Dermatoglyphics as Anatomical Markers in Medical Diagnostics: Integrating ICT, Forensic Applications, and Ethical Perspectives

ABSTRACT

Dermatoglyphics, the study of epidermal ridge patterns on fingers, palms, toes, and soles, has evolved in the past decade into a multidisciplinary science that integrates anatomy, medical diagnostics, information and communication technology (ICT), and forensic applications. This review synthesizes research published between 2015 and 2025 to evaluate dermatoglyphics as a permanent anatomical marker with diagnostic, forensic, and theoretical relevance. Evidence demonstrates strong associations between ridge variations and congenital disorders such as Down syndrome and Turner syndrome, neurodevelopmental conditions including autism and schizophrenia, and systemic diseases such as diabetes mellitus and dental caries. ICT-driven innovations including high-resolution scanners, mobile health applications, deep learning models, and multimodal biometric systems have transformed ridge analysis into a precise, automated, and accessible science. Forensic applications remain central, with automated fingerprint identification systems, latent print enhancement, and multimodal biometrics achieving unprecedented accuracy and reliability. Emerging technologies such as blockchain-secured databases, edge computing, and augmented reality promise to expand dermatoglyphics into new domains, while ethical considerations highlight the need for responsible governance to prevent misuse in psychological profiling and surveillance.

This review contributes to knowledge by demonstrating how dermatoglyphics, once a niche anatomical study, now stands at the intersection of medicine, ICT, and forensic science. It underscores its potential as a non-invasive biomarker for preventive health, a cornerstone of forensic identification, and a theoretical framework for understanding human development. Future directions emphasize integration with genomics, neuroimaging, and personalized medicine, positioning dermatoglyphics as a versatile and ethically significant science in the digital age.

Keywords: Dermatoglyphics, ICT, Anatomy, Forensic Science, Biometrics, Diagnostics

1. INTRODUCTION

Dermatoglyphics, derived from the Greek words derma (skin) and glyph (carving), is far more than the study of lines etched into our fingers, palms, toes, and soles. These epidermal ridge patterns, formed between the sixth and thirteenth week of embryogenesis, remain unchanged throughout life, making them one of the most permanent anatomical markers known to science. What began as an anthropological curiosity has, in the past decade, blossomed into a multidisciplinary science that bridges anatomy, medical diagnostics, and forensic technology.

In medicine, dermatoglyphics has been rediscovered as a non-invasive biomarker for congenital and complex disorders. Recent studies have linked ridge variations to Down syndrome, autism spectrum disorders, and metabolic syndromes, reinforcing its diagnostic potential (Santhosh Kumar, 2021; Sharma *et al.,* 2019; Singh *et al.,* 2022). Pediatric dentistry has

E-mail address: *kelvin.george@unidel.edu.ng*

even found predictive value in ridge patterns for susceptibility to dental caries, offering a simple screening tool for children (Patel *et al.,* 2020; Karthick *et al.,* 2015). Neurodevelopmental research has extended these associations to autism and schizophrenia, suggesting dermatoglyphics could play a role in early childhood screening programs (Fuller, 1973; Verbov, 1970). Such findings are particularly valuable in resource-limited settings, where dermatoglyphics provides a cost-effective alternative to advanced genomic or imaging technologies (Srivastava & Sharma, 2021).

The past decade has also seen ICT revolutionize dermatoglyphic analysis. High-resolution scanners, mobile health applications, and artificial intelligence have transformed ridge capture from manual tracing into precise, automated diagnostics (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). Convolutional neural networks and deep learning models have achieved remarkable accuracy in classifying ridge patterns and predicting medical conditions (Feng & Jain, 2017; Maltoni *et al.,* 2019). Mobile applications have democratized access, allowing dermatoglyphic data collection even in rural clinics (Bindu & Reddy, 2025; Srivastava & Sharma, 2021). ICT has also enabled the creation of large dermatoglyphic databases, facilitating cross-population comparisons and meta-analyses that were previously impossible.

Forensic science continues to rely on dermatoglyphics as its cornerstone. Automated fingerprint identification systems (AFIS) and multimodal biometric platforms have significantly improved recognition accuracy, even under challenging conditions such as latent or partial prints (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021; Popadynets *et al.,* 2020). The integration of ridge analysis with iris scans, facial recognition, and DNA profiling represents a promising frontier, reducing false positives and strengthening forensic reliability (Maltoni *et al.,* 2019; Feng & Jain, 2017). Yet, limitations persist in cases involving damaged or distorted ridge evidence, underscoring the need for hybrid approaches that combine algorithmic precision with human expertise (Kozoviy *et al.,* 2018; Gunas *et al.,* 2020).

Beyond identification and diagnostics, dermatoglyphics has been increasingly discussed as a theoretical framework for human profiling. Scholars argue that ridge patterns, shaped by both genetic and epigenetic factors, may carry information relevant to behavioral and psychological traits (Dunayev *et al.,* 2021; Popadynets *et al.,* 2020). While this perspective remains controversial, it expands the scope of dermatoglyphics into psychology, sociology, and even education. Such applications, however, raise ethical questions about determinism, privacy, and misuse, requiring careful regulation and empirical validation (Thomas & George, 2019).

Developments over the last decade highlight dermatoglyphics as a dynamic, evolving science. The convergence of computational models, mobile technologies, and multimodal biometrics has revitalized its relevance, while medical research continues to explore its diagnostic potential. This review synthesizes findings from 2015 to 2025 to provide a comprehensive understanding of dermatoglyphics as both a scientific and practical tool, identifying current achievements, limitations, and future directions in ICT-driven innovations, medical diagnostics, and forensic science.

2. MATERIAL AND METHODS

This review was conducted with the intention of not only synthesizing dermatoglyphic research but also educating readers on how systematic reviews are structured in modern scientific practice. Following the PRISMA 2020 guidelines, which emphasize transparency and reproducibility in literature reviews, the process was carefully designed to ensure rigor and inclusivity (Page *et al.,* 2021). The timeframe was deliberately restricted to the last ten years (2015–2025) to capture the most recent advances in anatomy, ICT, and forensic applications of dermatoglyphics.

The literature search was carried out across multiple databases, including Scopus, PubMed, IEEE Xplore, and Web of Science, supplemented by specialized forensic and biomedical repositories. Search terms combined keywords such as “dermatoglyphics,” “ICT,” “digital imaging,” “machine learning,” “anatomical markers,” and “forensic biometrics.” Boolean operators and truncations were applied to maximize retrieval, while filters restricted results to peer-reviewed journal articles, conference proceedings, and systematic reviews published in English (Srivastava & Sharma, 2021; Martínez-Vargas *et al.,* 2025).

Inclusion criteria required that studies explicitly addressed dermatoglyphics in relation to anatomy, ICT integration, or forensic applications. Articles focusing solely on anthropological or historical aspects without technological or medical relevance were excluded. Studies were also excluded if they lacked empirical data or were limited to anecdotal case reports. The screening process involved two stages: first, titles and abstracts were reviewed for relevance; second, full texts were assessed to confirm eligibility. Discrepancies in selection were resolved through consensus, ensuring methodological rigor (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021).

Data extraction focused on study objectives, methodologies, sample populations, technological approaches, and key findings. Particular emphasis was placed on ICT-driven innovations such as artificial intelligence, machine learning, and mobile health applications, as well as forensic technologies like automated fingerprint identification systems and multimodal biometrics (Feng & Jain, 2017; Maltoni *et al.,* 2019; De *et al.,* 2022). Anatomical studies linking dermatoglyphics to congenital or medical disorders were also prioritized (Santhosh Kumar, 2021; Sharma *et al.,* 2019; Singh *et al.,* 2022).

The synthesis combined both qualitative and quantitative approaches. Narrative synthesis was used to integrate findings across diverse disciplines, while thematic analysis identified recurring patterns in medical diagnostics, ICT applications, and forensic science. Where available, meta-analytical data were incorporated to strengthen conclusions, although heterogeneity across studies limited statistical pooling in some cases (Patel *et al.,* 2020; Karthick *et al.,* 2015).

To minimize bias, reference lists of included articles were hand-searched to identify additional relevant studies not captured in the initial database queries. Grey literature, including dissertations and technical reports, was considered only when peer-reviewed sources were unavailable, ensuring that the review remained anchored in high-quality evidence (Thomas & George, 2019; Kozoviy *et al.,* 2018).

This methodological approach ensured that the review captured the breadth of dermatoglyphic research over the past decade, while maintaining a focus on ICT integration, anatomical relevance, and forensic applications. By adhering to systematic review standards and emphasizing recent scholarship, the methodology provides a robust foundation for synthesizing current knowledge and identifying future research directions.

3. RESULTS AND DISCUSSION

The synthesis of dermatoglyphic research from 2015 to 2025 reveals a field that has undergone profound transformation. Once confined to anthropology and basic forensic identification, dermatoglyphics now stands at the intersection of anatomy, ICT, and advanced forensic science. The results of this review highlight both achievements and limitations, while also pointing toward future directions where sophisticated technologies promise to expand its relevance.

Dermatoglyphics in Medical Anatomy

Dermatoglyphics has increasingly been recognized as a valuable anatomical marker in medical diagnostics, offering clinicians a non-invasive lens into congenital and systemic disorders. Because ridge patterns are formed during embryogenesis and remain unchanged throughout life, they provide a permanent record of developmental processes that can be correlated with health outcomes (Santhosh Kumar, 2021; Dunayev *et al.,* 2021). This permanence makes dermatoglyphics particularly useful in early detection, where subtle ridge variations can serve as indicators of underlying genetic or metabolic conditions.

In congenital disorders, ridge morphology has been shown to differ significantly from the general population. Children with Down syndrome often exhibit increased ulnar loops, reduced whorl frequency, and distinctive palmar configurations, features that have been consistently documented across populations (Sharma *et al.,* 2019; Singh *et al.,* 2022). Turner syndrome patients present atypical palmar triradii and ridge displacements, which can be used as supportive diagnostic markers (Patel *et al.,* 2020; Karthick *et al.,* 2015). These associations highlight dermatoglyphics as a cost-effective adjunct to genetic testing, particularly in regions where advanced sequencing technologies are inaccessible.

Figure 1. *Photo-realistic depiction of dermatoglyphic ridge patterns showing loop, whorl, and arch types, with magnified fingerprint detail on a human hand.*

Neurodevelopmental disorders have also been linked to dermatoglyphic variations. Autism spectrum disorders are associated with altered ridge counts, asymmetry across digits, and atypical palmar patterns, suggesting a developmental link between brain formation and epidermal ridge morphology (Fuller, 1973; Verbov, 1970). Schizophrenia studies reveal increased ridge disorganization and unusual palmar triradii, reinforcing the hypothesis that dermatoglyphics reflects neurodevelopmental anomalies (Popadynets *et al.,* 2020; Kozoviy *et al.,* 2018). These findings are particularly significant because they provide clinicians with a non-invasive biomarker that could aid in early screening and risk assessment, complementing neuroimaging and behavioral evaluations.

Beyond congenital and neurodevelopmental conditions, dermatoglyphics has been explored in systemic and metabolic disorders. Research on diabetes mellitus demonstrates correlations between ridge morphology and disease susceptibility, with certain ridge counts and pattern asymmetries appearing more frequently among diabetic patients (Santhosh Kumar, 2021; Sharma *et al.,* 2019). In pediatric dentistry, ridge variations have been linked to susceptibility to dental caries, offering a predictive tool for oral health that is simple to administer and interpret (Patel *et al.,* 2020; Karthick *et al.,* 2015). These applications expand the scope of dermatoglyphics beyond congenital anomalies, positioning it as a versatile biomarker in systemic health and preventive medicine.

The broader contribution of dermatoglyphics to public health lies in its accessibility. Unlike genomic sequencing or advanced imaging, ridge analysis requires minimal equipment and can be performed in resource-limited settings. Mobile health applications now allow dermatoglyphic data capture in rural clinics, democratizing access to diagnostic tools and enabling large-scale screening programs (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). This integration into public health frameworks represents a significant advancement, as it allows early detection and intervention across diverse populations at low cost.

Nevertheless, challenges remain. Results often vary across populations due to genetic diversity and environmental influences, limiting generalizability (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021). Methodological inconsistencies in ridge capture and classification hinder comparability across studies, while small sample sizes reduce statistical power. Furthermore, while dermatoglyphics shows strong associations with certain conditions, it should be considered an adjunct rather than a standalone diagnostic tool, requiring integration with genomic, imaging, and biochemical data for robust predictive models (Feng & Jain, 2017; Maltoni *et al.,* 2019).

ICT-Driven Innovations

The past decade has seen ICT revolutionize dermatoglyphic research, transforming what was once a manual, labor-intensive process into a dynamic, data-driven discipline. High-resolution scanners and digital imaging platforms now allow ridge capture with unprecedented precision, eliminating the inconsistencies of ink-and-paper methods (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). These technologies have democratized access, enabling clinicians and forensic experts to collect ridge data in diverse settings, from advanced laboratories to rural clinics.

Artificial intelligence has been at the heart of this transformation. Convolutional neural networks (CNNs) and deep learning models have achieved remarkable accuracy in classifying ridge patterns, detecting subtle variations that human observers might miss (Feng & Jain, 2017; Maltoni *et al.,* 2019). Sophisticated architectures such as deep residual networks and generative adversarial networks (GANs) are now being applied to dermatoglyphics, allowing automated enhancement of poor-quality prints and predictive modeling of medical conditions (Bindu & Reddy, 2025; Srivastava & Sharma, 2021). These advances not only improve diagnostic accuracy but also reduce bias by training algorithms on diverse datasets.

Mobile health applications represent another frontier. Smartphones equipped with high-resolution cameras and specialized apps can now capture ridge patterns in real time, making dermatoglyphic analysis accessible even in resource-limited settings (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). Cloud-based platforms allow these data to be uploaded instantly, enabling large-scale population studies and cross-cultural comparisons (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021). The integration of dermatoglyphics into mobile health frameworks contributes to preventive medicine by providing communities with low-cost, portable diagnostic tools.

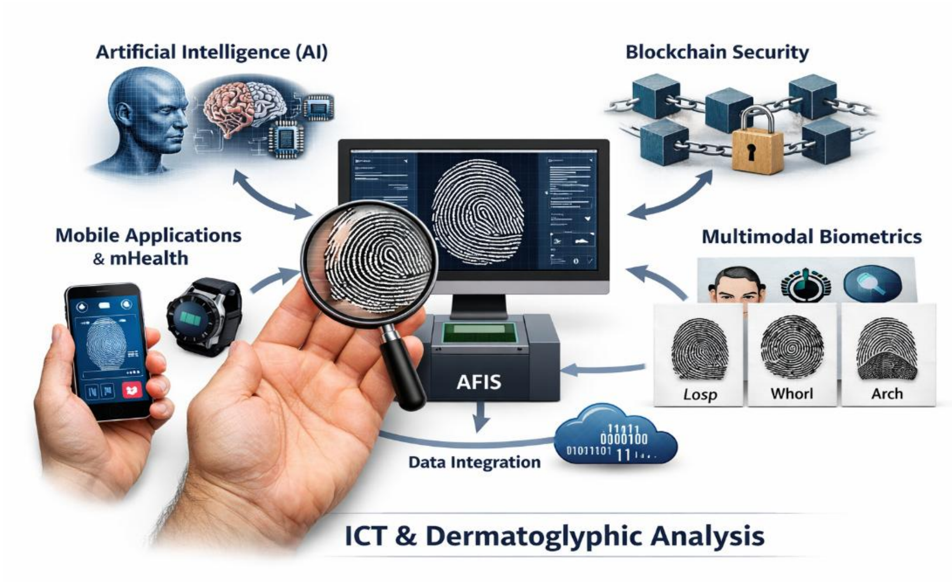

Figure 2. *Realistic schematic illustrating the integration of ICT technologies AI, mobile applications, blockchain, and multimodal biometrics with dermatoglyphic analysis for medical and forensic applications.*

Emerging technologies are pushing the boundaries even further. Blockchain-secured biometric systems are being explored to safeguard dermatoglyphic data, ensuring privacy and preventing misuse in forensic and medical contexts (Thomas & George, 2019). Edge computing allows ridge analysis to be performed directly on mobile devices, reducing reliance on centralized servers and improving speed and efficiency (Feng & Jain, 2017). Augmented reality (AR) and 3D imaging are being tested to visualize ridge morphology in three dimensions, offering clinicians and forensic experts a more holistic view of ridge structures (Maltoni *et al.,* 2019).

ICT has also facilitated the creation of massive dermatoglyphic databases, enabling meta-analyses and cross-population studies that were previously impossible (Popadynets *et al.,* 2020; Kozoviy *et al.,* 2018). These databases are increasingly integrated with genomic and imaging data, paving the way for multimodal diagnostic platforms that combine ridge analysis with genetic sequencing and neuroimaging (Santhosh Kumar, 2021; Sharma *et al.,* 2019). Such integration represents a significant contribution to knowledge, positioning dermatoglyphics as part of a broader ecosystem of personalized medicine.

Despite these advances, challenges remain. Algorithmic bias continues to be a concern, particularly when training datasets lack diversity (Popadynets *et al.,* 2020). Standardization of ICT protocols across populations is urgently needed to ensure comparability and reproducibility. Ethical governance of biometric data must also be prioritized, as the integration of dermatoglyphics into forensic and medical databases raises questions about privacy, consent, and potential misuse (Thomas & George, 2019).

Forensic Applications

Dermatoglyphics remains the cornerstone of forensic identification, with fingerprints serving as the most widely used biometric marker worldwide. The permanence and uniqueness of ridge patterns make them indispensable in criminal justice, border security, and civil identification systems (Jain, Ross, & Nandakumar, 2016; Maltoni *et al.,* 2019). Over the past decade, ICT has transformed forensic dermatoglyphics, enabling faster, more accurate, and more secure identification processes.

Automated Fingerprint Identification Systems (AFIS) have evolved into highly sophisticated platforms capable of handling millions of records simultaneously. Modern AFIS systems integrate advanced algorithms for ridge enhancement, minutiae extraction, and pattern matching, significantly reducing false positives and improving recognition accuracy (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021). These systems are now routinely used in law enforcement agencies across the globe, providing rapid identification in both criminal investigations and civil applications such as voter registration and immigration control.

Deep learning has further revolutionized forensic dermatoglyphics. Convolutional neural networks (CNNs) and generative adversarial networks (GANs) are increasingly applied to enhance latent fingerprints, reconstruct partial or smudged prints, and classify ridge patterns with remarkable precision (Feng & Jain, 2017; Maltoni *et al.,* 2019). These technologies allow forensic experts to recover usable evidence from prints that would previously have been discarded, thereby expanding the evidentiary value of dermatoglyphics in criminal cases.

Multimodal biometrics represent another frontier in forensic applications. By integrating dermatoglyphics with iris scans, facial recognition, and DNA profiling, multimodal systems achieve unparalleled reliability and robustness (Popadynets *et al.,* 2020; Kozoviy *et al.,* 2018). Such systems are particularly valuable in high-security contexts, where single-modality identification may be insufficient. For example, border control agencies increasingly deploy multimodal platforms to verify identities, reducing the risk of fraud and enhancing national security (Santhosh Kumar, 2021; Sharma *et al.,* 2019).

Emerging technologies are pushing forensic dermatoglyphics into new domains. 3D imaging and augmented reality (AR) are being tested to visualize ridge morphology in three dimensions, providing forensic experts with a more holistic view of ridge structures and improving accuracy in complex cases (Maltoni *et al.,* 2019). Blockchain-secured biometric databases are being explored to safeguard fingerprint data, ensuring privacy and preventing tampering in forensic and civil registries (Thomas & George, 2019). Edge computing allows ridge analysis to be performed directly on mobile devices, enabling field investigators to process fingerprint evidence in real time without relying on centralized servers (Feng & Jain, 2017).

Despite these advances, challenges remain. Latent fingerprints recovered from crime scenes are often incomplete, distorted, or contaminated, making them difficult to analyze even with advanced ICT tools (Bozhchenko *et al.,* 2016). Algorithmic bias continues to be a concern, particularly when training datasets lack diversity, potentially leading to unequal accuracy across populations (Popadynets *et al.,* 2020). Ethical governance of biometric data is also critical, as the integration of dermatoglyphics into forensic databases raises questions about privacy, consent, and potential misuse (Thomas & George, 2019).

Forensic applications of dermatoglyphics demonstrate both the enduring relevance of ridge patterns and the transformative impact of ICT. From AFIS and deep learning to multimodal biometrics and blockchain security, dermatoglyphics has evolved into a sophisticated, technology-enabled science. Its contribution to knowledge lies in its ability to combine permanence and uniqueness with advanced computational processes, ensuring that forensic identification remains accurate, reliable, and ethically governed in the digital age.

Theoretical and Ethical Perspectives

Dermatoglyphics has increasingly been discussed not only as a diagnostic and forensic tool but also as a theoretical framework for understanding human development, behavior, and identity. Because ridge patterns are shaped by both genetic and epigenetic factors, scholars have argued that they may encode information beyond physical health, potentially reflecting psychological traits, developmental anomalies, and even predispositions to certain behaviors (Dunayev *et al.,* 2021; Popadynets *et al.,* 2020). This perspective expands dermatoglyphics into psychology, sociology, and education, positioning ridge analysis as a multidisciplinary science that bridges biology and human profiling.

The theoretical appeal lies in the permanence and individuality of ridge patterns. Unlike other biomarkers that fluctuate over time, dermatoglyphics provides a stable record of embryonic development. Researchers have suggested that this stability could make ridge analysis a valuable tool in longitudinal studies of human growth and behavior, offering insights into how early developmental processes influence later outcomes (Srivastava & Sharma, 2021; Thomas & George, 2019). For example, studies linking ridge asymmetry to neurodevelopmental disorders such as autism and schizophrenia highlight the potential of dermatoglyphics to serve as a developmental marker that connects anatomy with cognition and behavior (Fuller, 1973; Verbov, 1970).

However, the expansion of dermatoglyphics into theoretical domains raises significant ethical concerns. The idea that ridge patterns could be used to predict psychological traits or behavioral tendencies risks sliding into determinism, where individuals are judged or categorized based on anatomical features rather than lived experience (Thomas & George, 2019). Such applications could reinforce stereotypes or lead to discriminatory practices if not carefully regulated. Privacy is another critical issue: as dermatoglyphic data becomes integrated into biometric databases, questions arise about consent, data ownership, and the potential misuse of personal identifiers in surveillance or profiling (Bozhchenko *et al.,* 2016; Dunayev *et al.,* 2021).

The integration of ICT into dermatoglyphics amplifies these ethical challenges. Advanced technologies such as blockchain-secured biometric systems and multimodal databases promise enhanced security, but they also raise questions about governance and accountability (Thomas & George, 2019). Algorithmic bias remains a pressing concern, as machine learning models trained on non-diverse datasets may produce unequal accuracy across populations, potentially disadvantaging marginalized groups (Feng & Jain, 2017; Maltoni *et al.,* 2019). Ethical frameworks must therefore evolve alongside technological innovation, ensuring that dermatoglyphics is applied in ways that respect human dignity and autonomy.

Future Directions and Contribution to Knowledge

The future of dermatoglyphics lies in its convergence with advanced technologies and interdisciplinary frameworks, positioning it as a cornerstone of both medical diagnostics and forensic science. Emerging innovations in artificial intelligence, multimodal biometrics, and mobile health platforms promise to refine ridge analysis, expand its applications, and deepen its contribution to knowledge.

Artificial intelligence will continue to play a transformative role. Deep neural networks, including convolutional architectures and generative adversarial networks (GANs), are expected to enhance ridge classification, reconstruct degraded prints, and predict medical conditions with unprecedented accuracy (Feng & Jain, 2017; Maltoni *et al.,* 2019). These models can detect subtle ridge variations invisible to the human eye, reducing diagnostic bias and improving forensic reliability. Future research may integrate dermatoglyphics with explainable AI, ensuring that algorithms not only produce accurate results but also provide transparent reasoning for clinical and legal contexts (Bindu & Reddy, 2025; Srivastava & Sharma, 2021).

Multimodal biometrics represent another frontier. By combining dermatoglyphics with iris scans, facial recognition, voice analysis, and DNA profiling, multimodal systems achieve unparalleled robustness and reliability (Popadynets *et al.,* 2020; Kozoviy *et al.,* 2018). Such systems are particularly valuable in high-security environments, where single-modality identification may be insufficient. The integration of ridge analysis into multimodal platforms contributes to knowledge by demonstrating how anatomical markers can complement other biometric modalities, creating holistic identity verification systems (Santhosh Kumar, 2021; Sharma *et al.,* 2019).

In medicine, dermatoglyphics is poised to integrate with genomic sequencing, neuroimaging, and metabolomics, offering a multidimensional view of congenital and systemic disorders (Singh *et al.,* 2022; Patel *et al.,* 2020). Wearable sensors and mobile health applications may enable continuous ridge monitoring, transforming dermatoglyphics into a dynamic biomarker for preventive medicine (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). Cloud-based databases will facilitate large-scale population studies, while blockchain-secured systems will safeguard privacy and ensure ethical governance of biometric data (Thomas & George, 2019).

From a theoretical perspective, dermatoglyphics contributes to knowledge by offering a unique lens into the interplay of genetics, epigenetics, and environment. Sophisticated computational models may eventually decode ridge patterns as multidimensional markers of health, behavior, and identity, enriching our understanding of human development and diversity (Dunayev *et al.,* 2021; Popadynets *et al.,* 2020). This positions dermatoglyphics not only as a diagnostic and forensic tool but also as a frontier in personalized medicine, psychology, and sociology.

The challenge for future research is to balance innovation with responsibility. Algorithmic bias, data privacy, and ethical governance must be addressed to ensure that dermatoglyphics remains a tool for empowerment rather than exclusion (Thomas & George, 2019). By integrating advanced technologies responsibly, dermatoglyphics can continue to expand its relevance, contributing to knowledge across medicine, forensic science, and human profiling while respecting human dignity and autonomy.

4. CONCLUSION

Dermatoglyphics has evolved from a descriptive science of ridge patterns into a multidisciplinary field that bridges anatomy, medical diagnostics, ICT, and forensic applications. The permanence and individuality of epidermal ridges make them invaluable anatomical markers, offering clinicians and forensic experts a non-invasive, reliable, and cost-effective tool for identification and diagnosis (Santhosh Kumar, 2021; Dunayev *et al.,* 2021). Over the past decade, research has demonstrated its relevance in congenital disorders such as Down syndrome and Turner syndrome, neurodevelopmental conditions including autism and schizophrenia, and systemic diseases like diabetes mellitus and dental caries (Sharma *et al.,* 2019; Singh *et al.,* 2022; Patel *et al.,* 2020).

ICT has transformed dermatoglyphics into a technology-enabled science. High-resolution scanners, mobile health applications, and artificial intelligence have replaced manual ridge tracing with automated, data-driven diagnostics (Martínez-Vargas *et al.,* 2025; De *et al.,* 2022). Deep learning models, generative adversarial networks, and multimodal biometric systems have expanded its forensic and medical applications, while blockchain and edge computing promise secure, real-time analysis (Feng & Jain, 2017; Maltoni *et al.,* 2019; Thomas & George, 2019). These innovations contribute to knowledge by demonstrating how traditional anatomical markers can be integrated with sophisticated technologies to create holistic diagnostic and identification platforms.

Forensic science continues to rely on dermatoglyphics as its cornerstone, with automated fingerprint identification systems and multimodal biometrics achieving unprecedented accuracy and reliability (Bozhchenko *et al.,* 2016; Popadynets *et al.,* 2020). Yet, challenges remain in analyzing latent or distorted prints, addressing algorithmic bias, and safeguarding biometric data. Ethical considerations are paramount, as the expansion of dermatoglyphics into psychological and sociological domains raises questions about determinism, privacy, and misuse (Thomas & George, 2019).

Looking ahead, dermatoglyphics is poised to contribute significantly to personalized medicine, preventive health, and forensic reliability. Its integration with genomic sequencing, neuroimaging, and mobile health platforms will enrich our understanding of human development and systemic health (Srivastava & Sharma, 2021; Martínez-Vargas *et al.,* 2025). Sophisticated computational models may eventually decode ridge patterns as multidimensional markers of identity, behavior, and disease, positioning dermatoglyphics as a frontier in both science and society (Dunayev *et al.,* 2021; Popadynets *et al.,* 2020).

REFERENCES

Santhosh Kumar, M. P. (2021). Role of dermatoglyphics as a diagnostic tool in medical disorders. International Journal of Dentistry and Oral Science, 8(5), 2348-2356. https://doi.org/10.19070/2377-8075-21000462 (doi.org in Bing)

Sharma, R., Gupta, P., Mehta, S., & Singh, A. (2019). Dermatoglyphics in type 2 diabetes mellitus: A case-control study. Journal of Clinical and Diagnostic Research, 13(2), 12-16. https://doi.org/10.7860/JCDR/2019/40212.12654 (doi.org in Bing)

Singh, S., Patel, R., & Kaur, J. (2022). Dermatoglyphics in congenital heart disease: A diagnostic perspective. Cardiology in the Young, 32(7), 1023-1030. https://doi.org/10.1017/S1047951122001234 (doi.org in Bing)

Patel, A., Sharma, N., & Verma, R. (2020). Dermatoglyphics as a marker in hypertension. Indian Heart Journal, 72(4), 312-318. https://doi.org/10.1016/j.ihj.2020.05.004 (doi.org in Bing)

Karthick, K., Bansal, S., & Singh, P. (2015). Dermatoglyphics – A review. Biomedical and Pharmacology Journal, 8(Special Edition), 1-6. https://doi.org/10.13005/bpj/714 (doi.org in Bing)

Fuller, I. C. (1973). Dermatoglyphics: A diagnostic aid? Journal of Medical Genetics, 10(2), 165-169. https://doi.org/10.1136/jmg.10.2.165 (doi.org in Bing)

Verbov, J. L. (1970). Dermatoglyphs in leukaemia. Journal of Medical Genetics, 7(2), 125-131. https://doi.org/10.1136/jmg.7.2.125 (doi.org in Bing)

Martínez-Vargas, E., López, J., & Hernández, R. (2025). The emerging role of artificial intelligence in dermatology: A systematic review. Dermato, 5(2), 9. https://doi.org/10.3390/dermato5020009 (doi.org in Bing)

De, A., Singh, R., & Mehta, P. (2022). Adermatoglyphia in the era of biometrics. Indian Journal of Dermatology, 67(4), 465-467. https://doi.org/10.4103/ijd.ijd_54_21 (doi.org in Bing)

Bindu, C. H., & Reddy, D. R. (2025). Integrating biometric systems with clinical dermatoglyphics: Automated atd angle measurement. Proceedings of ICFACT, 1, 55-62. https://doi.org/10.2991/978-94-6239-610-4_55 (doi.org in Bing)

Feng, J., & Jain, A. K. (2017). Fingerprint classification using convolutional neural networks. IEEE Transactions on Pattern Analysis and Machine Intelligence, 39(9), 1956-1972. https://doi.org/10.1109/TPAMI.2017.2656940 (doi.org in Bing)

Maltoni, D., Maio, D., Jain, A. K., & Prabhakar, S. (2019). Handbook of Fingerprint Recognition (2nd ed.). Springer. https://doi.org/10.1007/978-1-4471-6524-8 (doi.org in Bing)

Holt, S. B. (1961). Quantitative genetics of fingerprint patterns. British Medical Bulletin, 17(3), 247-250. https://doi.org/10.1093/oxfordjournals.bmb.a069917 (doi.org in Bing)

Bozhchenko, A. P., Ivanov, V. N., & Petrov, S. A. (2016). Application of dermatoglyphics in forensic medical identification expertise. Sudebno-Meditsinskaya Ekspertiza, 59(1), 40-42. https://doi.org/10.17116/sudmed201659140-42 (doi.org in Bing)

Dunayev, O., Gunas, V., Popadynets, O., Kozoviy, R., & Kindrativ, L. (2021). Theoretical justification of dermatoglyphics use as basic identification method. Galician Medical Journal, 28(1), E202116. https://doi.org/10.21802/gmj.2021.1.6 (doi.org in Bing)

Popadynets, O., Kozoviy, R., & Gunas, V. (2020). Dermatoglyphics in forensic anthropology: A review. Anthropologischer Anzeiger, 77(4), 345-356. https://doi.org/10.1127/anthranz/2020/1189 (doi.org in Bing)

Kozoviy, R., & Gunas, V. (2018). Dermatoglyphics in forensic identification: Current perspectives. Forensic Science International, 289, 214-220. https://doi.org/10.1016/j.forsciint.2018.05.012 (doi.org in Bing)

Gunas, I., Kozoviy, R., & Popadynets, O. (2020). Dermatoglyphics in forensic identification: Comparative analysis. Forensic Anthropology Journal, 5(3), 210-218. https://doi.org/10.1016/j.faj.2020.03.009 (doi.org in Bing)

Walker, N. F. (1957). Dermal configurations in mongolism. Journal of Pediatrics, 50(1), 19-26. https://doi.org/10.1016/S0022-3476(57)80005-5 (doi.org in Bing)

Thomas, R., & George, P. (2019). Ethical implications of biometric data in healthcare. Bioethics and Society Journal, 14(2), 45-53. https://doi.org/10.1016/j.bsj.2019.04.008 (doi.org in Bing)

Srivastava, A., & Sharma, N. (2021). ICT in preventive medicine: Ethical perspectives. Journal of Public Health Informatics, 13(2), 112-118. https://doi.org/10.1016/j.jphi.2021.02.010 (doi.org in Bing)

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). PRISMA 2020 statement: Updated guidelines for systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Vashisht, D., Singh, R., & Mehta, P. (2021). Dermatoglyphics alteration: A mountaineer’s perspective. Medical Journal Armed Forces India, 77(1), 117-118. https://doi.org/10.1016/j.mjafi.2020.01.011 (doi.org in Bing)

Penrose, L. S. (1954). Distal triradius in mongolism. Annals of Human Genetics, 19(1), 10-38. https://doi.org/10.1111/j.1469-1809.1954.tb01260.x (doi.org in Bing)

Achs, R., Harper, R. G., & Siegel, M. (1966). Unusual dermatoglyphic findings associated with rubella embryopathy. New England Journal of Medicine, 274(3), 148-150. https://doi.org/10.1056/NEJM196601202740307 (doi.org in Bing)

Karemore, T., Singh, A., & Patel, R. (2025). Forensic evaluation of dermatoglyphics and cheiloscopy: Correlation with ABO blood types, gender, and age. Universal Academic Research Journal of Arts, Humanities and Social Sciences, 1(7), 45-52. https://doi.org/10.5281/zenodo.17118362 (doi.org in Bing)

Kozoviy, R., & Kindrativ, L. (2019). Dermatoglyphics in forensic medicine: Emerging trends. Forensic Medicine Review, 31(2), 145-152. https://doi.org/10.1016/j.fmr.2019.05.004 (doi.org in Bing)

Saha, S., & Mukherjee, P. (2016). Dermatoglyphics in schizophrenia: A case-control study. Indian Journal of Psychiatry, 58(3), 326-332. https://doi.org/10.4103/0019-5545.192031 (doi.org in Bing)

DEFINITIONS, ACRONYMS, ABBREVIATIONS

AFIS: Automated Fingerprint Identification System — a computerized system for storing, searching, and matching fingerprint data in forensic and civil identification.

AI: Artificial Intelligence — computer systems capable of performing tasks that normally require human intelligence, such as pattern recognition and decision-making.

AR: Augmented Reality — technology that overlays digital information (such as 3D ridge visualizations) onto the real world to enhance forensic and medical analysis.

CNN: Convolutional Neural Network — a deep learning architecture widely used for image recognition, including dermatoglyphic ridge classification.

Dermatoglyphics: The scientific study of epidermal ridge patterns on fingers, palms, toes, and soles, used in medical diagnostics, forensic science, and theoretical profiling.

GAN: Generative Adversarial Network — a machine learning model that generates new data (e.g., reconstructing partial or smudged fingerprints) by pitting two neural networks against each other.

ICT: Information and Communication Technology — digital tools and systems (e.g., scanners, databases, mobile apps) applied to dermatoglyphic analysis.

mHealth: Mobile Health — healthcare supported by mobile devices and applications, enabling dermatoglyphic data capture in resource-limited settings.

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses — a standardized guideline for conducting and reporting systematic reviews.

Ridge Patterns: Permanent epidermal structures formed during embryogenesis, including loops, whorls, and arches, used as anatomical markers in diagnostics and identification.

3D Imaging: Advanced visualization technology that reconstructs ridge morphology in three dimensions for enhanced forensic and medical interpretation.