

REVIEWS

INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) IN DERMATOLOGICAL DIAGNOSTICS AND SKIN ANALYSIS—CONTEMPORARY APPROACHES AND APPLICATIONS

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ABSTRACT

INTRODUCTION: Artificial intelligence (AI) is rapidly transforming medical practice, particularly in fields reliant on image-based diagnostics such as dermatology. The increasing prevalence of skin diseases and the expanding use of telemedicine highlight the need for accurate and accessible diagnostic tools. As a result, a growing body of research has focused on the application of AI in dermatological diagnosis and skin analysis.

AIM: The aim of the present study is to analyze the scope, developmental directions, achievements, trends, prospects, and challenges in the application of AI in dermatological diagnosis and skin analysis based on contemporary scientific literature.

MATERIALS AND METHODS: A search of scientific studies was conducted in the electronic databases PubMed, Google Scholar, and ResearchGate using the keywords: artificial intelligence in dermatology, skin image analysis, dermatology imaging, computer-aided diagnosis, deep learning in dermatology, digital dermatopathology. The search period was set from January 2015 to November 2025.

RESULTS: The review includes 62 articles published between 2015 and 2025 related to the integration of AI in dermatological diagnosis and skin analysis. The study shows that the integration of artificial intelligence in dermatology leads to significant improvements in diagnostic accuracy, efficiency, and accessibility, encompassing a wide range of applications—from dermoscopy and clinical visual assessment to dermatopathology, multimodal imaging, and teledermatology systems. The results highlight the need for developing more generalizable, ethically grounded, and interoperable AI models that can be validated across diverse clinical and population contexts, as well as the need for establishing standards, regulatory frameworks, and sustainable infrastructures to ensure the safe, effective, and equitable implementation of AI in dermatological practice.

CONCLUSION: The integration of AI in dermatological diagnosis and skin analysis has already demonstrated strong potential to enhance diagnostic accuracy, efficiency, and access to care, but requires systematic efforts to overcome methodological, ethical, organizational, and regulatory challenges in order to become a sustainable and equitable component of routine clinical practice.

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INTRODUCTION

The accelerated development of algorithms for skin lesion recognition, the growing volume of research, and the accumulation of new technological solutions create a need for a systematic synthesis of the current state of knowledge.

The relevance of this study stems from the rapid integration of artificial AI decision-making are highly dependent on visual information and its precise interpretation. The accelerated development of algorithms for skin lesion recognition, the growing volume of research, and the accumulation of new technological solutions create a need for a systematic synthesis of the current state of knowledge. The need for such an overview is even more pronounced in the context of the increasing prevalence of skin diseases and the growing importance of telemedicine, which position AI as a potential tool for improving access, accuracy, and equity in dermatological care. A detailed mapping of the literature is necessary to identify the actual benefits and limitations of these technologies, to outline the ethical, regulatory, and organizational challenges, and to support the informed implementation of AI systems in clinical practice.

MATERIALS AND METHODS

For the purpose of the scoping review of studies in the field of AI applications in dermatological diagnostics and skin analysis, scientific publications published worldwide were used. The search was conducted in the electronic databases PubMed, Google Scholar, and ResearchGate in November 2025. Two groups of keywords/phrases were employed. The first group was related to AI and included: *artificial intelligence, machine learning, deep learning, convolutional neural networks, neural networks, generative adversarial networks, explainable AI, computational pathology, computer vision, clinical decision support systems*. The second group of keywords was related to dermatological conditions and/or dermatological skin care: *dermatology, dermatology practice, skin care, skin problems*. The predefined search period covered January 2015 to November 2025.

Publications meeting the following inclusion criteria were considered: availability of full text, publication in English or Bulgarian, publication in peer-reviewed scientific journals, and inclusion of the predefined keywords and phrases. For articles meeting

these criteria, the title, abstract, keywords, and cited references were reviewed, and additional relevant publications were identified and included from the reference lists. Information was extracted regarding thematic focus, methodological approach, algorithms used, and the main findings of each study, with the aim of identifying trends and outlining key directions in the development of artificial intelligence in dermatological diagnostics and skin analysis.

RESULTS

As a result of the search, 62 full-text articles were identified.

The geographical scope of the included studies is broad and reflects the global nature of research on AI in dermatological diagnostics and skin analysis. A substantial proportion of the publications originate from the USA and other English-speaking centres, where models for dermoscopic and histopathological diagnostics, clinical decision support systems, and teledermatology platforms are being developed and validated [1–8]. European countries are strongly represented by studies from Italy, Spain, Austria, Germany, Romania, Poland, the Scandinavian countries, and others, encompassing both clinical and purely methodological research in the fields of dermoscopy, dermatopathology, virtual staining, and super-resolution [9–22].

The Asian region also shows a distinct presence, with numerous studies from China, India, and other countries focusing on deep learning, virtual histological staining, assessment of psoriasis, melasma, and pigmentary lesions, as well as national specificities in the implementation of AI in dermatology [23–33]. Australia and New Zealand contribute through a strong tradition in melanoma research, total body photography, and AI applications in diseases with a high global burden [22,34,35]. The review also includes studies from Latin America, the Middle East, and Africa, which examine the potential of AI to improve access to dermatological diagnostics in resource-limited settings and in low- and middle-income countries [31,36,37]. This wide geographical coverage ensures diversity in clinical contexts, populations, types of skin lesions, and organizational models of healthcare, enabling a more comprehensive assessment of the current state and potential of AI in dermatology.

The design of the included studies outlines a spectrum dominated by observational, diagnostic, and methodological research, supplemented by a limited number of real-world clinical and multicenter studies. A large proportion consists of diagnostic studies based on imaging datasets, in which the performance of various models—most commonly deep neural networks—for skin lesion classification is evaluated, typically through retrospective analyses of already collected dermoscopic, clinical, or histopathological images [1,2,3,5,10,11,12,25,38,39,40,41]. This group also includes numerous technical developments aimed at optimizing architectures and pre-processing, such as super-resolution and multi-reso-

lution models, virtual staining, and analyses of the impact of architecture on image quality and diagnostic usability. These are usually formulated as methodological studies with experimental designs based on whole-slide histological images and microscopic datasets [20,21,28,42,43,44,45,46,47,48].

An important subgroup comprises systematic reviews, meta-analyses, and narrative reviews that synthesize accumulated evidence on the accuracy and applicability of AI in dermatology, often including assessments of bias, methodological limitations, and regulatory challenges [6,7,9,13,17,18,22,29,30,34,36,37,49,50,51,52]. Alongside these, real-world clinical and prospective designs stand out, including

Table 1. Main themes in research on the application of artificial intelligence in dermatological diagnostics and skin analysis.

Theme	Brief description	References
Image-based diagnosis of skin cancer (melanoma and non-melanoma tumors)	AI models for the classification of dermoscopic and clinical images: melanoma versus nevus/seborrheic keratosis; comparison between AI and clinicians; systematic reviews and meta-analyses on diagnostic accuracy in skin cancer; applications in teledermatology and triage.	Matsunaga 2017 [38]; Díaz 2017 [39]; Codella 2018 [2]; Marchetti 2018 [3]; Roffman 2018 [5]; Yang 2020 [25]; De Logu 2020 [12]; Aggarwal & Papay 2021 [1]; Courtenay 2022 [11]; Li Z. 2022 [52]; Das 2023 [55]; Salinas 2024 [36]; Ali 2025 [50]; Trager 2024 [56]; Sanchez 2023 [57]; Soe 2024 [35]; Conger 2024 [4]; Utti 2025 [8]; Sales & Coates 2025 [34]; Uwishema 2025 [37]
Dermatopathology and digital pathology	Deep learning for the analysis of whole-slide images and histological specimens; classification of melanoma and metastases at the pathologist level; virtual staining; super-resolution and multi-resolution convolutional neural networks (CNNs) for digital pathology; review articles on <i>computational dermatopathology</i> .	Olsen 2018 [58]; Mukherjee 2018 [42]; Mukherjee 2019 [43]; Hekler 2019 [59]; Li D. 2020 [45]; De Logu 2020 [12]; Li B. 2021 [45]; Wells 2021 [6]; Kosaraju 2022 [60]; Bai 2023 [46]; Khan 2023 [21]; Tsaris 2023 [47]; Sauter 2023 [13]; Li Y. 2024 [28]; Siarov 2024 [19]; Huttunen 2019 [20]; Wang S. 2024 [48]
Chronic, inflammatory, and high-burden dermatoses	AI for diagnosis, severity assessment, and risk stratification in psoriasis, vitiligo, melasma, and other pigmentary and inflammatory dermatoses; focus on conditions with a high disease burden and limited access to specialist care.	Shrivastava 2015 [23]; Shrivastava 2016 [24]; Yang 2020 [25]; Liu L. 2023 [26]; Huang 2023 [54]; Liu Z. 2023 [27]; Wang Z. 2024 [33]; Smith 2024 [7]; Rokni 2024 [31]; Sales & Coates 2025 [34]; Uwishema 2025 [37]
Emerging imaging modalities and multimodal analysis	AI applications in reflectance confocal microscopy, multiphoton microscopy, and label-free imaging; integration of different image types and clinical data; total body photography and multi-source models.	Huttunen 2019 [20]; Yoon 2024 [61]; Wang S. 2024 [48]; Liu L. 2023 [26]; Wang Z. 2024 [33]; Primiero 2024 [22]; Tsai 2024 [32]

Methodological, systematic, and narrative reviews	Systematic reviews and meta-analyses on the diagnostic accuracy of AI; narrative reviews on the current state and future perspectives of AI in dermatology (overall, by country, or by disease group); syntheses addressing integration into clinical practice.	Shrivastava 2015 [23]; Shrivastava 2016 [24]; Cazzato 2021 [9]; Wells 2021 [6]; Kuo 2023 [49]; Sauter 2023 [13]; Sengupta 2023 [30]; Li Z. 2022 [52]; Manole & Tiplica 2024 [17]; Smith 2024 [7]; Primiero 2024 [22]; Ali 2025 [50]; Yu 2025 [29]; Zbrzezny & Krzywicki 2025 [18]; Utti 2025 [8]; Sales & Coates 2025 [34]; Uwishema 2025 [37]
Explainability, trust, clinical integration, and equity	Explainable AI (“dermatologist-like explainable AI”); studies conducted in real-world clinical settings; trust of clinicians and patients; issues of bias, fairness, and access in resource-limited settings; integration into clinical workflows.	Chanda 2024 [53]; Heinlein 2024 [14]; Aggarwal & Papay 2021 [1]; Manole & Tiplica 2024 [17]; Sales & Coates 2025 [34]; Uwishema 2025 [37]; Utti 2025 [8]; Yu 2025 [29]; Sengupta 2023 [30]
Technological innovations and model architectures	Development and evaluation of diverse architectures: CNNs, ensemble models, super-resolution and multi-resolution networks, generative adversarial networks and conditional generative adversarial networks (GANs), reinforcement learning, and clinical decision support systems; analysis of the impact of model architecture on diagnostic applicability.	Matsunaga 2017 [38]; Díaz 2017 [39]; Codella 2018 [2]; Mukherjee 2018 [42]; Mukherjee 2019 [43]; Li B. 2021 [45]; Bai 2023 [46]; Khan 2023 [21]; Barata 2023 [15]; Díaz-Ramón 2023 [16]; Tsai 2024 [32]; Wang S. 2024 [48]

multicenter studies conducted in routine practice, which test the impact of AI implementation on diagnostic accuracy, workflow, and physicians’ behavior [4,14,53]. Some of these studies focus on real patients and real-world data in conditions such as psoriasis, melasma, infectious skin diseases, and sexually transmitted infection (STI)-related lesions, typically using prospective or retrospective observational designs and evaluating both diagnostic performance and practical applicability [23,24,26,27,31,33,35,54].

Finally, part of the literature is formulated around the development of clinical decision support systems and prognostic models, including reinforcement learning frameworks and decision support systems for melanoma, combining technical and applied elements and often based on retrospective cohorts followed by a validation phase [8,15,16]. Overall, the profile of study designs demonstrates a strong predominance of diagnostic accuracy and methodological research, alongside a smaller but growing number of prospective and real-world clinical stud-

ies assessing the impact of AI on actual dermatological practice.

The main themes identified across the studies are systematized and presented in Table 1.

Image-based diagnosis of skin cancer is developing as one of the most intensive research directions, in which deep neural networks and ensemble models are used for the automatic differentiation of melanoma from benign lesions such as nevi and seborrheic keratosis, as well as for the prediction of non-melanoma skin tumors [2,3,5,38,39]. In parallel, an increasing number of studies compare the performance of algorithms with that of dermatologists in realistic clinical scenarios, including dermoscopic and clinical images and large real-world test datasets [1,11,12,25,52]. Systematic reviews and meta-analyses consolidate evidence on the sensitivity and specificity of AI compared with clinicians, as well as its applicability in screening, second-opinion support, and teledermatological triage [36,50,55]. Particular attention is paid to the use of AI in contexts of unequal access to specialized dermatological care, includ-

ing global and resource-limited settings, where algorithms are viewed as a tool to compensate for shortages of specialists [4,8,34,35,37,56,57].

Dermatopathology and digital pathology represent a second key line of AI integration into dermatological practice, focusing on the automated analysis of whole-slide images and histological specimens. In this field, deep neural networks are used to classify melanoma and its metastases, often achieving performance comparable to that of experienced pathologists, and to support diagnostic standardization [12,19,58,59]. At the same time, methods for virtual staining of unstained tissues and for the automatic reconstruction of hematoxylin–eosin (H&E) and other histological protocols are being developed, reducing reliance on chemical stains and accelerating sample processing [28,44,46]. A significant subgroup of studies is devoted to super-resolution and multi-resolution CNNs, which improve the quality of digital slides and enable work with gigapixel images without loss of diagnostically relevant information [42,43,45,47]. Reviews in the field of *computational dermatopathology* systematize these approaches and analyze their role in diagnostics, education, and research practice [6,13,20,21,48,60].

Chronic, inflammatory, and high-burden dermatoses are also the focus of targeted efforts to introduce AI, with an emphasis on automated severity assessment, objectification of clinical indices, and risk stratification. In psoriasis, early studies demonstrate the potential of machine learning for reliable and accurate disease classification and for multi-class risk assessment using complex feature spaces extracted from images [23,24]. More recent research employs deep learning for automated severity measurement, longitudinal monitoring, and integration of real-world clinical data, bringing algorithmic assessment closer to clinicians' needs [7,27,54]. Similar approaches are applied to melasma and other facial pigmentary lesions, where multimodal models with combined input data support differential diagnosis and therapeutic decision-making [25,26]. In vitiligo and infectious skin diseases, multi-source analysis and AI are used to identify key features and to better understand patterns of distribution, which is particularly important in the context of conditions with a high global burden and limited access to specialist care [31,33,34,37].

Emerging imaging modalities and multimodal analysis further complement the picture of AI in dermatology by expanding the data spectrum beyond classical dermoscopy and standard clinical photography. In reflectance confocal microscopy and multiphoton microscopy, deep models are being developed to automatically recognize subtle structural changes and identify dysplastic or pathological tissues at the dermoepidermal junction, often without the need for additional staining [20,48,61]. Models using multimodal and multi-source data combine different image types and clinical variables to improve diagnostic accuracy in pigmentary disorders and other dermatoses [26,33]. In parallel, approaches based on total body photography and the complex analysis of large-scale skin image datasets are being developed, opening opportunities for early detection and dynamic monitoring of skin lesions at the population level [22,32].

Methodological, systematic, and narrative reviews play a key role in structuring accumulated knowledge and outlining future perspectives for AI in dermatology. Some of the earliest works on psoriasis not only propose specific models but also function as demonstrative frameworks for the application of machine learning in dermatology, laying the groundwork for later synthesizing analyses [23,24]. More recent review articles integrate evidence from computational dermatopathology, digital pathology, dermoscopic diagnostics, and clinical decision support systems, discussing methodological challenges, limitations, and future directions [6,9,13,49,52]. Narrative reviews examine the integration of AI into dermatology across different national contexts and healthcare systems, focusing on regulatory, organizational, and ethical aspects, as well as on specific nosological groups such as psoriasis, infections, and diseases with a high global burden [8,9,17,18,22,29,30,34,37,50].

Trust, clinical integration, and equity emerge as a distinct thematic focus that goes beyond purely technical accuracy metrics and encompasses the interaction between AI systems, clinicians, and patients. Studies on “dermatologist-like” explainable models show that providing interpretable maps, rules, and visual justifications can increase trust and confidence in the use of AI for the diagnosis of melanoma and other lesions [53]. Prospective multicenter studies demonstrate how integrating AI

into real clinical workflows affects diagnostic decisions, response times, and doctor–patient interactions [1,14]. Review and conceptual papers address issues such as algorithmic bias, validation across diverse populations, access to technology in resource-limited settings, and the need for regulations and standards to ensure ethical and equitable use of AI [8,17,29,30,34,37].

Technological innovations and model architectures represent a horizontal axis intersecting all other thematic areas, defining the capabilities and limitations of AI systems. The earliest studies on skin lesion classification rely on classical CNN architectures and ensembles of deep networks, gradually introducing more complex training strategies and model combinations [2,3,38,39]. In dermatopathology, the focus shifts towards multi-resolution and super-resolution networks capable of processing gigapixel whole-slide digital histological images and restoring fine details critical for histological interpretation [21,42,43,45,46,49]. Advanced approaches such as reinforcement learning, generative adversarial networks, and conditional GANs are used to develop decision support systems, image synthesis and transformation pipelines, and enhanced analysis of pigmentary and other skin lesions [15,16,32,48]. As a result, architectural choice becomes a key determinant of clinical applicability, generalizability, and explainability of AI solutions.

DISCUSSION

The main achievements in the application of AI in dermatological diagnostics and skin analysis are primarily associated with the proven ability of deep neural networks to reach—and often surpass—the diagnostic accuracy of dermatologists in recognizing melanoma and non-melanoma skin cancer from dermoscopic and clinical images [1,2,3,5,25,38,48]. Algorithms for classifying benign and malignant lesions, including hyperspectral approaches and complex ensembles, achieve high sensitivity and specificity and are validated on real clinical datasets and challenges [10,11,40,55]. Systematic reviews and meta-analyses confirm that AI can compete with clinicians in skin cancer diagnosis and can be used as a tool for second opinions and screening [36,46,49,50,57]. At the same time, clinical triage and teledermatology systems are being developed to support early detection and case

prioritization, including within online platforms and remote consultation settings [4,35,37,55].

Substantial progress is also observed in dermatopathology and digital pathology, where deep learning is applied to the analysis of digitized histological specimens and whole-slide images. Numerous studies demonstrate “pathologist-equivalent” performance of models in the classification of melanoma and metastases on histological sections, as well as in other common dermatopathological diagnoses [6,12,13,19,58,59]. In parallel, approaches for virtual histological staining and super-resolution enable reconstruction of (H&E) staining and improvement of image quality without additional laboratory procedures, thereby accelerating workflows and expanding opportunities for remote and automated assessment [21,28,42,43,44,45,46,47]. In the field of multimodal and advanced imaging diagnostics, multiphoton microscopy and reflectance confocal microscopy are combined with AI to detect dysplastic changes at the dermoepidermal junction and to develop label-free diagnostic solutions [20,48,61]. Beyond oncology, AI is successfully applied to the classification and severity assessment of psoriasis, melasma, vitiligo, infectious diseases, and other high-burden dermatoses, including in real-world clinical settings and global contexts with limited access to specialists [7,23,24,26,27,31,33,34,54].

Trends and future perspectives in AI development in dermatology indicate a shift from single-channel classifiers towards complex clinical decision support systems that combine different architectures and data types. Reinforcement learning, generative adversarial networks, and multimodal models are used to build dynamic platforms supporting diagnosis and treatment selection for skin cancer and pigmentary lesions, including contextualization with clinical and imaging data [15,16,32,62]. There is growing interest in total body imaging registries and population-based approaches for early lesion detection and longitudinal monitoring, combining automated AI analysis with long-term digital surveillance [8,22,35]. In dermatopathology, trends point towards integrating super-resolution and virtual staining models into routine diagnostic processes and expanding their applications in education and research [6,13,43,45]. Review articles and nationally

oriented analyses outline prospects for closer integration of AI with telemedicine, precision medicine, and multidisciplinary care models, including in China, Central and Eastern Europe, and global settings with uneven resource distribution [17,18,29,37,51].

Alongside these achievements, challenges remain substantial and persistent across almost all analyzed sources. At the methodological level, a key issue is the limited generalizability of models due to imbalanced, homogeneous, or insufficiently annotated datasets, as well as differences in devices, acquisition conditions, and demographic characteristics—particularly critical for applications in diverse and racially heterogeneous populations and in low- and middle-income countries [1,36,37,50]. Ethical and legal issues related to data protection, algorithmic transparency, and responsibility for misdiagnosis are identified as central barriers to widespread clinical adoption [17,29,30,51]. Models often function as “black boxes,” hindering trust among clinicians and patients, despite the emergence of explainable solutions that mimic dermatologists’ reasoning and increase AI acceptability [8,53]. Infrastructure and organizational barriers—such as the need for substantial investment, integration into existing information systems, and staff training—further slow implementation, while some authors also warn of the risk of over-reliance on algorithms at the expense of clinical skills [17,30,51]. In this context, reviews emphasize the need for a multi-stakeholder approach involving clinicians, engineers, ethicists, and regulators to develop AI solutions that are not only technically robust but also transparent, fair, and aligned with real clinical needs [6,13,18,34,53].

CONCLUSION

The reviewed literature shows that AI has already secured a stable place in dermatological diagnostics and skin analysis, demonstrating high diagnostic accuracy in skin cancer, chronic and infectious dermatoses, expanding the capabilities of dermatopathology, and supporting teledermatology, triage, and medical education. At the same time, development is moving from isolated classifiers towards complex, multimodal, and explainable clinical decision support systems that have the potential to improve access to specialized care and reduce health inequalities. Despite these advances, significant chal-

lenges remain related to data quality and representativeness, algorithmic transparency and ethics, regulatory frameworks, infrastructure readiness, and the need for professional training. The future development of AI in dermatology depends on a balanced approach in which technological progress is combined with clear ethical standards, interdisciplinary collaboration, and a focus on the dermatologist’s role as the central figure in the interpretation and responsible application of these new tools.

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