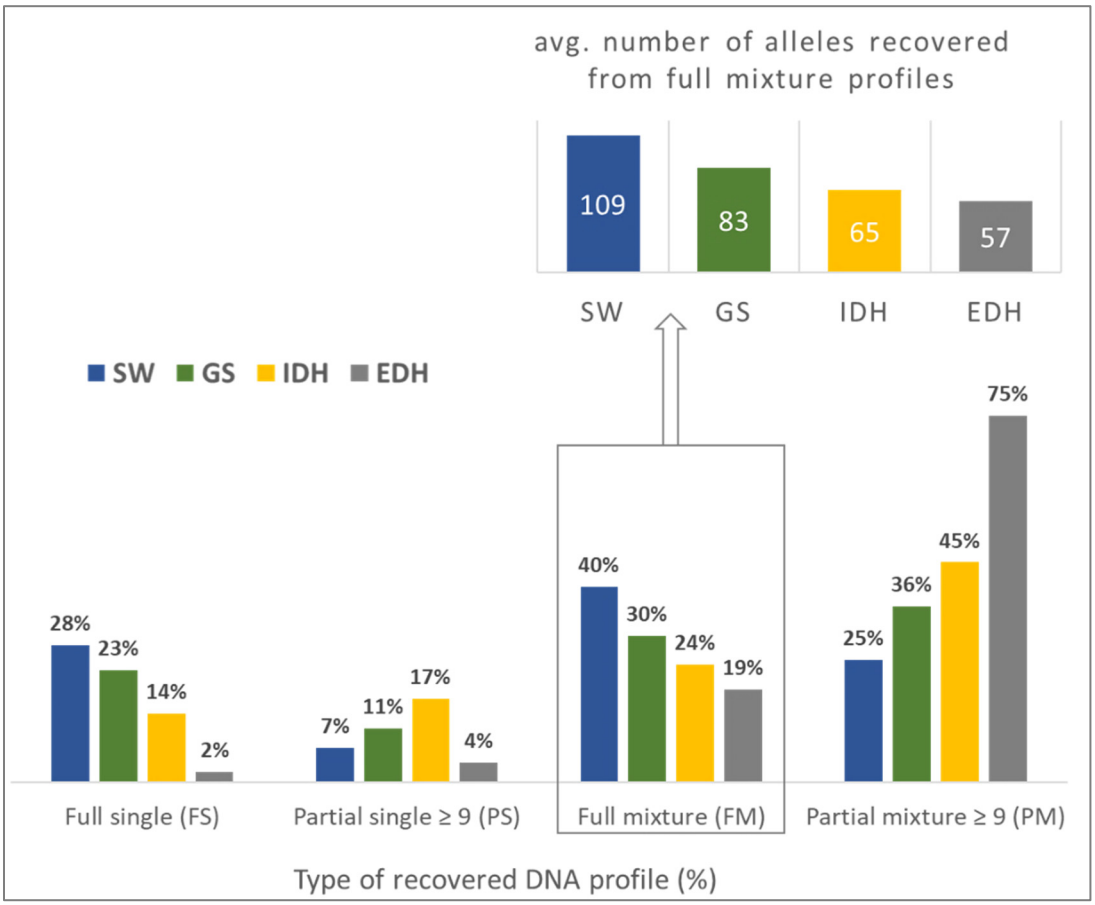

Figure 2. Comparative analysis of Touch DNA profile types obtained from 970 positive samples collected across four primary vehicle sampling sites: steering wheel (SW), gear shift (GS), interior door handle (IDH), and exterior door handle (EDH), from 359 hit-and-run case vehicles between 2020 and 2023. DNA profiles were categorized as full single (FS), full mixture (FM), partial single (PS), or partial mixture (PM), with partial profiles defined as those containing alleles in at least nine loci. The figure also presents the average number of alleles recovered from full mixed (FM) profiles by site: SW (109), GS (83), IDH (65), and EDH (57). The results indicate that the steering wheel and gear shift produced more complete and information-rich profiles. At the same time, the interior and exterior door handles yielded comparatively fewer alleles, suggesting lower evidentiary value.

3.4. Criteria for Interpretable DNA Profiles

A DNA profile was considered interpretable or positive if it met two main criteria:

(1) The profile included homozygous or heterozygous alleles across at least eight of the 13 CODIS core loci.

(2) The profile met the statistical rarity threshold, approximating the probability of a single match within the National DNA Index System (NDIS) database.

These criteria ensured that only high-quality, probative DNA profiles were considered in subsequent analysis.

4. Discussion

Steering wheels (SW) and gear shifts (GS) have emerged as the most effective sites for Touch DNA recovery in hit-and-run investigations, owing to their high success rates in yielding complete and interpretable DNA profiles [56]. These components are among the most frequently and directly contacted surfaces by drivers, substantially increasing the likelihood of consistent DNA deposition. Their forensic utility is further supported by operational findings, which confirm that driver-contact surfaces retain the most probative DNA even under variable environmental and casework conditions [57].

The results of this study reveal marked disparities in DNA recovery efficiency across the sampled vehicle sites. The steering wheel, for instance, produced an average DNA concentration of 0.56 ng/µL—approximately twenty times higher than that recovered from the exterior door handle (0.027 ng/µL)—and accounted for nearly four times the proportion of positive profiles (42% versus 11%). Such differences are not merely statistically significant; they are operationally consequential. The superior yield and profile quality associated with SW and GS sampling reinforce their status as strategic priority targets during the initial stages of evidence collection in vehicular forensic investigations. Prioritizing these surfaces enhances the likelihood of obtaining viable genetic profiles, thereby increasing the probability of successful suspect identification and evidentiary linkage.

While less effective than SW and GS, interior and exterior door handles (IDH and EDH) can still serve as secondary sampling sites. These handles may provide crucial DNA evidence, particularly in cases involving multiple suspects or when additional genetic information is needed. However, IDH and EDH are more prone to contamination, especially during vehicle handling, transportation, and post-incident processing. Contaminants from various individuals, such as investigators and first responders, may compromise the DNA samples. Therefore, their use requires rigorous contamination control measures to preserve sample integrity [33,34]. All interpretable DNA profiles obtained during this study were routinely screened against an internal elimination database containing reference profiles from forensic examiners, evidence handlers, and first responders. These cross-checks detected no matches between casework profiles and any individuals listed in the elimination records.

The EDH is especially vulnerable to DNA degradation due to its exposure to environmental elements. Exterior handles, often metallic, are susceptible to heat, humidity, and UV radiation, which can degrade DNA, particularly in hot climates like Dubai [2,10]. Environmental studies confirm that sunlight exposure results in progressive DNA degradation across multiple substrates, including vehicle metals and glass [58,59]. Notably, short tandem repeat (STR) profiles can sometimes still be generated even when quantitative PCR signals are lost. This highlights the need to employ quantification and amplification methods during analysis of compromised samples [59].

Similarly, interior surfaces such as the IDH, though somewhat protected, may also be affected by overheating, especially in vehicles left in direct sunlight. To mitigate this, vehicles should be transported to shaded or climate-controlled areas immediately following an incident to preserve DNA integrity. This highlights the need for specialized forensic teams trained in handling vehicles post-incident. Proper protocols, including protective gear and sterile tools, along with swift transportation to controlled environments, will help minimize contamination and degradation, ensuring the recovery of high-quality DNA for forensic analysis [2,36].

Beyond environmental considerations, the efficiency of Touch DNA recovery is also influenced by the physical characteristics of the substrate and the type of collection tool used. Surfaces like metal or plastic may retain DNA differently than porous substrates, and the recovery efficiency is often dictated by the compatibility of swabs with specific surface types [10]. Comparative studies have shown that collection efficiency varies significantly across swab types. In recovering low amounts of DNA from vehicle surfaces like the gear shift and steering wheel, such as PurFlock® outperform traditional cotton or FLOQ swabs in recovering low amounts of DNA from vehicle surfaces [60]. Adoption of optimized swabbing tools may further enhance success rates in real-world forensic settings.

Recent investigations have also demonstrated that vehicle components such as driver's seats or headrests may yield useful DNA under certain conditions, particularly in warm climates where skin contact is maximized due to lightweight clothing [60,61]. However, despite their potential, these surfaces often show lower consistency in producing uploadable or unique contributor profiles compared to the SW and GS. Therefore, while such sites can serve as supplemental collection points, the SW and GS remain the most reliable and interpretable for routine casework.

The findings of this study also carry important operational implications. Existing standard operating procedures (SOPs) should be updated to reflect empirical evidence favoring high-contact interior surfaces. Routine inclusion of SW and GS as primary targets, supplemented by optional IDH and EDH collection when warranted, would optimize resource use and evidentiary outcomes. This evidence-based refinement supports more efficient and accurate suspect identification, especially in high-throughput forensic labs.

Importantly, the results presented here are derived from real-world casework, offering high ecological validity and demonstrating the practical reliability of these sampling trends outside of controlled laboratory conditions. Nonetheless, further research is warranted to explore the generalizability of these findings across different vehicle types, surface materials, environmental conditions, and post-incident intervals. Additional studies examining the impact of inter-individual DNA shedding variability and combined recovery of DNA and latent prints may further inform forensic best practices.

5. Conclusions

This study provides critical operational insight into the success rates of Touch DNA recovery from various vehicle surfaces in real-world hit-and-run casework. The steering wheel emerged as the most consistent and reliable source of usable DNA profiles among the sampled sites, followed by the gear shift. In contrast, the exterior door handle demonstrated the lowest yield and profile quality, likely due to environmental exposure and reduced contact duration.

These findings underscore the importance of strategic site selection during forensic sampling and highlight the need to prioritize high-contact interior surfaces when collecting DNA evidence from vehicles. Optimizing sampling protocols based on empirical performance enhances the likelihood of obtaining probative genetic material, ultimately supporting more accurate suspect identification and legal resolution.

Future research should investigate advanced or alternative collection techniques to improve DNA recovery across all vehicle surfaces, including adhesive-based methods or surface-specific swab technologies. Moreover, further studies examining contamination risks during vehicle handling, transport, and evidence processing are essential to strengthen quality assurance protocols. Addressing these variables will contribute to more robust, reliable, and reproducible DNA profiling outcomes in forensic investigations of vehicular crimes.

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Author Contributions

S.K.A. was responsible for sample collection, data analysis, and drafting the main manuscript, as well as writing—review and editing. N.I.A. (Nashmi I. Aidarous), A.A.A., H.M.A., A.M.A. (Amna M. Alrazouqi), A.F.A., S.M.A., A.M.A. (Alanoud M. Alsaadi), N.I.A. (Noura I. Aldabal), and M.A.A. contributed to sample collection, data analysis, and visualization. H.J.A. was responsible for conceptualization and supervision. All authors have read and approved the final version of the manuscript and participated in the revision process.

Ethics Statement

This study was carried out in accordance with the ethical guidelines established by the General Department of Forensic Science and Criminology, Dubai Police General Headquarters, Dubai, UAE. The research protocol, including data collection and analysis procedures, was reviewed and approved by the Department to ensure adherence to both institutional and international ethical standards (Ref. No. STEMH 912, May 2024). All aspects of the study were conducted with a commitment to maintaining the highest levels of scientific integrity and ethical responsibility, with the objective of contributing to the advancement of forensic science practice.

Informed Consent Statement

Not applicable.

Data Availability Statements

Not applicable.

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Declaration of Competing Interest

The authors declare no conflicts of interest. There are no known financial or personal relationships that could have influenced the research, analysis, or conclusions presented in this study.

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