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# A Review of Some Recent Advances in the Use of Cheiloscopy and Dermatoglyphics for Forensic Investigations

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**Abstract**

The field of forensic investigation has advanced significantly, particularly in developed countries, with new technologies enhancing the reliability of human identification. This review highlights recent innovations in lip printing (cheiloscopy) and fingerprinting (dermatoglyphics), focusing on their application in forensic science. While dermatoglyphics remains a conventional method, cheiloscopy has emerged as a complementary, less conventional tool for investigation and research. Recent developments incorporate artificial intelligence (AI) and machine learning (ML) techniques, which have improved the accuracy and efficiency of forensic analyses. Multimodal biometric systems that integrate cheiloscopy and dermatoglyphics further reduce error rates and increase reliability, offering stronger fraud resistance. Despite these advancements, many developing countries have yet to fully adopt or master AI- and ML-based forensic tools, limiting their application in real-world investigations. The review concludes that integrating these technologies into forensic practice has the potential to significantly improve human identification, though challenges related to accessibility, expertise, and infrastructure must be addressed.

**Keywords:** Forensic; Cheiloscopy; Dermatoglyphics; Human Identification; Artificial Intelligence

## Introduction

Forensic science is continually evolving, with Cheiloscopy, the study of lip prints, emerging as a valuable tool for human identification, especially in developing countries where advanced technologies may be less accessible (Caputo *et al.,* 2018). Like fingerprints, lip prints have unique characteristics that can be used for individual identification, providing a distinct option when conventional methods such as dental records or DNA analysis are not feasible (Bandyopadhyay *et al*., 2013; Caldas *et al*., 2007). Traditionally, lip print examination relied on analog methods that are susceptible to human error and variability. However, recent technological breakthroughs have necessitated the integration of cutting-edge technologies like artificial intelligence, machine learning, and other digital forensic software in Cheiloscopy analysis to enhance the accuracy, reliability, reproducibility, and efficiency of lip print analysis, thus addressing previous limitations (Di Vita *et al*., 2025; Palakurthi *et al.,* 2023; Sandhya *et al.,* 2022).

Dermatoglyphics: the scientific study of epidermal ridge patterns found on fingers, palms, toes, and soles, has long been a cornerstone of forensic identification. These skin ridge patterns are formed during the 10th to 16th weeks of gestation and remain unaltered throughout a person's life, making them highly reliable biometric markers for individual identification. Forensic dermatoglyphics encompasses traditional fingerprinting, pattern-based classification, and increasingly, computational techniques such as deep learning and AI-based image restoration. Its multidisciplinary utility spans from criminal profiling and victim identification to anthropological investigations and genetic diagnostics.

In forensic medicine and mass disaster scenarios, dermatoglyphic patterns serve as a foundational tool for identity verification, especially when DNA or facial features are unrecognizable. Mahapatra *et al*., (2024), demonstrated that ridge density and digital pattern types show significant sexual dimorphism, enabling gender estimation with notable forensic implications. This form of biometric classification provides valuable corroborative evidence in situations where conventional identifiers are compromised (Mahapatra *et al*., 2024). The uniqueness and permanence of fingerprint patterns have enabled their use even in extreme post-mortem conditions. A notable advancement was presented by Cohen *et al.*, (2024), who successfully restored fingerprints from mummified remains using forensic dermatology techniques. This review also mentions the practical importance of dermatoglyphics in posthumous identifications where decomposition has obscured traditional biometrics (Cohen *et al.,* 2024).

**Artificial Intelligence (AI) and Machine Learning (ML)**

AI and Deep Learning for Automated Lip and Finger Print Recognition:

Recent work in AI has leveraged deep learning architectures, particularly Convolutional Neural Networks (CNNs) to automatically extract and analyze highly detailed features from lip print images (Maheswari *et al.*, 2024). These algorithms learn intricate spatial hierarchies through multilayer processing, similar to approaches successfully applied in lip reading and other image-based biometric tasks (Khapra *et al.,* 2024). By training on large, annotated datasets, deep learning models have demonstrated a capacity to differentiate subtle variations in textural and geometric features, thereby standardizing the recognition process while minimizing human intervention (Farrukh & Van der Haar, 2023; Sandhya *et al.,* 2022). This enhanced automation improves throughput in clinical screening and forensic investigations and establishes a benchmark for future research in biometric identification (Kalburgi *et al.,* 2023).

Machine Learning Models for Improved Lip Print Classification and Matching:

Complementary to deep learning approaches, conventional machine learning models have been effectively applied to pinpoint and match defining features in lip prints. Techniques such as Support Vector Machines (SVM), K-Nearest Neighbors (KNN), and various ensemble classifiers harness advanced feature extraction methods, like Local Binary Patterns (LBP), to quantify texture and shape information (Maheswari *et al.*, 2024; Sandhya *et al.,* 2022). Comparative analyses have indicated that combining traditional machine learning classifiers with deep convolutional features yields classification accuracies exceeding 90%, underscoring the efficacy of these hybrid systems (Khapra *et al.,* 2024; Farrukh and Van der Haar, 2023). Furthermore, these models facilitate rapid matching against forensic databases, enhancing identification reliability in clinical and security-related applications (Kalburgi *et al.,* 2023; Sandhya *et al.,* 2022).

Integrating AI and machine learning in lip print analysis represents a significant advancement in biometric identification. Deep learning models enable automated, high-throughput recognition of lip print features, while traditional machine learning classifiers enhance the precision of classification and matching processes. Continued research is necessary to validate these methodologies across diverse populations and operational contexts, promising improved accuracy, efficiency, and reliability for medico-legal and diagnostic applications.

Recent modalities in Artificial Intelligence (AI) and Machine Learning (ML) for dermatoglyphics

One of the most transformative trends in forensic dermatoglyphics is the adoption of artificial intelligence (AI), particularly deep learning. Traditional image-matching algorithms have limitations when prints are smudged, distorted, or partial conditions common in real-world investigations. To overcome this, researchers have developed Convolutional Neural Networks (CNNs) and Siamese networks capable of learning complex fingerprint features and improving classification accuracy. A notable innovation by Sawhney *et al.*, (2025) introduced a Siamese deep learning architecture combined with ResNet50 and multihead attention to match noisy or degraded fingerprint samples. The model achieved high precision in identifying prints with distortions, rotational variances, and poor contrast-common challenges in latent print analysis. Such AI-powered tools have not only improved identification accuracy but also reduced examiner bias by shifting analysis from subjective interpretation to algorithmic decision-making.

Additionally, Generative Adversarial Networks (GANs) have been employed to restore latent or partial fingerprints by generating plausible completions of missing ridge segments (Sankaran *et al.*, 2020). This helps recover valuable forensic information from compromised evidence.

On the radar are also Mobile, Edge-AI, and Real-Time Identification Systems. Recent advances in mobile biometric technology have enabled real-time fingerprint capture and matching in the field. Handheld fingerprint scanners integrated with cloud-based AFIS systems or on-device neural networks now allow border control agents, military personnel, and crime scene investigators to verify identities within seconds. These mobile systems are supported by edge AI architectures, which process biometric data locally on the device, enhancing response time and data privacy (Zhao, Li, & Lin, 2022). Moreover, integration with geolocation tagging and networked crime databases ensures that investigators can assess suspect histories or prior alerts instantly. This mobility is particularly valuable in disaster victim identification (DVI), border security, and counterterrorism operations where speed and reliability are critical.

In parallel with hardware innovations, forensic imaging software has advanced significantly. Modern tools offer automatic latent print enhancement, including contrast amplification, noise reduction, and ridge flow reconstruction. Techniques such as adaptive histogram equalization, Gabor filtering, and Fourier transform-based enhancement improve ridge visibility even under challenging conditions. Some systems also offer context-aware enhancement that adapts preprocessing based on background interference or surface texture, allowing prints lifted from curved, reflective, or multicolored surfaces to be processed with higher fidelity (Champod, Lennard, Margot, & Stoilovic, 2004). These tools, often integrated into AFIS platforms, bridge the gap between raw latent evidence and usable biometric data.

**Multimodal Biometric Systems**

Multimodal biometrics involve integrating multiple biometric traits to improve identification accuracy and security. By combining data from different sources, such as lip prints, fingerprints, and DNA, forensic investigators can cross-verify identities, reducing error rates and enhancing reliability (Jain *et al.,* 2020). Fusion can occur at various levels feature, score, or decision—allowing for flexible integration of biometric data. In forensics, this approach is particularly valuable due to the diverse nature of crime scene evidence.

Digital Forensic Software Integration and Advancements in 3D Cheiloscopy:

Modern digital forensic platforms now incorporate specialized modules for lip print analysis. High-resolution optical scanners such as the Medit i700 capture detailed 3D models of lip impressions. Furthermore, 3D intraoral imaging systems are used to acquire detailed lip print data, overcoming limitations of analog methods by minimizing material inconsistencies and operator-dependent error and achieving 70% average similarity between scans with a standard deviation of 0.229 mm (Di Vita *et al.,* 2025). Software solutions apply machine learning algorithms to encode lip groove patterns into digital formats, enabling forensic examiners to perform rapid and objective comparisons. This digital transformation not only refines the analysis of lip prints but also bridges the gap between traditional Cheiloscopy and a more integrated, data-driven forensic approach (Abedi *et al.,* 2020). Compared to fingerprint analysis and dental profiling, which have benefited from 3D technologies, 3D Cheiloscopy holds promise for similar advancements in forensic applications.

Just like lip prints, fingerprint recognition is increasingly part of multimodal biometric systems that include iris scans, facial recognition, gait analysis, and voice authentication. Dermatoglyphics provides a strong biometric anchor due to its invariance across time and resistance to environmental effects. In high-security domains such as banking, national ID verification, and military access control, combining fingerprints with other modalities improves accuracy, reduces spoofing risk, and enhances user trust (Maltoni, Maio, Jain, & Prabhakar, 2003).

### Artificial Intelligence and Machine Learning

The integration of machine learning (ML) and artificial intelligence (AI) into dermatoglyphic forensics represents a paradigm shift in how fingerprint data are processed and interpreted. Traditional manual methods, often prone to human error and subjective interpretation, are increasingly replaced by automated classification systems that detect minutiae features such as ridge endings and bifurcations. Convolutional Neural Networks (CNNs), in particular, have demonstrated high levels of precision in matching fingerprint images, even when degraded by noise, distortion, or partial loss (Kumar & Singla, 2015). These models learn hierarchical features of ridge patterns and enable rapid matching against large-scale fingerprint databases, dramatically reducing processing time and enhancing objectivity.

### 3D Imaging and Ridgeology

Advancements in three-dimensional imaging have added new analytical dimensions to the study of dermatoglyphics. Techniques like optical coherence tomography (OCT), structured light scanning, and photometric stereo imaging allow forensic experts to visualize not only the surface pattern of ridges but also their depth, curvature, and topographic variation. This is particularly beneficial in the analysis of deformed, stretched, or partial fingerprints, where traditional 2D imagery falls short (Champod *et al*., 2004). By reconstructing ridge structures volumetrically, forensic practitioners can conduct more nuanced comparisons, increasing the likelihood of accurate identifications.

Enhanced Latent Print Visualization Techniques

The recovery of latent fingerprints often invisible and left unintentionally at crime scenes has been significantly improved through advances in both chemical and physical enhancement methods. Notable techniques include nanomaterial-based powders, cyanoacrylate (superglue) fuming with fluorescent dyes, and vacuum metal deposition (VMD). These methods enhance ridge clarity while preserving the structural integrity of the print, enabling effective recovery from a wide range of surfaces including porous such as paper, non-porous such as glass and plastic, and wet environments (Champod *et al*., 2004). In practical terms, these methods expand the forensic applicability of dermatoglyphics to more complex and compromised crime scenes.

Cross-Disciplinary Applications and Multimodal Integration

Modern biometric systems are increasingly adopting multimodal frameworks that integrate a wide variety of biometric traits such as dermatoglyphics, Cheiloscopy, DNA profiling, facial recognition, and iris scanning. These integrated systems are more resilient to fraud; offer better performance under variable environmental conditions, and provide a higher degree of certainty in personal identification (Maltoni *et al*., 2003). In scenarios such as mass disaster victim identification or border control, where a single biometric trait may be compromised or unavailable, multimodal systems ensure that identification processes remain robust, inclusive, and error-tolerant.

Integration of Cheiloscopy with Other Biometric Techniques:

The integration of lip print data with other biometric modalities such as fingerprints, facial recognition, and DNA profiles, represents a significant advancement in digital forensic software. This multimodal approach enhances the robustness and reliability of identification systems by leveraging the unique strengths of each biometric trait (Han *et al.,* 2021; Singh, Singh, and Ross, 2019). Advanced AI algorithms facilitate pattern recognition across these diverse datasets, enabling comprehensive suspect profiling and matching even when individual identifiers are incomplete or degraded (Palakurthi *et al.,* 2023; Abedi *et al.,* 2020). This multimodal approach can significantly enhance case resolution, particularly in complex crime scenes and mass disaster scenarios where conventional methods may fall short (Sen *et al.,* 2023).

1. Combining Cheiloscopy with DNA: A significant way to combine Cheiloscopy with DNA analysis is through biological traces in lip prints. Lip prints often contain saliva, which can be swabbed and analyzed for DNA profiling. A study by Sharma *et al.* (2016) demonstrated that DNA could be extracted from lip prints on surfaces like tissue paper, cotton cloth, ceramic tiles, and glass, with successful typing of short tandem repeat (STR) loci in multiple samples (Sharma *et al.,* 2016). For example, in a 2017 case presented at the International Symposium on Human Identification, a lip print on a glass door was swabbed, yielding a full STR profile that matched a suspect in a database, confirming their identity (Sundquist, 2017). This dual approach leverages both the pattern-based identification of lip prints and the genetic identification of DNA, providing robust evidence.
2. Combining Cheiloscopy with Fingerprints:

   When lip prints and fingerprints are found on the same object, such as a drinking glass or document, both can be analyzed to confirm a suspect's identity. While there is limited research on the technical fusion of Cheiloscopy and dactyloscopy, forensic practice often involves cross-verifying these independent biometric results. For instance, a study exploring correlations between lip print and fingerprint patterns found that certain lip print types- for example, Type I- and fingerprint patterns such as whorl, were predominant in specific populations, suggesting potential for combined use in narrowing down suspects (Abidullah *et al.,* 2023). In practical scenarios, such as a burglary case in Poland (1985–1997), lip prints and other physical evidence, including fingerprints, were used together to aid identification (Hawkeye Forensic, 2023).

## Challenges and Limitations

Challenges and Limitations of the use of Cheiloscopy

Despite its potential, integrating lip print analysis into digital forensic systems faces several challenges. Standardizing lip print capture techniques, classification systems, and image processing protocols remains a critical concern. Variability in imaging conditions and differences across devices can affect data consistency, necessitating rigorous validation of digital algorithms (Di Vita *et al.,* 2025; Sen *et al.,* 2023). Environmental factors, such as cosmetics or lip conditions, can affect print quality, and the lack of standardized protocols and comprehensive databases limits their widespread use (Clove Dental, 2023). In contrast, fingerprints benefit from established standards, and DNA analysis requires intact samples, which may not always be available. Additionally, the admissibility of lip print evidence in court is debated due to limited scientific validation, though experts suggest it can be admissible with proper corroboration (Hawkeye Forensic, 2023).

While fingerprints and DNA are widely accepted in legal proceedings, the admissibility of Cheiloscopy remains controversial due to its lack of standardization. However, when combined with other biometrics, such as DNA from lip print, saliva, or corroborating fingerprints, its evidential weight increases. Forensic expert Professor Jay Siegel has noted that lip prints can be admissible with proper validation, particularly when supported by other evidence (Hawkeye Forensic, 2023).

Furthermore, as forensic systems become increasingly automated and reliant on AI, important ethical and legal challenges have emerged. These include concerns over data privacy, informed consent, and the potential for algorithmic bias. Biometric data, being inherently sensitive, require careful handling to avoid misuse or discrimination. Furthermore, the "black box" nature of many AI algorithms can complicate judicial transparency and challenge their admissibility in court if forensic experts cannot explain how decisions are derived (Rizwan, Naqvi, Fatima, & Qadir, 2014). Regulatory frameworks and forensic standards are therefore being updated to ensure that the implementation of dermatoglyphic AI adheres to principles of fairness, accountability, and transparency.

## Future Directions

Future research should focus on expanding forensic databases, refining cross-modal matching techniques, and establishing universal guidelines to ensure interoperability and data security.

Advancements in 3D cheiloscopy and digital methods, such as automated image processing, are addressing current limitations by improving precision and reducing subjectivity (Di Vita *et al.*, 2025). Future research could explore generating simulated lip prints from 3D models for comparative analyses with other biometric methods, enhancing integration into multimodal systems. Developing standardized databases and protocols for cheiloscopy will further its forensic utility, potentially aligning it with the reliability of fingerprints and DNA.

The field of forensic dermatoglyphics is equally gaining significant evolution due to rapid advancements in artificial intelligence, imaging technologies, and multimodal integration. These innovations not only improve the accuracy and speed of fingerprint analysis but also expand its applicability across diverse forensic scenarios. At the same time, ethical and legal concerns regarding the use of biometric data have gathered increasing attention, necessitating a balance between technological efficiency and human rights protections.

## Conclusion

The field of forensic science and the methods employed in crime scene investigation has evolved over time to achieve higher levels of accuracy and reliability. The use of AI and ML are at the fore fronts of this evolution. Print analysis, including cheiloscopy and dermatoglyphics remain a cornerstone  for identity have also evolved to more sophisticated, more reliable methods that have proven very efficient in human identification in complex crime scenarios that were difficult to solve in time past. Also multimodal approaches to crime solving as it pertains to individual identification have significantly enhanced their forensic utility, making them fraud- proof. Digital imaging, AI, 3D scanning, and improved visualization methods have collectively increased the reliability and scope of print analysis. There is a growing future for both cheiloscopy and dermatoglyphics especially when used with other modalities as multimodal frameworks. However, these advances do not come without their challenges and limitations. As technology continues to evolve, so too will the forensic applications of dermatoglyphics, making it an increasingly indispensable tool in modern investigations.

## References

1 Abedi, M., Afoakwah, C., and Bonsu, D. N. O. (2020). *Lip Print Enhancement: Review. Forensic Sciences Research,* 7 (1), 24–28.

2 Abidullah, M. (2023). Correlation among lip print pattern, fingerprint pattern and ABO blood group. *Journal of Pharmacy and Bio Allied Sciences*, 15(1), S27-S30.

3 Bandyopadhyay, S.K., Arunkumar, S., and Bhattacharjee, S. (2013). Feature extraction of human lip prints. *arXiv preprint arXiv:1312.0852*. https://arxiv.org/abs/1312.0852

4 Caldas, I. M., Magalhães, T., and Afonso, A. (2007). Establishing identity using cheiloscopy and palatoscopy. *Forensic Science International*, *165*(1), 1–9.

5 Caputo, I. G. C., Antonio, L. U., André, A. P. R., de Castro, M. G., Pinto, L. B., da Cunha, R. D., and Carvalho, M. S. O. A. (2018). Cheiloscopy in the human identification. *Forensic Research and Criminology International Journal*, 6(6), 371–374.

6 Champod, C., Lennard, C., Margot, P., & Stoilovic, M. (2004). Fingerprints and other ridge skin impressions. CRC Press.

7 Clove Dental. (2023). Cheiloscopy: A crucial technique in forensic science for personal identification. Retrieved from https://www.clovedental.in/blogs/cheiloscopy-a-crucial-technique-in-forensic-science/

8 Cohen, P. R., Abdulkarim, B., Wnuk, M., Sutton, L., & Others. (2024). Identification of decedents by restoring mummified fingerprints: Forensic dermatology in the investigation of mummy dermatoglyphics. *Clinics in Dermatology*. https://www.sciencedirect.com/science/article/pii/S0738081X24001858

9 Di Vita, E., Cacioppo, A., Sciarra, F. M., Messina, P., Cumbo, E. M., Caivano, G., Zerbo, S., Argo, A., Albano, G. D., and Scardina, G. A. (2025). Preliminary insights into 3D cheiloscopy for forensic applications: A pilot study. *Applied Sciences, 15*(4), 1726

10 Farrukh, W., and Van der Haar, D. (2023). *Lip print-based identification using traditional and deep learning. IET Biometrics*, 12(1), 1–12.

11 Han, Q., Yang, H., Weng, T., Chen, G., Liu, J., and Tian, Y. (2021). Multimodal identification based on fingerprint and face images via a hetero-associative memory method. Mathematics, 9(22), 2976.

12 Hawkeye Forensic. (2023). Cheiloscopy: Role in forensic investigations. Retrieved from https://hawkeyeforensic.com/2023/11/24/cheiloscopy-role-in-forensic-investigations/

13 Jain, J., Khanapure, S. C., Ananda, S. R., Supreetha, S., Abhishek, K. N., and Shilpa, M. (2020). Reliability of digitized cheiloscopy, dactyloscopy, and combination approach in gender identification. *Annals of Maxillofacial Research*, *10*(1), 5–10

14 Kalburgi, S., Lomte, V. M., Jain, N., Buge, A., and Kankal, S. (2023). A survey on lip reading recognition using artificial intelligence. *International Journal of Creative Research Thoughts (IJCRT)*, *11*(11).

15 Khapra, P., Agarwal, S., and Sharma, U. (2024). Deep learning for lip reading and speech recognition. *International Journal of Science, Engineering and Technology*, 12(1), 575–580.

16 Kumar, S., & Singla, R. (2015). A machine learning approach for dermatoglyphics analysis. *International Journal of Computer Applications, 121*(1), 6–12.

17 Mahapatra, N., Behura, S. S., Bhuyan, L., & Patra, M. (2024). Gender determination from ridges using dermatoglyphics techniques. *Journal of Forensic Medicine and Toxicology*. https://pmc.ncbi.nlm.nih.gov/articles/PMC11795458/

18 Maheswari, T. N. U., Bohra, A., and Sharuniveda, S. (2024). Pioneering a new frontier: Artificial intelligence (AI)-driven lip print pattern analysis—A systematic review. *Journal of Indian Academy of Oral Medicine and Radiology*, 36(3), 206–212.

19 Maltoni, D., Maio, D., Jain, A. K., & Prabhakar, S. (2003). Handbook of fingerprint recognition. Springer.

20 Palakurthi, N., Priyanka, G. V., Narayen, V., Sowmya, P., and Veenila. (2023). Cheiloscopy: Scope in forensics, classification systems and limitations. *International Journal of Novel Research and Development, 8*(4), 572–578.

21 Palakurthi, S., Reddy, P. S., and Kumar, V. (2023). Comparative analysis of machine learning algorithms for lip print-based person identification. *International Journal of Computer Applications*, *182*(1), 1–5.

22 Rizwan, M., Qazi, R., & Farooq, M. (2014). Dermatoglyphics in schizophrenia: A review. *International Journal of Research in Medical Sciences, 2*(4), 1236–1241.

23 Sandhya, D., and Daware, S. (2012). A study of digital forensics: Process and tools. In *Proceedings of the 2nd National Conference on Innovative Paradigms in Engineering and Technology (NCIPET 2013)* (pp. 29–31). Foundation of Computer Science (FCS), NY, USA. https://ijcaonline.org/proceedings/ncipet/number10/5267-1079/

24 Sandhya, S., Fernandes, R., Sapna, S., and Rodrigues, A. P. (2022). Comparative analysis of machine learning algorithms for lip print-based person identification. *Evolutionary Intelligence*. https://doi.org/10.1007/s12065-022-00775-7:

25 Sankaran, A., Alhindi, T., Ross, A., & Ho, J. (2020). Enhancing the quality of latent fingerprints using generative adversarial networks. *IEEE Transactions on Information Forensics and Security, 15*, 3640–3655. https://doi.org/10.1109/TIFS.2020.2990944

26 Sen, S., Ghosh, K., Chattopadhyay, J., Bhattacharya, M., Bose, S., and Shetty, R. (2023). Cheiloscopy: A diagnostic aid in forensic science to differentiate between smokers and non-smokers. *IOSR Journal of Dental and Medical Sciences, 22*(11), 25–30.

27 Sen, S., Rani, M., Dillon, D. J., and Sunil. (2023). Lip print analysis: A study on patterns and forensic applications. *Indian Journal of Forensic Medicine and Toxicology,* 18(4), 69-74.

28 Sharma, P., Sharma, N., Wadhwan, V., and Aggarwal, P. (2016). Can lip prints provide biological evidence? *Journal of Forensic Dental Sciences*, 8(3), 175-178.

29 Singh, M., Singh, R., and Ross, A. (2019). A comprehensive overview of biometric fusion. *arXiv preprint arXiv:1902.02919*. https://arxiv.org/abs/1902.02919

30 Sundquist, T. (2017). *DNA evidence from lip prints and used cups: Interesting cases from the International Symposium on Human Identification. Part I.* ISHI News. https://www.ishinews.com/dna-evidence-from-lip-prints-and-used-cups-interesting-cases-from-the-international-symposium-on-human-identification-part-i/

31 Sawhney, T., Sharma, A., Abrol, P., & Lehana, P. K. (2025). Fingerprint matching for noisy and distorted patterns using a Siamese network with ResNet50 and multihead attention. *IEEE Transactions on Computational Intelligence and AI in Forensics*. https://ieeexplore.ieee.org/abstract/document/10988862

32 Zhao, H., Li, C., & Lin, J. (2022). Edge-AI framework for real-time biometric authentication in mobile forensic systems. *Forensic Science International: Digital Investigation, 41*, 301120. https://doi.org/10.1016/j.fsidi.2022.301120