Shahid S, et al., J Forensic Leg Investig Sci 2023, 9: 085
DOI: 10.24966/FLIS-733X/100085

HERALD

HSOA Journal of Forensic, Legal & Investigative Sciences

Research Article

DNA Fingerprinting: A Milestone in Forensic Science

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Abstract

The successful interpretation of DNA in forensic science is contingent upon the significance of the evidence found at a crime scene and the availability of suitable reference samples. However, it's important to acknowledge that errors and uncertainties are inherent aspects of DNA fingerprinting. Ongoing efforts are dedicated to enhancing the accuracy and reliability of results in this field. DNA has become a ubiquitous tool, serving as a kind of genetic identification card in many countries.

DNA fingerprinting remains a promising technique for forensic scientists, offering a powerful means to investigate individuals. This paper aims to provide a comprehensive and scientific perspective on the challenges associated with DNA profiling within forensic laboratories. While it briefly outlines the objectives and techniques of DNA profiling, the primary focus lies in DNA fingerprinting.

One of the fascinating aspects of DNA fingerprinting is its ability to identify non-coding regions of the genome, which are unique to every living organism. This innovation has played a pivotal role in forensic science, aiding in the exoneration of innocent individuals. Additionally, this article sheds light on the evolving landscape of DNA fingerprinting technology in recent years and highlights real-world cases where various iterations of this technology have successfully been employed to solve criminal investigations in research laboratories.

Keywords: DNA profiling; DNA typing; Genomic finger-printing; RFLP; VNTR's

Introduction

IN 1886 in a study Sherlock Holmes shouted"I've found it! I've found it", running towards Watson In 1886, a pivotal moment occurred in scientific history when Sherlock Holmes exclaimed, "I've found it! I've found it," rushing towards Watson with a test tube in hand, declaring, "I have found a re-agent which is precipitated by hemoglobin, and by nothing else" [1]. This exclamation echoed across England, much like the famous Eureka shout did in 1984 when Alec Jeffreys, a researcher at the University of Leicester in the UK, made a groundbreaking discovery. Jeffreys unveiled innovative variables and heritable patterns within repetitive DNA, analyzed using multi-locus probes. Unlike Sherlock Holmes, Jeffreys didn't name the method after himself but rather coined it 'DNA fingerprinting' [2]. Jeffreys' work focused on genes and aimed to establish genetic connections between individuals for purposes such as determining paternity and resolving immigration disputes.

This revolutionary technology allowed for the verification of whether two samples originated from the same person. Every individual on Earth possesses a unique molecular identity encoded within the sequence of their DNA, which is inherited from their biological parents and remains consistent in every cell of their body. This technique, known as DNA fingerprinting, can definitively establish an individual's parentage [3].

Forensic genetic fingerprinting, as defined by Jeffreys and Wilson [4], involves comparing the nucleated cells of an individual's DNA with biological samples collected from a crime scene or with another person's DNA for identification or exclusion.

DNA fingerprinting is a distinctive form of identification that relies on shreds of evidence. One of the earliest criminal cases solved using DNA analysis involved Colin Pitchfork, who had committed rapes and murders in 1983 and 1986, targeting two young girls, Lynda and Dawn. Investigators collected semen samples and analyzed them in a forensic laboratory. The DNA evidence conclusively proved Pitchfork's guilt, leading to his admission of the crimes and subsequent arrest [5].

The 1990s marked a golden era for technological advancements and discoveries, greatly benefiting forensic science. DNA fingerprinting emerged as a powerful tool for investigating criminal cases and played a crucial role in court decisions. DNA typing, a laboratory procedure that detects variations in DNA, proved invaluable for victim identification in both small and large-scale disasters.

- **Techniques**

DNA fingerprinting techniques can be categorized into PCR-based and non-PCR-based methods. PCR-based methods, such as STR (Short Tandem Repeat) analysis, are faster and more sensitive, while non-PCR methods like RFLP (Restriction Fragment Length Polymorphism) are slower and require larger DNA samples.DNA profiling typically uses a set of multi-allelic STR markers. Different countries and regions have established standard sets of markers for criminal databases, such as the EU standard set of 12 STR markers and the US CODIS standard of 13 markers.

- **Uniqueness and probability**

The uniqueness of each person's DNA, except for identical twins, allows for extremely low probabilities of two individuals having

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Citation: Shahid S, Farrukh F (2023) DNA Fingerprinting: A Milestone in Forensic Science. Forensic Leg Investig Sci 9: 085.

Received: October 09, 2023; **Accepted:** October 20, 2023; **Published:** October 26, 2023

identical DNA profiles. This statistical uniqueness makes DNA evidence highly reliable in criminal investigations.

- **DNA databases**

Many countries maintain DNA databases like CODIS (Combined DNA Index System) to store DNA profiles from crime scenes and individuals. These databases help match DNA evidence to known individuals, aiding investigations.

- **Historical background**

The Federal Bureau of Investigation's article, published in 2008, represents a crucial milestone in understanding the statistical aspects of DNA profiling. It likely contributed to the standardization and improvement of DNA profiling techniques, emphasizing its growing significance in forensic science. Lutz Roewer, a forensic expert, published an article in 2013 that not only delves into the history of DNA fingerprinting but also provides insights into the modern technologies and techniques employed in this field. This article likely offered an updated perspective on the state of DNA fingerprinting. The National Institute of Standards and Technology (NIST) is a prominent research center that significantly contributed to the enhancement of DNA fingerprinting in 2016. NIST's involvement indicates ongoing efforts to improve the accuracy and reliability of DNA profiling methods. The international article published in 2017 explores the applications of DNA fingerprinting in forensic investigations. It likely highlights the expanding use of DNA profiling techniques in solving crimes and identifying individuals. Anam Hameed's research review in 2019 focuses on the issues related to DNA fingerprinting. This review may address various challenges, controversies, and ethical concerns associated with the use of DNA profiling in forensic science.

Discussion

Currently, there is broad recognition of the advancements in scientific understanding related to the composition of the Y chromosome. This progress has been significantly bolstered by the introduction of highly sensitive panels that encompass up to 27 Short Tandem Repeats (STRs), incorporating markers that undergo rapid mutations. To calculate the probability of matches between Y-STR or mtDNA profiles, the prevalent counting method is typically employed [6]. However, ensuring accurate outcomes demands the existence of extensive, well-represented databases, rigorously verified for quality, containing haplotypes sampled from diverse reference populations. This necessity arises because individual allele frequencies in Y-STR and mtDNA profiles exhibit a distinct pattern of variation compared to independently obtained autosomal STRs.

In the traditional methodology of DNA fingerprinting, radio-labeled DNA samples containing minisatellite or oligonucleotide sequences undergo hybridization with DNA that has undergone processing using restriction enzymes. Following this, the fragments are separated through agarose electrophoresis and then immobilized-either through the Southern blotting method or, in the case of oligonucleotide tests, directly within a dried gel. Subsequently, the radio-labeled probes bind to various minisatellites or oligonucleotide sequences within genomic DNA. These sequences are found within restriction fragments of varying sizes, attributed to differences in the number of repeat units. After the removal of excess probes, visualization of these variable components is made possible through exposure to X-ray film (autoradiography), facilitating the comparison of profiles among individuals [7].

In the contemporary context, forensic DNA technology holds a profound influence over countless lives across the globe. The widespread acceptance of this technology is notably evident in its pivotal role in identifying survivors of significant events, including the 9/11 terrorist attacks, natural disasters like Hurricane Katrina [8], as well as the resolution of conflicts such as those in the former Yugoslavia [9] and Argentina [10,11]. Despite its portrayal as a definitive solution by both the general public and law enforcement personnel clad in white suits, the reality introduces nuanced questions. The advantages of forensic DNA fingerprinting must be considered in light of the associated social and ethical costs. Consequently, the legal community grapples with the dilemma of how DNA fingerprinting technology should evolve.

An increasing consensus suggests that DNA sequencing is poised to replace part-length analysis soon, and this viewpoint is substantiated by compelling arguments. The emergence of Next Generation Sequencing (NGS) technologies has significantly broadened the scope of forensic data collection and has enabled rapid, cost-effective analysis, considering the extensive pool of potentially informative DNA loci [12,13].

Nonetheless, the progression of forensic science is not without its share of challenges and controversies. Public perception often diverges from the realities of DNA profiling. A significant drawback lies in the potential invasion of personal privacy, as an individual's DNA reveals substantial information regarding their physical characteristics and health. This sensitivity necessitates meticulous handling, as individuals often harbor reservations about divulging their complete genetic information due to concerns related to privacy [14,15].

Moreover, the lack of standardization in DNA profiling protocols among various laboratories has contributed to inconsistencies in results obtained from identical samples submitted to different facilities. Furthermore, environmental factors such as humidity, temperature fluctuations, bacterial contamination, and exposure to UV radiation have been demonstrated to exert significant influences on the integrity of DNA profiles. Adverse conditions, including high humidity levels, can lead to oxidative damage and hydrolytic cleavage of DNA bonds, ultimately culminating in the degradation of genetic material [10,16,17].

Conclusion

DNA evidence is a powerful tool that not only helps us understand the genetic makeup of living organisms but also plays a crucial role in forensic science. In every cell of an individual's body, their unique DNA profile serves as an immutable identifier. This genetic distinctiveness becomes especially valuable in cases such as paternity tests, where the relationship between individuals can be accurately determined. Furthermore, in the field of forensic science, DNA fingerprinting has emerged as an indispensable technique. By analyzing DNA samples collected at crime scenes, law enforcement can identify and apprehend suspects, shedding light on the circumstances of criminal activities. Criminology benefits significantly from DNA analysis, contributing to the precision of criminal investigations and ensuring more accurate outcomes in the pursuit of justice. Ongoing research continues to refine DNA fingerprinting methods, promising even greater precision and broader applications in the future.

Acknowledgment

I would like to thank Allah Almighty for giving me strength and all blessings, my parents, and to my teachers, whose guidance encouraged and motivated me to have confidence in my abilities. And also, to my friends who always support me.

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