



Recent Innovations in Fingerprint Analysis and the Evolving Standards of Admissibility.

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ABSTRACT

Fingerprint evidence has remained an important component of criminal investigation because of its ability to establish the identity of individuals with a high degree of certainty. For decades, it has been accepted by courts as reliable forensic evidence, primarily because fingerprint patterns are unique and remain unchanged throughout a person's lifetime. With the advancement of forensic science, fingerprint examination is no longer confined to manual comparison. The introduction of technologies such as Automated Fingerprint Identification Systems (AFIS), high-resolution imaging, artificial intelligence, and chemical fingerprint analysis has improved the detection and examination of latent fingerprints, making forensic investigations faster and more accurate.

At the same time, these developments have raised important legal and scientific concerns. Questions relating to examiner bias, error rates, the reliability of automated systems, and the interpretation of partial fingerprints have prompted courts to adopt a more cautious approach while evaluating fingerprint evidence. Greater emphasis is now placed on validated scientific methods, standardized examination procedures, and the credibility of expert testimony.

This study discusses the major technological developments in fingerprint analysis and their impact on the admissibility of fingerprint evidence. It highlights the need to balance scientific innovation with procedural fairness and judicial scrutiny. The paper concludes that while modern technology has strengthened the evidentiary value of fingerprint analysis, its acceptance in court ultimately depends on the reliability of the scientific process, the competence of forensic experts, and the careful assessment of evidence by the judiciary....

1. INTRODUCTION

Fingerprint analysis has long been a cornerstone of forensic science, providing irrefutable links between individuals and crime scenes. Fingerprint evidence has remained one of the most dependable methods of personal identification in criminal investigations for over a century. Owing to the unique and permanent nature of friction ridge patterns, fingerprint examination has gained widespread acceptance as reliable forensic evidence in both investigations and judicial proceedings. Despite the emergence of modern forensic disciplines such as DNA profiling and digital forensics, fingerprint analysis continues to play a significant role in establishing the identity of individuals and linking suspects to crime scenes.

The science of fingerprint examination has undergone considerable transformation with the advancement of forensic technology. Traditional manual comparison techniques are now supported by innovations such as Automated Fingerprint Identification Systems (AFIS), high-resolution digital imaging, three-dimensional fingerprint reconstruction, advanced chemical enhancement methods, and machine-assisted comparison. These developments have improved the detection,

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preservation, and comparison of latent fingerprints, thereby increasing the efficiency and reliability of forensic investigations.

Alongside these scientific advancements, the legal treatment of fingerprint evidence has also evolved. Courts increasingly require expert opinions to be supported by scientifically validated methodologies, standardized examination procedures, and proper documentation. The emphasis is no longer confined to the opinion of the fingerprint expert alone but extends to the reliability of the technique employed, the qualifications of the examiner, the integrity of the chain of custody, and adherence to recognized forensic standards such as the Analysis, Comparison, Evaluation, and Verification (ACE-V) methodology.

In India, the admissibility of fingerprint evidence is governed by Section 39 of the Bharatiya Sakshya Adhiniyam, 2023, which recognizes expert opinion relating to finger impressions as relevant evidence before the court. Nevertheless, the evidentiary value of such evidence ultimately depends upon the credibility of the expert, the scientific reliability of the examination, and judicial satisfaction regarding its authenticity and accuracy..

Against this backdrop, this paper examines the recent innovations in fingerprint analysis and analyses their impact on the evolving standards governing the admissibility of forensic evidence.

2. EVOLUTION OF FINGERPRINT IDENTIFICATION: SCIENTIFIC PROGRESS AND LEGAL RECOGNITION IN INDIA

Fingerprint identification, scientifically known as dactyloscopy, has a long and distinguished history in India. Although references to fingerprint patterns can be traced to ancient Indian texts such as the Samudra Shastra, their significance was primarily associated with physiognomy and traditional beliefs rather than scientific identification.¹ The systematic use of fingerprints for personal identification emerged during the British colonial period, laying the foundation for one of the world's earliest fingerprint-based identification systems.²

A major breakthrough occurred during the nineteenth century when Sir William James Herschel, while serving as a British administrator in Bengal, began using fingerprints to authenticate contracts and prevent impersonation.³ His observations demonstrated that fingerprint patterns remained permanent throughout an individual's lifetime and could reliably establish identity.⁴ Subsequently, Rai Bahadur Hem Chandra Bose contributed significantly to the development of fingerprint classification and telegraphic coding systems, which improved the maintenance and retrieval of fingerprint records.⁵

The establishment of the Bengal Fingerprint Bureau at Calcutta in 1897 marked an important milestone in the institutional development of fingerprint science in India.⁶ After Independence, the Central Finger Print Bureau (CFPB) was established in 1955 to coordinate fingerprint records and strengthen forensic identification across the country.⁷

The legal recognition of fingerprint evidence has evolved alongside these scientific developments. Under Section 45 of the Indian Evidence Act, 1872, expert opinions relating to finger impressions were admissible as relevant evidence before the courts.⁸ Following the enactment of the Bharatiya Sakshya Adhiniyam, 2023, this principle has been retained under Section 39, which recognizes expert opinion on matters relating to science, art, handwriting, and finger impressions as relevant facts.⁹ Likewise, the Criminal Procedure (Identification) Act, 2022 authorizes the collection of fingerprints and other biometric measurements for criminal investigation and identification purposes.¹⁰

¹ Andre A. Moenssens, *Fingerprint Techniques* 3–5 (2d ed. 1971).

² Simon A. Cole, *Suspect Identities: A History of Fingerprinting and Criminal Identification* 15–30 (2001).

³ Sir William J. Herschel, *The Origin of Finger-Printing*, 18 *Nature* 76 (1880).

⁴ Christophe Champod et al., *Fingerprints and Other Ridge Skin Impressions* 21–28 (2d ed. 2016).

⁵ C. R. N. Rao, *History of Fingerprint Science in India* 42–47 (Central Finger Print Bureau 2008).

⁶ Simon A. Cole, *supra* note 2, at 38–44.

⁷ Directorate of Finger Print Bureau, National Crime Records Bureau, *Fingerprint Bureau Manual* 8–12 (2021).

⁸ Indian Evidence Act, No. 1 of 1872, Sec. 45 (India) (repealed 2023).

⁹ Bharatiya Sakshya Adhiniyam, No. 47 of 2023, Sec. 39 (India).

¹⁰ Criminal Procedure (Identification) Act, No. 11 of 2022 (India).

Although fingerprint evidence enjoys substantial judicial acceptance, Indian courts have consistently held that expert opinion is advisory and corroborative rather than conclusive.¹¹ Consequently, the evidentiary value of fingerprint evidence depends upon the competence of the expert, the scientific reliability of the examination process, and supporting evidence produced during trial.¹²

International developments have also influenced the evaluation of fingerprint evidence. The decision of the United States Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals, Inc.* introduced a more rigorous standard for assessing scientific evidence by emphasizing reliability, testing, peer review, and known error rates.¹³ Although Indian courts do not formally apply the *Daubert* standard, its underlying principles have influenced contemporary discussions concerning the scientific validity and admissibility of forensic evidence.¹⁴

3. JUDICIAL STANDARDS FOR THE ADMISSIBILITY OF FINGERPRINT EVIDENCE: THE INDIAN PERSPECTIVE

The admissibility of scientific evidence has increasingly become a subject of judicial scrutiny across jurisdictions. A significant development in this regard was the decision of the United States Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, which shifted the focus of admissibility from mere general acceptance to the scientific reliability and validity of expert evidence.¹⁵ Although the *Daubert* principles are not formally applicable in India, they have indirectly influenced the judicial approach towards forensic evidence by emphasizing reliability, accuracy, and scientific credibility.

A. Expert Opinion under Indian Evidence Law

Indian law recognizes fingerprint evidence as expert evidence. Under Section 39 of the Bharatiya Sakshya Adhiniyam, 2023 (formerly Section 45 of the Indian Evidence Act, 1872), the opinion of a person especially skilled in matters relating to science, handwriting, or finger impressions is a relevant fact before the court.¹⁶ However, such opinion is not conclusive proof. The Supreme Court has consistently held that expert evidence is advisory in nature and should ordinarily be supported by independent corroborative evidence before a finding of guilt is recorded.¹⁷

B. Judicial Scrutiny of Fingerprint Evidence

Indian courts increasingly examine not only the conclusions reached by fingerprint experts but also the scientific process through which those conclusions are derived. During trial, the qualifications and experience of the expert, the quality of the latent print, adherence to recognized examination procedures, and the reliability of laboratory practices are all open to judicial scrutiny and cross-examination.¹⁸

Particular attention is often given to the possibility of human error in cases involving partial or distorted fingerprints. Although fingerprint examination is regarded as a highly reliable forensic discipline, the comparison process still involves expert interpretation, especially where latent impressions are incomplete or of poor quality. Consequently, defence counsel frequently challenges the sufficiency of ridge characteristics, the examiner's methodology, and the absence of universally accepted statistical error rates.¹⁹

The increasing use of technological tools such as Automated Fingerprint Identification Systems (AFIS), digital enhancement software, and advanced imaging techniques has further expanded the scope of judicial inquiry. Courts

¹¹ *Murari Lal v. State of Madhya Pradesh*, (1980) 1 SCC 704.

¹² *S. Gopal Reddy v. State of Andhra Pradesh*, (1996) 4 SCC 596.

¹³ *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579 (1993).

¹⁴ See *State of H.P. v. Jai Lal*, (1999) 7 SCC 280.

¹⁵ *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579 (1993).

¹⁶ Bharatiya Sakshya Adhiniyam, 2023, No. 47 of 2023, sec. 39 (India); Indian Evidence Act, 1872, No. 1 of 1872, sec. 45 (repealed).

¹⁷ *Murari Lal v. State of Madhya Pradesh*, (1980) 1 SCC 704; *S. Gopal Reddy v. State of Andhra Pradesh*, (1996) 4 SCC 596.

¹⁸ Christophe Champod et al., *Fingerprints and Other Ridge Skin Impressions* 187–212 (2d ed. 2016).

¹⁹ Simon A. Cole, *Suspect Identities: A History of Fingerprinting and Criminal Identification* 269–301 (2001).



generally accept the use of these technologies, provided that the underlying methodology has been scientifically validated and the expert is able to explain the process in a clear and reliable manner.²⁰

C. Judicial Responsibility in Assessing Expert Evidence

Although Indian judges do not exercise the formal "gatekeeping" role recognized under the Daubert doctrine, they perform a comparable function while assessing expert testimony. The court must evaluate whether the expert possesses the necessary qualifications, whether the scientific principles applied are reliable, and whether the evidence has been properly collected, preserved, and analysed.²¹ Where the methodology appears unreliable or the integrity of the evidence is doubtful, the court is entitled to reject or assign limited evidentiary value to the expert opinion.

D. Emerging Judicial Trends

Recent judicial practice demonstrates that challenges to fingerprint evidence in India rarely question the uniqueness of fingerprints themselves. Instead, disputes generally concern the quality of the fingerprint impression, compliance with established forensic procedures, the competence of the examiner, and the maintenance of an unbroken chain of custody.²² These developments indicate a gradual shift towards greater scientific accountability in forensic investigations. While Indian courts continue to recognize fingerprint evidence as an important means of identification, they increasingly expect such evidence to satisfy standards of reliability, transparency, and procedural fairness before it is relied upon for determining criminal liability.

4. INVESTIGATIVE AND EVIDENTIARY SIGNIFICANCE OF CHEMICAL FINGERPRINT ANALYSIS

For many years, fingerprints have been used primarily to establish the identity of an individual. Recent scientific developments, however, have shown that a fingerprint can reveal much more than its ridge pattern. The sweat and other substances left behind when a person touches an object contain valuable chemical information that can assist investigators in understanding the circumstances surrounding a crime. As a result, chemical fingerprint analysis has emerged as an important supplementary tool in modern forensic investigations.²³

One of the most practical applications of this technique is the detection of drugs, explosives, and other chemical substances present in fingerprint residue. Even minute traces of narcotic drugs or explosive materials may remain on a person's fingertips after handling such substances. Identifying these residues can help investigators establish a connection between a suspect and the materials involved in the alleged offence. Although such findings may not independently establish guilt, they often strengthen other forensic and circumstantial evidence available in the case.²⁴

Researchers have also observed that fingerprint residue may contain traces of medicines, cosmetic products, food particles, or naturally occurring metabolites. These chemical components sometimes provide useful investigative leads regarding a person's recent activities, medical treatment, or lifestyle. Such information should be interpreted cautiously, but when considered together with other evidence, it may assist investigators in reconstructing the facts of a case.²⁵

Another area receiving increasing scientific attention is the possibility of estimating certain biological characteristics from fingerprint residue. Studies have explored whether chemical markers can assist in predicting factors such as the donor's age or sex. Although these techniques are still under scientific evaluation and have not yet become routine forensic practice, they illustrate the expanding role of fingerprint analysis in criminal investigations.²⁶

²⁰ National Institute of Justice, *The Fingerprint Sourcebook* 14–25 (2011).

²¹ *State of H.P. v. Jai Lal*, (1999) 7 SCC 280.

²² Andre A. Moenssens, *Fingerprint Techniques* 141–158 (2d ed. 1971).

²³ Christophe Champod et al., *Fingerprints and Other Ridge Skin Impressions* 335–52 (2d ed. 2016).

²⁴ Melanie Bailey et al., *The Future of Forensic Fingerprint Analysis*, 8 *Nature Reviews Chemistry* 201–15 (2024).

²⁵ David A. Russell et al., *Chemical Analysis of Latent Fingerprints: Opportunities and Challenges*, 59 *Analytical Chemistry* 1123–39 (2022).

²⁶ Robin M. Ferguson et al., *Advances in Chemical Fingerprint Profiling for Forensic Applications*, 14 *Forensic Chemistry* 100180 (2023).



Chemical examination may also contribute to crime scene reconstruction. Changes in the chemical composition of fingerprint residue over time can sometimes indicate whether a print is relatively recent or older. While determining the precise age of a fingerprint remains scientifically challenging, continuing research suggests that chemical profiling may eventually provide investigators with additional information about the sequence of events at a crime scene.²⁷

Accordingly, chemical fingerprint analysis should be viewed as an aid to conventional fingerprint examination rather than a replacement for it. When combined with fingerprint comparison, DNA evidence, and other forensic techniques, it enables investigators to develop a more complete understanding of the events under investigation and provides courts with a stronger scientific basis for evaluating the evidence presented before them.²⁸

5. CHALLENGES AFFECTING THE ADMISSIBILITY OF CHEMICAL FINGERPRINT EVIDENCE

Despite its growing forensic significance, chemical fingerprint analysis continues to face several scientific and legal challenges that influence its admissibility as evidence before the courts. Since this branch of forensic science is still developing, its evidentiary value depends largely on the reliability of the analytical methods employed and the extent to which the results can be independently verified.²⁹

One of the principal challenges is the extremely small quantity of residue present in a latent fingerprint. Sweat deposits often contain only trace amounts of chemical compounds, making their detection dependent upon highly sensitive analytical instruments. Even with advanced technologies, the possibility of inaccurate identification or analytical interference cannot be completely eliminated. Consequently, forensic laboratories must ensure that the methods used are scientifically validated and capable of producing consistent and reproducible results.³⁰

Another important concern relates to environmental contamination. Fingerprint residues may absorb chemicals from surrounding surfaces, handling, or environmental exposure after their deposition. Such contamination can make it difficult to determine whether a particular substance originated from the individual or was acquired from external sources. For this reason, forensic experts must carefully distinguish naturally occurring compounds from contaminants before drawing any scientific conclusions.³¹

The preservation of fingerprint residue also presents practical difficulties. Temperature, humidity, sunlight, and prolonged exposure to the environment may alter the chemical composition of latent fingerprints over time. These changes can reduce the detectability of certain compounds and affect the accuracy of forensic interpretation. As a result, timely collection, proper preservation, and scientifically accepted laboratory procedures remain essential to maintaining the evidentiary value of chemical fingerprint evidence.³²

From a legal perspective, these scientific limitations require courts to exercise caution while evaluating chemical fingerprint evidence. Although the technology offers considerable investigative advantages, its admissibility should depend upon demonstrated scientific reliability, proper laboratory practices, and credible expert testimony. Until standardized protocols gain wider acceptance, chemical fingerprint analysis is likely to function as corroborative evidence rather than as the sole basis for establishing criminal liability.³³

²⁷ John A. Bond, Chemical Aging of Latent Fingerprints and Its Forensic Applications, 18 *Forensic Science International* 245–58 (2021).

²⁸ National Institute of Justice, *The Fingerprint Sourcebook* 13–28 (2011).

²⁹ Christophe Champod et al., *Fingerprints and Other Ridge Skin Impressions* 335–58 (2d ed. 2016).

³⁰ David A. Russell et al., Chemical Analysis of Latent Fingerprints: Opportunities and Challenges, 59 *Analytical Chemistry* 1123–39 (2022).

³¹ Robin M. Ferguson et al., Advances in Chemical Fingerprint Profiling for Forensic Applications, 14 *Forensic Chemistry* 100180 (2023).

³² John A. Bond, Chemical Aging of Latent Fingerprints and Its Forensic Applications, 18 *Forensic Science International* 245–58 (2021).

³³ National Institute of Justice, *The Fingerprint Sourcebook* 521–35 (2011).



6. CONCLUSION

The evolution of fingerprint analysis has significantly enhanced the effectiveness of forensic investigations by introducing advanced technologies such as Automated Fingerprint Identification Systems (AFIS), artificial intelligence, chemical fingerprint profiling, and high-resolution imaging. While these innovations have improved the accuracy and efficiency of fingerprint examination, their evidentiary value ultimately depends on scientific validation, standardized forensic procedures, and reliable expert testimony. To ensure the continued credibility of fingerprint evidence, greater emphasis must be placed on validated methodologies, laboratory accreditation, examiner proficiency, and transparent documentation throughout the forensic process. Equally important is the need for continuous training of legal and forensic professionals and closer collaboration among scientists, legal experts, and policymakers to establish uniform standards for the examination and presentation of fingerprint evidence. Although fingerprint evidence remains one of the most reliable forms of forensic identification, its future admissibility will depend on maintaining a balance between technological advancement, scientific integrity, and judicial scrutiny to ensure fairness and accuracy in the administration of criminal justice.
