

■ REVIEW ARTICLE

DNA Technology as Forensic Tool in Advancing Justice

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ABSTRACT

Forensic biology is an application which involves a union of people to firstly suspect the crime location, artifact's and person on basis of the data provided by the victim. The provided data is analyzed by various investigations to solve criminal and civil cases. Various techniques are implemented that can be used in forensic science such as ABO blood grouping, Variable number tandem repeats, polymerase chain reaction, short tandem repeat and single cell analysis. These techniques play a significant role to completely study the samples. The entire process of the DNA analysis is divided into 4 major parts. Nanotechnology is another major field of biotechnology is currently under study for the developments of further more techniques that can be utilized in on the spot detection of sample in no time. Distinct portable devices are already developed to carry out detection and few are under study. In the forthcoming times, the process of investigation might be at rapid rate which will prevent contamination as well as mishandling of samples. The main requirement is of bioinformatics tools in laboratories in order to handle vast samples.

KEY MESSAGES: Investigation is key step of criminal cases and DNA technology will make this step rapid and error free. Thus, Development of authentic, portable and user friendly molecular techniques is necessity of present era for fast and accurate process of justice.

KEYWORDS | DNA fingerprinting, RFLP, nanotechnology, genetics

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How to cite this article

Lovepreet Kaur. DNA Technology as Forensic Tool in Advancing Justice. *Indian J Forensic Med Pathol.* 2021;14(3 Special):717-722.

INTRODUCTION

THE PROCESS OF ANALYTICS STUDY, SEQUENCING, as well as cutting and pasting of DNA with incorporation of various techniques forms the backbone of the DNA technology. Techniques such as DNA sequencing, polymerase chain reaction followed by cloning and further processing via electrophoresis plays a significant role in various experimentations of the DNA. A vast number of techniques are developed that include DNA fingerprinting, gene therapy, DNA microarray and gene therapy (Thanakiatkrai *et al.*, 2013). Each technique has its own important role in science research. DNA comprises of genetic instructions in the form of molecules of nucleotides in all living

organisms. It is organized into chromosomes in a very structural manner. DNA techniques are helpful in tracking the ancestors of species, to determine the culprit in case of forensics and to find out the paternity of a child. Likewise, various pathogens can be identified through the biological remains recovered from the archaeological sites which can be helpful in proper identification of the remains (Ian *et al.*, 2014). Thus, these techniques are very helpful in proper analysis of the forensic laboratory samples.

Forensic science is a branch of science that conducts investigations from the evidences collected at the site of incident, from suspects

and victim. It involves the use of scientific methods in which the samples collected are analyzed using different DNA techniques (Kashyap *et al.*, 2004). The results obtained are then represented in the court to punish the culprit. Similarly, the inferences are utilized to acquire knowledge about the dead remains in case of the archaeological studies. In order to resolve legal matters various evidences are collected, studied, experimented and then interpreted to create a link between them so that an investigatory lead can be provided. Different fields such as toxicology, engineering, computing and pathology form the term forensics (Lowe, A. *et al.*, 2003). Earlier, the ABO blood grouping method was used for the detection purposes, but this approach was not successful. In 1981, DNA (deoxyribonucleic acid) was used for the testing in criminal justice. It has become a vital part of the forensic science to carry out investigations over different samples. The process of DNA technology was initially used in 1985 for the study of casework in United Kingdom. Later on, in 1988 the Federal Bureau of Investigation (FBI) started using forensic analysis to investigate crimes. During the investigation process the genetic material is the epicentre (MacKnight, 2004). With the advancements in technology the repeated sequences came into practice in 1985, under which restriction fragment length polymorphism (RFLP) and variable number tandem repeat (VNTR). Following it, the technique of polymerase chain reaction discovered which help in amplifying the segments of DNA in less time, this approach provide a great benefit in case of low quantity and quality of samples. The research on DNA techniques to be utilized for forensic studies was on peak for a decade. From 1985-1995, distinct approaches were introduced such as microsatellite and simple sequence repeats (SSRs) in which short sequences of 2-6 base pairs long was taken as target sequence (Shanly *et al.*, 2018). In 1990, this technique was successfully used in forensic DNA analysis for the investigation purpose as they represent

those alleles which are distinguishable from each other, in case of evidence loci is stable and even small amount of sample can be used as short length of fragments is required. Later on, low copy number technique developed to deal with sensitive samples and single nucleotide polymorphism is used extensively to solve rape cases (Murray, C *et al.*, 2001).

In order of on spot detection the need of time demands the development of investigation tools such as Sci-Fi which is a hand-held device. Sci-Fi comprises of a chip which is enough to test the samples at the crime scene in order to generate their sequences of the DNA, it is one of the kind of lab on the chip (Gill, 2001). For this purpose nanotechnology serves a great role as it has already been used in detection of illicit drugs. The nanoparticles have been used to develop a smart system for the detection of codeine sulphate, the citrate-stabilized gold nanoparticles (AuNPs) was used as a probe. Additionally, with aid of micro fabrication of capillary electrophoresis development of a single integrated platform is in process. Single integrated platforms will save time as the extraction; amplification and sequencing of the DNA will be carried out at one space (Hariprashad *et al.*, 2021). The use of three dimensional computer automated techniques for morphological analysis of skull has already been implemented in forensic biology. Under the next generation technologies of the DNA fingerprinting, the determination of the color of skin, hair and eyes with help of the various techniques of gene sequencing is the main focus.

Steps in DNA Fingerprinting

The process of DNA fingerprinting involves the collection of sample, analysis; examination or experimentations and then observations of sample are done. The genetic material can be in the form of hair, skin and blood collected from the suspects, victims and crime scene. The collected material is then analyzed by DNA techniques such as RFLP, VNTR, STR, SNP (single -nucleotide polymorphism), Low copy number and Y- chromosome analysis (Manteen

et al., 2020). Following analysis, the results of obtained gene sequence or fingerprints are compared to the DNA databases. These databases comprises of a large number of profiles worldwide or area wise maintained they serve as a great purpose for the depiction of the diseases related to genes and genealogy purposes. Scientifically, the three major parts namely, serology, DNA technology and genetics form the backbone of testing of samples using various techniques (Bruce R. *et al.*, 2019).

Serology – It is the main step in which the investigators report the crime site registered by police administration. They collect samples such as semen, hair, skin patches, blood or saliva from the site. Additionally, photography is done of the entire location (Alves *et al.*, 2007). It is important to collect and mark the sample properly to prevent any cross- contamination. Then, the sample is carried out to laboratories for further investigations.

DNA technology – The extraction of the DNA is done from the sample collected from both the victim and the suspect. Following it the quantification of the sample is done using spectrophotometer. Then the amplification of desired bands is done with help of polymerase chain reaction performed under controlled conditions. After amplification with help of the STR markers the regions are located and the final analysis between the two sequences is done (Bhatt *et al.*, 2020). For making out comparisons with databases, the human and non-human DNA are separated following it genome sequences are compared.

Genetics – The final report is generated after statistical interpretations obtained from the set of data collected from the crime scene. From the date of crime registered to the final test reporting date, every minute detail is mentioned in the report presented in the court room (Pandya *et al.*, 2018). The information in a report consists of the photographs from the crime scene taken as evidence, list of samples collected as evidence, reason why the a specific person is taken as suspect and analysis of the DNA genome sequence that shows the

matching of the two sequences giving clear information about the accused.

Various Techniques used in Solving Criminal Cases

After 1985, the advancements in DNA profiling increased extensively, the modern techniques of the forensic science evoke from the first application taken from the work of Alec Jeffrey's. In 1985 while working on the myoglobin gene, Sir Alec Jeffrey from the University of Leicester U.K. introduced with the new modern technique of the DNA fingerprinting that can be used for solving various cases in a short time period (Rahiman *et al.*, 2010). With advancements in technology initiating from the exploration in which the utilization of the restriction fragment length polymorphism was done to reaching the use of STR kits a lot of techniques came into practise (Shukla *et al.*, 2016). Each technique has its own specific role such as polymerase chain reaction helps in amplification of small amount of DNA to billions of copies. Likewise, detection of diseases which are specific for a locus with help of RFLP. (Table 1).

Role of DNA Technology in Forensic Science

- *Generation of DNA Data Banks* – In forensic science various techniques are used on daily basis and numbers of genome sequences is generated from the samples collected. These genome sequences forms a library or database of sequences which can looked later on for sample comparisons. Each sequence plays a significant role due to its individuality in nature (Angers, A. *et al.*, 2019). In order, to preserve the generated sequences the data banks are generated by the FBI.
- *Determination of Drug* – Examination of the toxic substances isolated from the critical samples such as hair, blood, saliva and fingerprints collected from the crime scene can be done by nanotechnology. For instance, the quantification of cocaine has already been done with help of nanoparticle titanium. The psychotropic substances given to the victim can also be

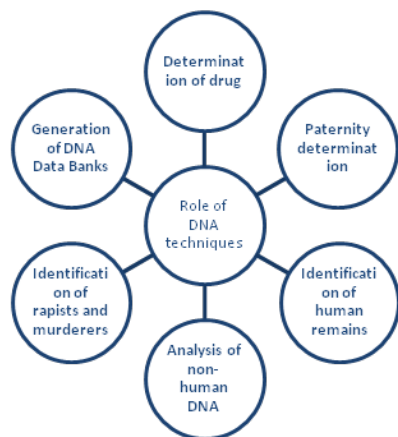


Figure 1: Role of dna techniques in forensic science

S.NO.	TECHNIQUE	ADVANTAGES	REFERENCES
1.	RFLP	Detection and diagnosis of diseases, specific for locus thus helping in detecting the gene responsible for a particular disease.	Thotakura et al., 2016
2.	PCR	Replication of specific nucleotide sequences from low levels of DNA or degraded DNA, Require small sample for analysis.	Chauhan et al., 2017
3.	STR	Use of separate chromosomes in STR markers makes the technique more simple and unique thus preventing any problem related to linkage between the markers.	Yang et al., 2014
4.	LCN analysis	The chances of the error are more as compared to other techniques.	Chaudhary & Jyoti 2017
6.	Y- Chromosome analysis.	Helpful in forensic analysis in case of sexual assault cases.	Alonso et al., 2004
7.	Single Cell DNA Fingerprinting	The DNA of the sperm cell is highly conserved and compacted in a protein head thus the technique of single cell DNA fingerprinting is effectively implemented in solving rape cases.	Pandya et al., 2018
8.	VNTR	To study genetic diversity and breeding patterns in population.	Shukla et al., 2016
9.	mtDNA analysis	In cases of highly damaged sample either due to burn samples or hair without root from which DNA is to be isolated the technique of mitochondrial DNA analysis is used.	Hariprashad et al., 2021

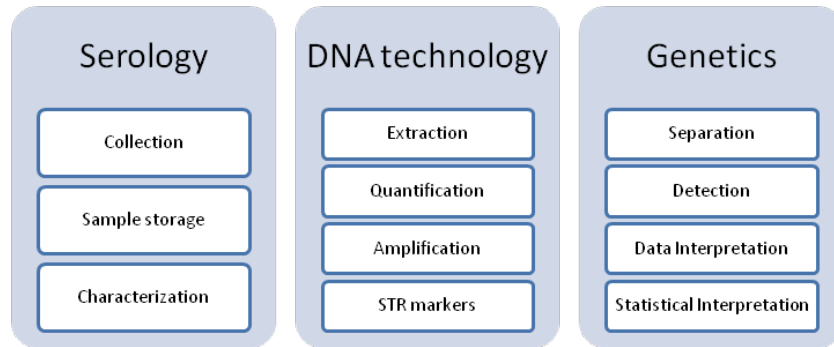
Table 1: Different molecular technoques and their applications in forensic science

analyzed with nanoparticle. Additionally, nanoparticles in detection save time and gives effective results (Bhushan *et al.*, 2015). Nano sensor has already been developed to detect the drug clonazepam from the samples of the blood and skeletal with help of the melamine modified nanoparticles of gold.

- *Paternity Determination* – To solve the paternity dispute cases of various offspring’s, the technique of the DNA analysis plays a crucial role. In case of completely burnt individuals, the bones can be used to identify the individual from bone samples (Budowle *et al.*, 2009). Various cases have already been solved in paternity dispute, a man doubted that out of two daughters he is not the biological father of second one, he filed a case on his wife for cheating. Later on, the DNA fingerprinting was carried out and results in court room declared that the fingerprinting shows completely matching of father to both the daughter, thus the officials proved him his doubt as wrong (Narajo & Avais 2012). This

is how the paternity cases are effectively solved via DNA technology and this method is widely accepted on legal basis.

- *Analysis of non-human DNA* – In cases bodies are recovered from damp forest area and their conditions is terrible which makes it difficult to analyze. It is advised to firstly analyze whether the isolated sample from such conditions contains a human DNA or non- human DNA. A forkhead box (FOXP2) can be used to determine the type of DNA. In addition to this; short tandem repeat can easily determine the presence of non-human DNA (Asplen *et al.*, 2004) (Fig. 1).
- *Identification of rapists and murderers* – In cases of sexual assault, the samples are collected by expertise from the victim either through vaginal swab or through semen found at the site of the crime. Semen, blood, hair or nail sample is taken from the suspect (Ballantyne Jack *et al.*, 1991). Additionally, the separation of cells is done by geneticist so that sperm cells can be separated from women cells collected via vaginal swabs. Moving further, the DNA is determined



and fingerprints are matched with that of the suspect's to declare the real culprit. For instance, on July 6, 2017, a sixteen year old girl's body was found in a dense forest. The case was taken over by Central Bureau of Investigation. They reported that numerous marks were found over her body, she has been gang-raped and murdered. To find out the culprit, approximately 200 blood samples were taken from nearby areas and various items like liquor bottle and clothes collected from crime scene (Butler, John M. 2007). Initially, the team didn't get any lead then they did percentage and lineage test and luckily a match was found with a family from Kangra. Then, samples were collected from family and a boy named Anil was turned out to be the main culprit.

Nanotechnology in DNA analysis

The use of nanoparticles in the field of the research and development give rise to the term nanotechnology. Nanoparticle of titanium has already been widely used for the detection of drug cocaine which is illegal to consume and supply. They are also used for determination of various narcotic drugs given to the victims in case of murders, kidnapping and sexual assault. Nanoparticles can help to detect the drugs very effectively due to their high mobility, specificity and stability (Pandya *et*

al., 2018). For instance, gold nanoparticles (AuNPs) are used to increase the specificity of the polymerase chain reaction. In addition to the gold nanoparticles, the carbon nanotubes and the silver nanoparticles are also used to enhance the specificity of the PCR (Alonso *et al.*, 2004). Various other uses of nanoparticles in forensic analysis is discussed as follows –

- Creation of biosensors using nanoparticles in order to perform on the spot analysis to save time.
- Death time estimation with help of fluorescent nanoparticle which can determine the level of amino acid (Bruce R. *et al.*, 2019).
- Detection of codeine sulphate drug with help of citrate-stabilized gold nanoparticle smart camera and phone, this provide quick and qualitative results.
- Thin films analysis to be used for the biomedical purposes, it provides in depth analysis of the various samples collected from the crime scene (Rahiman *et al.*, 2010).
- In order to generate fluorescent in nature Nano-composites are used in combination to the hybrid calcium sulphide quantum dots, this fluorescent helps in the better analysis of the fingerprints of the DNA present on a surface and hence nanoparticles can be used to detect surface DNA prints. (Gill, P. 2001). **IJFMP**

Acknowledgment:

The author would like to thank all his colleagues and family who encouraged him to do this review.

Conflict of Interest:

The authors declare that there is no commercial or financial links that could be construed as conflict of interests.

Source of Funding: None

REFERENCES

1. **Alonso Antonio, Martín Pablo, Albarrán, Cristina, García, Pilar, García, Oscar, Simón, Lourdes, García-Hirschfeld, Julia, Sancho, Manuel, De la Rúa, Conchi, Fernandez-Piqueras, Jose.** Real-time PCR designs to estimate nuclear and mitochondrial DNA copy number in forensic and ancient DNA studies. *Forensic science international* 2004;139: 141-9.
 2. **Angers A, Kagkli D, Oliva L, Petrillo M, Raffael B.** Study on dna profiling technology for its implementation in the central schengen information system, EUR 29766 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-07983-5, doi:10.2760/13343, JRC116742.
 3. **Asplen Christopher H.** The application of DNA technology in England and Wales. *A Professional Services Corporation, Governmental Affairs Attorneys at Law* 2004;1-32.
 4. **Narajo Nabi, Avais Muhammad.** Examining the role of forensic science for the investigative – solution of crimes. *Sindh University Research Journal (Science Series)* 2012;44(2):251-254.
 5. **Ballantyne Jack et al.,** DNA technology and forensic science. *The American Journal of Human Genetics* 1991;48(1): 173–80.
 6. **Bhatt PV, Pandey G, Tharmavaram M, Rawtani D and Mustansar Hussain C.** Nanotechnology and taggant technology in forensic science. In: *Technology in Forensic Science* (eds D. Rawtani and C.M. Hussain) (2020); 279-301.
 7. **Bhushan Bharat, Singh Yashpal, Birla Joni.** Computer forensic technology. *International Journal of Engineering Research & Technology* 2015;3(10): 1–5.
 8. **Bruce R McCord et al.,** Forensic DNA analysis. *Analytical Chemistry* 2019;91(1): 673–88.
 9. **Budowle Bruce, Arthur J. Eisenberg, Angela Van Daal.** Validity of low copy number typing and applications to forensic science. *Croatian Medical Journal* 2009;50(3): 207–17.
 10. **Butler, John M.** Short tandem repeat typing technologies used in human identity testing. *BioTechniques* 2007;43(4).
 11. **Chaudhary, Jyoti.** A Review: Nanotechnology and forensic science. *World Journal of Pharmacy and Pharmaceutical Sciences* 2017;1(1): 540–48.
 12. **Chauhan Vivek, Singh Vandana, Tiwari Archana.** Applications of nanotechnology in forensic investigation. *International Journal of Life-Sciences Scientific Research* 2017;3(3): 1047–51.
 13. **Da Silva, Ricardo Henrique Alves et al.,** Use of DNA Technology in Forensic Dentistry." *Journal of Applied Oral Science* 2007;15(3): 156–61.
 14. **Gill P.** Application of Low Copy Number DNA Profiling. *Croatian Medical Journal* 2001;42(3): 229–32.
 15. **Hariprasad Paikrao, Dipale Ashlesha, Patil Anita, and Tajane Diksha.** Nano-Forensics a Comprehensive Review. *Forensic Science & Addiction Research* 2021;5(3): 411–13.
 16. **Ian Turner.** Applications of nanotechnology in forensic science. *NanoSD Avila (Spain)* 2014; 1.
 17. **John, Shanly J, Rajaji Divya, Jaleel Dafniya, Mohan Arun, Kadar Neethu, Venugopal Vidya.** Application of saliva in forensics. *Oral & Maxillofacial Pathology Journal* 2018;9(2): 85–87.
 18. **Kashyap VK, Sitalaximi, Chattopadhyay P, Trivedi R.** DNA profiling technologies in forensic analysis. *International Journal of Human Genetics* 2004;4(1): 11–30.
 19. **Lowe A, Murray C, Richardson P, Wivell R, Gill P, Tully G, Whitaker J.** Use of low copy number dna in forensic inference. *International Congress Series* 2003;1239: 799–801.
 20. **MacKnight Kamrin.** The Polymerase Chain Reaction (PCR): The second generation of dna analysis methods takes the stand. *Santa Clara High Technology Law Journal* 2004;20(1): 95.
 21. **Mateen, Rana Muhammad, Asma Tariq, and Mureed Hussain.** Generating Dna Profile from Low Copy Number Dna: Strategies and Associated Risks. *Acta Scientiarum- Biological Sciences* 2020;42: 1–7.
 22. **Murray C et al.,** Use of low copy number (lcn) dna in forensic inference. *Promega Proceedings* 2001; 2–7.
 23. **Pandya Alok, Shukla Ritesh K.** New perspective of nanotechnology: role in preventive forensic. *Egyptian Journal of Forensic Sciences* 2018; 8(1)57-68.
 24. **Rahiman Shaik, Nissankararao Praveena, Kumar.** Restriction fragment length polymorphism (RFLP) application in DNA typing for crime investigation. *Indian Journal of Forensic Medicine and Toxicology* 2010;4(1): 79–82.
 25. **Shukla Ritesh K.** Nanotechnology: An applied and robust approach for forensic investigation. *Forensic Research & Criminology International Journal* 2016;2(1): 35–37.
 26. **ThanakiatkraiPhuvadol, Thitika Kitpipit.** Current STR-based techniques in forensic science. *Maejo International Journal of Science and Technology* 2013;7(1): 1–15.
 27. **The Royal Society of Edinburgh.** 2017. *Forensic Dna Analysis: A Primer for Courts.* <https://royalsociety.org/-/media/about-us/programmes/science-and-law/royal-society-forensic-dna-analysis-primer-for-courts.pdf>.
 28. **Thotakura Sowmya.** Touch DNA: An investigative tool in forensic science article. *International Journal of Current Research* 2016;8(02): 26093–97.
 29. **Yang Yaran, Bingbing Xie, Jiangwei Yan.** Application of next-generation sequencing technology in forensic science. *Genomics, Proteomics and Bioinformatics* 2014;12(5): 190–97.
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