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ADVANCES IN DNA TECHNOLOGY AND ITS ROLE IN FORENSIC MEDICINE

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Abstract: DNA technology has transformed forensic medicine by providing unprecedented accuracy in human identification, crime investigation, and the administration of justice. Since the discovery of DNA profiling in the 1980s, forensic scientists have been able to match biological samples to individuals with remarkable precision. This paper examines the historical development of DNA use in forensic medicine, the main methodologies applied in DNA analysis, and its broad applications in criminal justice, civil disputes, and humanitarian efforts. It also discusses limitations and ethical challenges, with attention to privacy, data protection, and the risk of misuse.

Keywords: forensic medicine, DNA profiling, STR analysis, genetic identification, criminal justice, forensic ethics, human rights.

Introduction

Forensic medicine, as an applied branch of medical science, is devoted to the interface between health sciences and law. Its central purpose is to provide objective, scientifically validated evidence to courts, law enforcement agencies, and policy makers. Among the many tools available to forensic medicine, DNA technology has emerged as the most transformative.

Before the development of DNA profiling, forensic investigations relied on classical methods such as serological blood typing, fingerprint comparison, dental analysis, and morphological assessments. While these approaches provided valuable information, they lacked the level of precision required to conclusively link an individual to a crime scene or exclude them as a suspect. This often left criminal investigations incomplete and increased the risk of wrongful convictions.

The discovery of DNA profiling by Sir Alec Jeffreys in 1985 revolutionized forensic science. For the first time, investigators were able to identify individuals based on their unique genetic blueprint, which remains consistent throughout life and is extremely difficult to falsify. The acceptance of DNA profiling in courts quickly followed, making it a gold standard for personal identification and legal evidence.

Today, the use of DNA in forensic medicine extends far beyond the realm of traditional criminal cases. It is employed in paternity and kinship testing, mass disaster victim identification, immigration disputes, and even in international humanitarian investigations aimed at uncovering war crimes or locating missing persons. Advances in molecular biology, such as Short Tandem Repeat (STR) analysis, mitochondrial DNA testing, and next-generation sequencing, have expanded the capacity of forensic experts to extract useful information even from degraded or minimal biological material.

The growing reliance on DNA evidence reflects both the demand for accuracy in modern justice systems and the increasing complexity of crime in a globalized world. At the same time,

it has introduced new debates concerning privacy, data security, and the ethical boundaries of genetic analysis. As such, the study of DNA technology within forensic medicine is not only a scientific endeavor but also a critical reflection on how societies balance justice, human rights, and technological innovation.

Methods

This article employs a review of scientific literature, forensic case reports, and international guidelines on DNA analysis. The focus includes Restriction Fragment Length Polymorphism, Polymerase Chain Reaction, Short Tandem Repeat profiling, and recent developments in next-generation sequencing. Comparative case examples from different jurisdictions are examined to demonstrate how DNA evidence contributes to legal outcomes.

Results

Forensic DNA analysis has generated major contributions to justice systems. In criminal investigations, DNA evidence has provided conclusive links between suspects and crime scenes, solving cases that would otherwise remain unresolved. Cold cases have been reopened and solved after decades due to the preservation of DNA evidence. The exoneration of the innocent has been another critical outcome. In numerous countries, post-conviction DNA testing has cleared individuals of crimes for which they were wrongfully imprisoned, demonstrating the value of DNA in preventing miscarriages of justice. In mass disasters and humanitarian contexts, DNA analysis has been central in identifying victims of earthquakes, wars, and terrorist attacks, offering closure to families and assisting governments in accurate record keeping. Civil applications of DNA profiling have also proven effective in resolving paternity disputes, inheritance claims, and issues of family reunification in immigration cases.

Discussion

The integration of DNA technology into forensic medicine has enhanced the precision, reliability, and credibility of legal proceedings. Its advantages include scientific accuracy, the ability to revisit unresolved cases, and support for international collaboration through global DNA databases. Despite these strengths, limitations exist. DNA evidence can be compromised by contamination, degradation, or partial profiles that complicate interpretation. Mixtures of DNA from multiple individuals often present analytical challenges that require advanced statistical models. Ethical considerations are equally pressing. Issues of privacy, informed consent, and the potential misuse of genetic information raise concerns about the balance between justice and individual rights. The expansion of national and international DNA databases has heightened debates regarding surveillance, data protection, and human rights.

Conclusion

DNA technology has revolutionized forensic medicine and remains indispensable for modern justice systems. It has strengthened the accuracy of criminal investigations, safeguarded individuals from wrongful convictions, and expanded applications to civil and humanitarian contexts. However, the power of DNA evidence demands careful regulation, standardization of laboratory practices, and respect for ethical principles. The future of forensic medicine lies in

maintaining scientific rigor while ensuring that technological progress serves both justice and human dignity.

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