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Touch DNA technique and its utility in Criminal Justice System

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ABSTRACT

DNA analysis or DNA profiling done on the samples available from the crime scenes is considered the most important evidence in present criminal justice system. The type of samples on which this analysis are done are blood, semen, body fluids etc. But lack of this sample and lack of proper quantity can be a problem in solving cases which then are labelled as cold cases. There has been many up gradation and research in DNA profiling and of them the most important is Touch DNA analysis. The advantages of this technique like possibilities of analysis of small quantities of sample, collection of DNA from areas of touch like surfaces, clothes, glasswares, mobiles, personal computers etc. has led to solving cold case and complicated cases. Various techniques of touch DNA have their share of challenges. There is constant research and development in new modalities in touch DNA. In present times throughout the globe touch DNA has generated huge interest. In this review we present the overview of the Touch DNA technique and its utility in criminology navigating almost all the aspects including the latest developments, accuracy, advantages, challenges, implications of global use and future perspectives.

Keywords: Touch DNA, DNA profiling, Polymerase Chain reaction, forensic science.

1. INTRODUCTION

Forensic DNA analysis is most important for criminal investigations, as they provide crucial evidence for identifying guilty and giving justice to innocent. This method has been revolutionary since its introduction in 1987, allowing for the generation of DNA profiles from only a few cells [1].Touch DNA analysis, a sub branch of forensic DNA analysis, involves the recovery and analysis of DNA from skin cells transferred during physical contact with surfaces [2] . This technique is so sensitive that it can analyze DNA profile from as few as seven to eight cells of epithelial tissue like skin. This method helps and enhances ability to extract DNA from places/things that were previously considered unsuitable for traditional DNA testing. Touch DNA refers to the genetic material which comes into effect when a person touches an object or surface. This type of DNA is often invisible to the naked eye and can be challenging to collect and analyze probably because of lesser quantity of DNA present. However, updates in forensic techniques helps to extract and analyze touch DNA, allowing forensic scientists to link individuals to crime scenes through their genetic material. Touch DNA has been instrumental in solving cases where traditional DNA evidence is lacking, providing valuable leads and evidence in criminal investigations [3]. Touch DNA analysis has revolutionized forensic investigations by allowing forensic experts to identify potential suspects, connect individuals to crime scenes, and provide crucial evidence in cases where other forms of DNA evidence may be absent or inconclusive [2]. The ability to extract DNA from a variety of surfaces, such as clothing, weapons, and electronic devices, has expanded the scope of forensic analysis and criminology. With advances in touch DNA technique, the same is expected to play an increasingly important role in solving crimes and delivering justice.

2. TOUCH DNA TECHNIQUE AT CRIME SCENES:

The collection of touch DNA at crime scenes involves meticulous procedures to recover minute traces of cellular material left behind by individuals. Common sources of touch DNA include skin cells shed through contact with surfaces such as

doorknobs, weapons, or clothing. Crime scene investigators employ different swabbing techniques to collect these samples like wet swabbing using sterile DNA free swabs moistened with buffer solutions to lift DNA material from surfaces. Research has shown that touch DNA can persist on surfaces for extended time line, with a handling time of just two seconds being enough to deposit sufficient DNA for a complete profile. Different recovery techniques, such as adhesive tape, dry swabbing, and cutting out, have been evaluated, with varying degrees of success in recovering the DNA of handlers and wearers [4].

Upon collection, touch DNA samples undergo a series of laboratory processes, including DNA extraction, amplification by polymerase chain reaction (PCR), and analysis using techniques such as capillary electrophoresis or next-generation sequencing [5]. The recovered DNA profiles are compared to known profiles from suspects or DNA databases to establish potential matches. However to mitigate the risk of contamination, crime scene investigators must adhere to strict protocols. These include restricting movement on the crime scene, not talking over evidence, wearing personal protective equipment, changing gloves frequently, collecting elimination samples, and using disposable tools. It is critical to follow guidelines for evidence collection and analysis, as outlined in best practice documents such as the National Best Practices for Sexual Assault Kits[2][6][7][8].

3. RECENT DEVELOPMENTS IN TOUCH DNA ANALYSIS

Recent advancements in touch DNA analysis have significantly enhanced sensitivity and cost-effectiveness while introducing innovative techniques and approaches to forensic investigations [9] [10]. These will improve the efficiency and accuracy of forensic analyses. Here's a brief of the latest breakthroughs:

1. Enhanced Sensitivity and Cost-Effectiveness: Researchers have developed a more accessible and affordable touch DNA test using quantitative PCR (qPCR). This method simplifies the identification of touch DNA, reducing costs and making the technique easier to implement in forensic settings [11].

2. Direct PCR and DNA Profiling: Direct PCR has emerged as a game-changer in touch DNA analysis, enabling the amplification of DNA profiles from as few as 40 cells. This method bypasses the DNA extraction step, reducing DNA loss and saving time and resources [2]. Direct PCR has been shown to produce higher quality DNA samples and complete profiles in less time compared to standard PCR methods. Single-cell DNA profiling has emerged, allowing for the construction of genomes from much smaller amounts of genetic material and potentially linking DNA profiles with images of the cell. These methods are crucial in cases where only minimal samples are available, and they have been instrumental in solving famous cases [12].

3. Transfer and Persistence Studies: Recent studies have analysed the transfer and persistence of touch DNA, revealing insights into primary, secondary, and tertiary transfers under various conditions. Understanding the dynamics of DNA transfer is crucial for interpreting forensic evidence accurately [13].

4. Impact of Individual Differences: Research indicates that individual differences, such as being a 'heavy shedder,' can significantly influence quantity of DNA left behind. Some individuals consistently leave informative DNA profiles, which can aid forensic investigations. Factors like age, ethnicity, and skin conditions do not appear to significantly affect touch DNA deposits [14].

5. Advanced Imaging Techniques: Innovative imaging methods, such as using diluted Diamond™ dye (DD) spray to visualize fingerprints under fluorescent digital microscopy, have been introduced to aid in the collection of touch DNA. These techniques enhance the identification and recovery of DNA evidence from surfaces [15].

6. Microbiome Analysis: Scientists are exploring the potential of analyzing the DNA of the microbiome, which varies from person to person, to extract additional information for forensic investigations. Microbiome analysis could help better understand individual’s lifestyle and environment [16].

7. Next Generation Sequencing (NGS): NGS technology allows for the parallel sequencing of multiple DNA samples, increasing sensitivity and speed of analysis. This technology revolutionizes criminal investigations by providing a deeper understanding of DNA profiles and facilitating complex analyses [17] [18].

8. Forensic Genetic Genealogy (FGG): FGG combines DNA profiling with genealogical research to identify potential suspects or victims by comparing DNA profiles to public genealogy databases. This technique has been instrumental in solving long pending unsolved cases and identifying unidentified remains, significantly advancing forensic genetics [19].

9. Short Tandem Repeat (STR): Touch DNA analysis has evolved to focus on specific Short Tandem Repeat (STR)

loci, such as THO1, CSF1PO, and TPOX, which are integral to the Combined DNA Index System (CODIS) [20]. The isolation of touch DNA can be achieved through various studies, including obtaining DNA from buccal smears and personal items like watches and cell phones. DNAzol is used for isolation, and the DNA quantity is measured using a UV Visible Spectrophotometer, with varying mean levels of DNA found on different types of swabs[21][22].

10. Microfluidic Devices: Latest advancements in touch DNA analysis highlights enhancing sensitivity, reducing contamination risks, and streamlining workflows. One notable advancement is the development of microfluidic devices capable of isolating and amplifying DNA from touch samples with unprecedented efficiency and sensitivity. These devices enable rapid on-site analysis, expediting investigative processes [23] [24].

11. Single Nucleotide Polymorphisms (SNPs): Studies have enabled the determination of phenotype from DNA sequences through the analysis of Single Nucleotide Polymorphisms (SNPs). The HIrisPlex-S system is such a method that is developed for this purpose [25].

12. Genotyping Algorithms: Furthermore, advancements in forensic bioinformatics have facilitated the interpretation of complex DNA mixtures often encountered in touch DNA samples. Probabilistic genotyping algorithms, such as STRmix™, incorporate statistical models to analyze mixed DNA profiles, improving accuracy in identifying contributors to samples containing DNA from multiple individuals[26][27].

In conclusion, recent developments in touch DNA analysis offer promising opportunities for improving forensic investigations. Enhanced sensitivity, cost-effectiveness, advanced techniques, and novel approaches contribute to the advancement of forensic genetics, ultimately leading to more accurate and reliable outcomes in criminal justice. Continued research and innovation in this field are necessary for addressing challenges and maximizing the potential of touch DNA analysis in forensic science.

4. ACCURACY OF TOUCH DNA ANALYSIS:

The accuracy of touch DNA is paramount, as it can confirm suspects or exonerate the innocent. It is influenced by factors like possibilities of contamination, the variability in the amount of DNA left by touch, degradation, interpretation of mixed DNA samples and proficiency of laboratory procedures. To mitigate these challenges, stringent quality control measures and validation protocols are essential in touch DNA analysis [28]. Additionally, advancements in forensic science have led to development of robust analytical tools and methodologies to enhance the reliability and accuracy of touch DNA results. Despite these challenges, touch DNA is used in high-profile cases, demonstrating its potential when used correctly.

5. ALTERNATIVE TECHNIQUES

In response to the limitations of touch DNA analysis, researchers have explored alternative techniques for forensic DNA analysis. These include utility of advanced imaging technologies for visualizing and locating touch DNA, the research of novel DNA extraction methods for improving DNA recovery from challenging substrates, and the added benefits of complementary forensic techniques such as trace evidence analysis and forensic odontology to compliment the evidentiary value of forensic investigations [29].

6. ADVANTAGES OF TOUCH DNA ANALYSIS:

Touch DNA analysis is at par with traditional DNA methods, particularly in cases where conventional sources of DNA may be lacking. It can recover DNA from surfaces touched by perpetrators or victims expands the horizon of forensic investigations, potentially linking individuals to crime scenes even in the absence of bodily fluids or tissue evidence. Touch DNA is fast becoming an important part in criminal investigations, more so if other body fluids, such as blood or saliva, are not visible. It is particularly valuable in sexual assault cases, like groping incidents, where it can provide confirmatory evidence. The National Institute of Justice has published best practice guidelines for the gathering and analysis of touch DNA in such cases [2] [30].

Touch DNA helps solve crime where there is minimal amount of any biological traces. In normal circumstances DNA collection and analysis lead to issues of privacy and intrusion which is not present in Touch DNA.

7. CHALLENGES IN TOUCH DNA

As forensic experts utilise touch DNA in day to day crime solving, they faces various challenges like insufficient samples for analysis. This has led to research and development of ultra-sensitive techniques with more specificity and sensitivity.

Another big challenge is contamination of the sample due to crime scene indiscipline. Stringent contamination controls and adherence to best practices are essential to minimize the risk of false positives or erroneous results [2] [31]. Environmental factors such as UV light, temperature, and humidity can affect DNA stability and degradation [32] [33]. Financial constraints and the need for extensive crime scene investigation to identify secondary and further transfers also pose challenges.

8. FUTURE PERSPECTIVES:

Future research in touch DNA analysis should focus on addressing the challenges of contamination, sensitivity, and interpretation, while also exploring emerging technologies and interdisciplinary approaches for enhancing the reliability and utility of touch DNA analysis in forensic science. Collaborative efforts between forensic scientists, geneticists, bioinformaticians, and law enforcement agencies will be essential for driving innovation and removing remaining barriers to widespread adoption of touch DNA analysis in forensic studies.

9. IMPLICATIONS FOR GLOBAL USE OF TOUCH DNA TECHNIQUES

The advancements and research findings in touch DNA techniques have far-reaching implications for forensic investigations on a global scale. These implications span several critical areas:

Training and Methodological Development: Proper training of forensic practitioners in touch DNA collection, analysis, and interpretation is paramount. As touch DNA analysis becomes more prevalent, standardized protocols and best practices are required and disseminated globally to ensure consistency and reliability in forensic investigations.

1. **Policy Development:** Policymaking at both national and international levels is essential to establish guidelines and regulations governing the use of touch DNA techniques in forensic science. These policies should address issues such as sample collection, storage, analysis, and data interpretation, while also considering ethical and legal considerations.

2. **Proficiency Testing:** Proficiency testing programs are necessary to assess the competency of forensic laboratories and personnel in conducting touch DNA analysis accurately and reliably. These programs help identify areas for improvement and ensure that laboratories maintain high standards of quality and performance.

3. **Sample Preservation and Collection Optimization**: With the increasing sensitivity of touch DNA analysis, proper sample preservation and optimal collection methods are crucial. Forensic practitioners must continuously optimize techniques for sample collection and preservation to maximize the chances of obtaining usable DNA evidence from crime scenes.

4. **International Collaboration:** Collaboration between forensic laboratories, researchers, policymakers, and law enforcement agencies on a global scale is essential for advancing touch DNA analysis. Sharing of knowledge, resources, and expertise can accelerate progress, facilitate technology transfer, and improve forensic capabilities worldwide.

5. **Capacity Building:** Developing countries, in particular, may face challenges in adopting and implementing touch DNA techniques due to limited resources and infrastructure. International efforts to support capacity building initiatives, including training programs, technology transfer, and availability of equipment and resources, can help bridge the gap and increase the use of touch DNA techniques in forensic investigations globally.

The advancements in touch DNA techniques is needed for enhancing forensic investigations worldwide. However, realizing this potential requires concerted efforts in training, methodological development, policymaking, proficiency testing, sample preservation, and international collaboration. By addressing these challenges touch DNA technique can continue to evolve and contribute significantly to the judiciary on a global scale.

10. CONCLUSION:

Touch DNA analysis represents a significant advancement in forensic science, revolutionizing the way investigators gather and analyze biological evidence. Despite its challenges, ongoing research and technological innovations continue to enhance the sensitivity, accuracy, and reliability of touch DNA techniques. As forensic capabilities evolve, touch DNA analysis will remain a vital tool in unravelling the mysteries of criminal investigations, offering hope for justice and closure to victims and communities alike.

Touch DNA is a valuable forensic tool that has seen significant advancements in recent years. The development of cost-

effective tests like qPCR and single-cell DNA profiling has enhanced the detection of trace amounts of DNA. However, challenges such as contamination, DNA degradation, and the interpretation of mixed DNA samples remain. Despite these challenges, touch DNA is a valuable asset in criminal investigations, offering the potential to solve cases that would otherwise remain cold. As the technology evolves, association with judiciary will be crucial to determine the best applications of these methods.

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