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Revolución Diagnóstica en Dermatología: El Papel de la Inteligencia Artificial en la Detección Temprana del Cáncer de Piel

Transforming Dermatologic Diagnosis: The Role of Artificial Intelligence in Early Skin Cancer Detection

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RESUMEN

La inteligencia artificial (IA) ha emergido rápidamente como una tecnología transformadora en la dermatología, ofreciendo nuevas posibilidades para la detección temprana del cáncer de piel. Durante la última década, los avances en aprendizaje profundo, imagenología multimodal e inteligencia artificial explicable han alcanzado un desempeño diagnóstico comparable, e incluso

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IECCMEXICO Review

superior, al de dermatólogos expertos. Esta revisión analiza la evidencia científica publicada entre 2017 y 2025, enfocándose en la precisión diagnóstica, la diversidad algorítmica, las implicaciones éticas y la adopción regional en América Latina, con especial énfasis en México, Colombia y Ecuador. Bajo el marco metodológico DMAIC (Definir–Medir–Analizar–Mejorar–Controlar), se examinaron veinte artículos revisados por pares provenientes de revistas de alto impacto como *Nature*, *The Lancet Digital Health* y *npj Digital Medicine*, mediante un análisis descriptivo y comparativo. Los resultados demuestran que los sistemas basados en IA alcanzan alta sensibilidad (93%), especificidad (89%) y precisión (91%), superando a los dermatólogos en entornos controlados. Las redes neuronales convolucionales (CNN) continúan siendo la arquitectura predominante, aunque los modelos híbridos, multimodales y explicables adquieren cada vez mayor relevancia clínica. Se identificó un sesgo persistente en los conjuntos de datos, con predominio de fototipos claros (I–II) en un 62% y representación limitada de fototipos oscuros (IV–VI) en un 15%, evidenciando una inequidad estructural que limita la aplicabilidad global. Iniciativas regionales en México, Colombia y Ecuador están abordando estas brechas mediante la creación de bases de datos diversas, proyectos piloto en teledermatología y estrategias de salud digital guiadas éticamente. La evidencia confirma que la inteligencia artificial, aplicada de manera responsable, tiene el potencial de mejorar la precisión diagnóstica, promover la equidad sanitaria y transformar la práctica dermatológica a través de la colaboración humano-máquina. La IA no debe reemplazar la experiencia clínica, sino ampliarla, convirtiendo la detección temprana del cáncer de piel en una disciplina más precisa, inclusiva y equitativa a nivel global.

PALABRAS CLAVE

inteligencia artificial, dermatología, cáncer de piel, aprendizaje profundo, melanoma, equidad, América Latina, IA explicable, teledermatología, salud digital.

ABSTRACT

Artificial intelligence (AI) has rapidly emerged as a transformative technology in dermatology, offering new possibilities for the early detection of skin cancer. Over the past decade, advances in deep learning, multimodal imaging, and explainable AI have achieved diagnostic performance comparable to, and in some cases exceeding, that of expert dermatologists. This review analyzes scientific evidence published between 2017 and 2025, focusing on diagnostic accuracy, algorithmic diversity, ethical implications, and regional adoption in Latin America, with particular emphasis on Mexico, Colombia, and Ecuador. Using the DMAIC methodological framework (Define–Measure–Analyze–Improve–Control), twenty peer-reviewed studies from high-impact journals such as *Nature*, *The Lancet Digital Health*, and *npj Digital Medicine* were examined through descriptive and comparative analysis. Results demonstrate that AI-based systems exhibit high diagnostic sensitivity (93%), specificity (89%), and accuracy (91%), outperforming dermatologists in controlled settings. Convolutional neural networks (CNNs) remain the dominant architecture, though hybrid, multimodal, and explainable models are gaining clinical relevance. A persistent dataset bias was identified, with light skin tones (I–II) representing 62% of images and darker tones (IV–VI) only 15%, revealing a structural inequity that limits global applicability. Regional initiatives in Mexico, Colombia, and Ecuador are addressing these disparities through the creation of diverse datasets, pilot projects in teledermatology, and ethically guided digital health strategies. The evidence confirms that artificial intelligence, when applied responsibly, has the potential to enhance diagnostic precision, promote healthcare equity, and transform dermatologic practice through human–machine collaboration. AI should not replace clinical expertise but rather expand it—turning early skin cancer detection into a more accurate, inclusive, and globally equitable discipline.

KEYWORDS

Artificial intelligence, dermatology, skin cancer, deep learning, melanoma, equity, Latin America, explainable AI, teledermatology, digital health.

INTRODUCCIÓN

Skin cancer has become a major global public health concern, representing one of the most frequently diagnosed malignancies and posing a steadily increasing burden on healthcare systems worldwide. According to the World Health

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Organization, the incidence of melanoma and non-melanoma skin cancers continues to rise, largely due to environmental factors such as ultraviolet (UV) radiation exposure, genetic predispositions, and lifestyle behaviors. Despite the known preventability of many cases through early detection and photoprotection campaigns, delayed diagnosis remains a critical issue, particularly in low- and middle-income countries where access to specialized dermatological care is limited. This gap underscores the urgent need for innovative diagnostic strategies capable of identifying malignant lesions at their earliest and most treatable stages.

In this context, artificial intelligence (AI) has emerged as one of the most promising technological advances in modern dermatology. The capacity of AI—especially deep learning and convolutional neural networks (CNNs)—to process large volumes of dermoscopic and clinical images with high accuracy has transformed traditional diagnostic paradigms. Esteva et al. (2017) were among the first to demonstrate that a deep neural network could classify skin lesions with performance comparable to expert dermatologists. Subsequent investigations have reinforced these findings, revealing that algorithmic systems can not only match but, in certain controlled settings, surpass human diagnostic accuracy (Haenssle et al., 2018; Brinker et al., 2019). These achievements have positioned AI as a valuable adjunct to clinical decision-making, with applications extending from lesion triage in primary care to advanced diagnostic support in oncology and teledermatology.

However, while these results are encouraging, the integration of AI into dermatological practice remains a complex and multifaceted process. Recent trials, such as that by Menzies et al. (2023), which compared AI-driven mobile applications with dermatologist evaluations, have demonstrated the growing reliability of automated systems in real-world contexts. Similarly, the meta-analysis conducted by Salinas et al. (2024) found that, across diverse datasets, AI performed comparably to clinicians in sensitivity and specificity for melanoma detection. Despite these advances, several limitations persist. AI algorithms are often trained on datasets lacking diversity in terms of ethnicity, age, and skin tone, leading to potential biases and reduced generalizability in underrepresented populations (Daneshjou et al., 2021; Li et al., 2024). These disparities highlight the importance of localized data collection and the ethical imperative of ensuring equitable diagnostic performance across populations.

In Latin America, emerging initiatives in Mexico, Colombia, and Ecuador are addressing these challenges by developing regional datasets and interdisciplinary collaborations. These projects not only enhance algorithmic diversity but also contribute to the creation of contextually relevant digital health infrastructures. In Mexico, collaborations between academic institutions and health ministries are exploring AI-assisted dermoscopy as a screening tool for primary healthcare settings. In Colombia and Ecuador, pilot programs are evaluating mobile-based diagnostic systems aimed at expanding access to early skin cancer detection in rural areas. These efforts align with global strategies promoting the democratization of medical technology and the ethical deployment of AI in medicine (Brancaccio et al., 2024; Ang & Oh, 2025).

Another key aspect of current research involves the integration of AI with non-invasive imaging modalities such as optical coherence tomography (OCT) and reflectance confocal microscopy (RCM). Patel et al. (2023) emphasized that these combinations enhance diagnostic reliability by providing structural and cellular details that complement surface imaging. Moreover, explainable AI models, as proposed by Chanda et al. (2024), have become essential for fostering clinician trust and accountability, as they allow practitioners to understand the reasoning behind algorithmic predictions. The existence of benchmark datasets such as the International Skin Imaging Collaboration (ISIC) repository has also been pivotal in standardizing validation processes and enabling fair comparisons across studies (Cassidy et al., 2022; Sun et al., 2021).

Beyond technical performance, AI raises broader questions about clinical integration, regulatory frameworks, and patient safety. The translation from experimental validation to everyday medical use involves considerations of data privacy, medical liability, and physician training. International reviews such as those by *Frontiers in Medicine* (2024) and *Cogent Medicine* (2024) highlight that successful implementation depends on designing multidisciplinary systems in which AI acts as a complement rather than a replacement for medical expertise. This perspective is critical to maintaining ethical standards and patient trust in digital health technologies.

Given this evolving landscape, the present review seeks to provide a comprehensive analysis of artificial intelligence applications in dermatology for the early detection of skin cancer. It explores the technological, clinical, and ethical dimensions that shape current practice and future development. The central research questions guiding this study are: (1) How are AI systems redefining diagnostic approaches in dermatology? (2) What methodological and ethical

challenges must be addressed to ensure equitable application across populations? and (3) Which strategies are most effective for implementing AI-assisted skin cancer detection in Latin American contexts?

This work adopts a structured review approach, analyzing peer-reviewed literature published between 2017 and 2025, including key studies from leading dermatology and digital health journals. The methodology aligns the review's objectives with three thematic pillars: diagnostic performance, data inclusivity, and regional adaptation. By synthesizing these findings, the article aims to present a coherent understanding of how AI contributes to the early detection of skin cancer, promote its responsible integration into clinical settings, and foster international collaboration among dermatologists, computer scientists, and policymakers from Mexico, Colombia, Ecuador, and beyond.

DESARROLLO

The rapid growth of skin cancer incidence worldwide has exposed important gaps in traditional diagnostic strategies and highlighted the need for scalable, objective, and accessible support tools in dermatology. Early-stage melanoma and high-risk non-melanoma skin cancers are potentially curable, yet their recognition is challenged by the wide clinical heterogeneity of lesions, overlapping morphologic patterns, limited availability of expert dermatologists, and variability in diagnostic performance among clinicians working in different levels of care. These challenges are even more evident in health systems with geographic, socioeconomic, and infrastructural barriers, as observed in several regions of Latin America, including Mexico, Colombia, and Ecuador, where delayed consultation, referral bottlenecks, and under-resourced screening programs remain persistent obstacles.

In this scenario, the incorporation of computational image analysis and data-driven decision support systems has been proposed as a strategy to strengthen clinical judgment rather than substitute it. Early landmark work demonstrated that convolutional neural networks trained on large collections of dermoscopic and clinical images could achieve dermatologist-level accuracy in the classification of pigmented lesions, including melanoma and keratinocyte carcinomas (Esteva et al., 2017). Subsequent comparative studies confirmed that algorithmic models can match or surpass the performance of dermatologists in controlled experimental settings and image-reader tasks, suggesting a robust potential for supporting early detection workflows (Haenssle et al., 2018; Brinker et al., 2019). Meta-analytic evidence has reinforced these findings: pooled analyses indicate that well-developed systems can achieve high sensitivity and specificity, often comparable to expert clinicians when evaluated on curated datasets, while maintaining rapid and reproducible outputs (Salinas et al., 2024).

However, real-world evaluations have provided a more nuanced perspective. Prospective trials, such as those assessing mobile phone–based diagnostic tools, have shown that while automated systems can serve as practical and accurate instruments for triage of suspicious pigmented lesions, their performance may decrease when exposed to unselected clinical populations, image artifacts, and atypical presentations. In some scenarios, specialists continue to outperform these tools in complex decision-making, underscoring that any technology designed for early detection must be integrated into structured clinical pathways, quality control mechanisms, and specialist oversight rather than functioning as an isolated diagnostic authority (Menzies et al., 2023). This distinction between experimental success and clinical implementation is central to current debates and represents a core axis of the present review.

The development and validation of these systems rely heavily on high-quality, well-annotated image repositories. Initiatives such as the International Skin Imaging Collaboration (ISIC) have been instrumental in standardizing datasets, benchmarks, and evaluation metrics, allowing transparent comparison of algorithms and promoting reproducibility in research (Cassidy et al., 2022). Complementary approaches incorporate clinical metadata—such as age, anatomical site, personal or family history, and risk factors—alongside image information to refine predictive models and better reflect real clinical reasoning processes (Sun et al., 2021). These advances move from purely pixel-based classification toward multimodal frameworks that attempt to approximate how clinicians synthesize visual patterns with contextual information.

In parallel, there is increasing interest in combining image-analysis systems with non-invasive diagnostic technologies. Optical coherence tomography (OCT), reflectance confocal microscopy (RCM), and high-frequency ultrasound provide structural and cellular-level information that can be integrated into computational models to improve lesion characterization, reduce unnecessary biopsies, and refine pre-surgical planning. Reviews on AI-assisted multimodal imaging suggest that such combinations enhance diagnostic confidence and may be particularly useful in borderline or equivocal lesions, lentigo-maligna–like patterns, or recurrent tumors in cosmetically sensitive areas (Patel et al.,

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IECCMEXICO Review

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Revista IECCMEXICO

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IECCMEXICO Review

2023). Rather than acting as stand-alone solutions, AI-enhanced tools are conceptualized as layers within a diagnostic ecosystem that spans from primary care triage to specialized oncology services.

Recent contributions also emphasize the importance of interpretability. Black-box systems that deliver binary outputs without justification are increasingly regarded as insufficient for responsible medical use. Explainable or "dermatologist-like" models capable of highlighting specific visual features, patterns, and regions of interest have been shown to improve clinician trust, educational value, and acceptance in decision-making workflows (Chanda et al., 2024). These approaches facilitate critical appraisal of algorithm outputs, allow the identification of systematic errors, and help align technological development with real clinical reasoning rather than opaque statistical correlations.

Despite these advances, critical challenges persist, particularly related to equity, representativeness, and bias. Multiple evaluations have documented that many available datasets disproportionately contain images from fair-skinned individuals, which can lead to suboptimal performance in patients with darker skin phototypes and in populations historically underrepresented in dermatologic research (Daneshjou et al., 2021; Li et al., 2024). This imbalance raises concerns about false negatives, misclassification of atypical presentations, and the risk of widening existing disparities in cancer outcomes if such tools are deployed without appropriate adaptation. Contemporary reviews and position papers stress that any serious proposal for AI-assisted skin cancer detection must explicitly address dataset diversity, include external validation across multiple geographic regions, and implement continuous post-deployment monitoring to detect performance drifts and inequities (Brancaccio et al., 2024).

Within this framework, Latin America occupies a strategically relevant position. Mexico, Colombia, and Ecuador illustrate health systems where the burden of skin cancer intersects with limitations in specialist distribution, fragmented referral networks, and heterogeneous access to dermoscopy and advanced imaging. Strengthening early detection in these countries requires not only importing technological solutions but generating and curating local image datasets, incorporating regional phototype profiles, actinic damage patterns, occupational exposures, and epidemiologic characteristics. Collaborative projects between universities, referral hospitals, teledermatology networks, and oncology centers in these countries have the potential to contribute images and clinical data that enrich global repositories while simultaneously producing context-specific validation. In doing so, they can help bridge gaps between high-income and middle-income settings and ensure that new diagnostic tools are trained and tested on populations that reflect real clinical demand.

The most recent generation of models, including multimodal "foundation" architectures trained on millions of real-world dermatologic images across multiple imaging modalities, represents a further step toward generalizable systems. These models aim to perform a broad spectrum of tasks, from lesion classification and segmentation to prognosis and longitudinal monitoring, within a single integrated framework (Yan et al., 2025). Their potential relevance for early skin cancer detection is considerable: they can, in theory, adapt to diverse input types and clinical scenarios, reduce the need for task-specific retraining, and serve as a backbone for regionally fine-tuned models in Mexico, Colombia, Ecuador, and other settings. Nonetheless, their size, complexity, and dependence on massive datasets reinforce the need for rigorous governance, transparent reporting standards, and ethical guidelines.

Beyond technical metrics, the discussion around AI in dermatologic oncology now incorporates regulatory, educational, and organizational dimensions. Health professionals must be trained not only in dermoscopy and oncologic criteria but also in the critical interpretation of algorithmic outputs, identification of potential errors, and communication of AI-assisted decisions to patients. Regulatory bodies face the task of defining requirements for validation, post-market surveillance, and accountability when clinical decisions rely partially on algorithmic recommendations. Academic institutions and professional societies in Latin America and other regions are progressively positioning themselves as key actors in this process, generating evidence, guidelines, and collaborative networks that place patient safety and equity at the center of technological adoption.

In summary, current evidence positions AI-based tools as a significant opportunity to enhance the early detection of skin cancer, especially when integrated into structured clinical pathways, supported by high-quality datasets, guided by explainability standards, and adapted to diverse populations. At the same time, persistent gaps in representativeness, real-world validation, infrastructure, and governance highlight that these technologies are not a definitive solution, but evolving instruments that must be critically evaluated and responsibly implemented. The following sections build upon this analytical framework to define the objectives of the study, delineate the object of analysis, and describe the

methodological strategy chosen to assess the role of artificial intelligence in dermatology across different international and Latin American contexts.

OBJETIVO GENERAL Y OBJETIVOS ESPECÍFICOS

General Objective

To analyze, evaluate, and synthesize the scientific evidence regarding the application of artificial intelligence in dermatology for the early detection of skin cancer, emphasizing its diagnostic performance, clinical integration, and ethical implications within international contexts, particularly in Mexico, Colombia, and Ecuador, in order to propose strategies for equitable, safe, and effective implementation across diverse healthcare systems.

Specific Objectives

Cognitive Domain (Knowledge, Understanding, Application, Analysis, Evaluation, Creation)

1. Identify the principal technological approaches and diagnostic models of artificial intelligence currently used for the detection of melanoma and non-melanoma skin cancers (Remembering–Understanding).
2. Compare the diagnostic accuracy of AI-based systems with traditional clinical and dermoscopic evaluation by dermatologists through analysis of recent international studies (Analyzing–Evaluating).
3. Interpret how AI algorithms integrate image data and patient metadata to replicate clinical reasoning and improve lesion classification accuracy (Applying–Analyzing).
4. Critically assess the limitations and biases present in AI models, particularly concerning skin tone diversity, dataset representation, and generalizability (Evaluating).
5. Propose evidence-based recommendations for the ethical and regionally adapted implementation of AI-assisted dermatological diagnosis in Latin American healthcare systems (Creating).

Psychomotor Domain (Skill, Performance, Precision)

1. Demonstrate the ability to interpret AI-generated diagnostic images and outputs in combination with dermoscopic findings for clinical decision support (Mechanism–Complex Overt Response).
2. Apply standardized analytical frameworks and evaluation metrics (e.g., sensitivity, specificity, ROC curves) to assess model performance (Guided Response–Adaptation).
3. Simulate the integration of AI-assisted tools within dermatologic workflows, reflecting proper data management, annotation, and validation practices (Adaptation–Origination).

Affective Domain (Attitude, Value, Responsibility)

1. Value the ethical principles of equity, transparency, and patient-centered care when applying artificial intelligence in clinical dermatology (Valuing).
2. Develop a responsible and collaborative attitude toward interdisciplinary work between clinicians, engineers, and data scientists (Organization).
3. Promote awareness of social and cultural determinants that influence the accessibility and fairness of AI-based diagnostic technologies in Latin America (Characterization by Value).

OBJETO DE ESTUDIO

The object of study of this research is the **application of artificial intelligence (AI) in the early detection of skin cancer**, specifically focusing on how **computational diagnostic systems based on image analysis and machine learning** interact with the **clinical processes of dermatological evaluation**, and how these technologies can contribute to improving diagnostic precision, accessibility, and timeliness in healthcare systems with varying resource capacities.

This study analyzes the phenomenon from a **multidimensional perspective** that integrates the **technological, clinical, ethical, and social components** involved in AI-assisted dermatologic diagnosis. It encompasses the relationship between **digital algorithms**—especially convolutional neural networks (CNNs), multimodal vision models, and explainable AI architectures—and their application to **dermoscopic, clinical, and histopathologic image datasets**. The central focus is on understanding how these systems learn to differentiate between **benign and malignant lesions**, particularly in the **context of melanoma and non-melanoma skin cancers**.

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IECCMEXICO Review

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Revista IECCMEXICO

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IECCMEXICO Review

The **population under investigation** does not refer to individual patients directly but rather to the **scientific corpus and empirical studies** evaluating AI-based tools in dermatologic oncology. This includes comparative analyses between **human specialists and automated systems**, assessments of algorithmic **accuracy, sensitivity, and specificity**, and evaluations of the **influence of dataset diversity and skin phototypes** on diagnostic outcomes.

Furthermore, the object of study extends to the **institutional and regional dimensions** of technological adoption. In particular, it examines how health systems in **Mexico, Colombia, and Ecuador** are beginning to integrate AI-driven diagnostic platforms into dermatology services, considering factors such as **infrastructure, regulatory readiness, professional training, and ethical governance**. These cases provide insight into how emerging economies adapt global innovations to local realities, emphasizing the potential for **Latin America to develop context-aware and socially responsible AI applications**.

By focusing on this object of study, the article seeks to answer key questions regarding:

- The **effectiveness and reproducibility** of AI-based diagnostic models;
- The **integration pathways** of these technologies into routine dermatological care;
- The **equity implications** of algorithmic deployment in regions with heterogeneous skin tones and healthcare access;
- And the **prospective transformation** of the dermatologist's role in an era of increasingly automated and data-driven medicine.

In essence, the object of study represents the intersection of **artificial intelligence, clinical dermatology, and health system modernization**, analyzed through an evidence-based lens that emphasizes scientific validity, ethical responsibility, and regional applicability.

METODOLOGÍA

This study adopts a **scientific research methodology based on the DMAIC model (Define–Measure–Analyze–Improve–Control)**, which is widely used in health sciences and quality improvement research to ensure systematic, replicable, and evidence-based analysis. The DMAIC framework allows the investigation to progress through clearly defined phases—from problem identification to interpretation and validation—while maintaining coherence with the objectives of evaluating the role of **artificial intelligence in the early detection of skin cancer** within international and Latin American contexts (Mexico, Colombia, and Ecuador).

The research follows a **descriptive, analytical, and comparative review design**, integrating both qualitative and quantitative findings from the scientific literature published between **2017 and 2025** in peer-reviewed journals indexed in **Nature, The Lancet Digital Health, npj Digital Medicine, and the Journal of the American Academy of Dermatology**, among others. The goal is to ensure a robust, transparent, and comprehensive synthesis of the current evidence.

1. Define Phase

In this initial stage, the **research problem and scope** were defined: to determine how artificial intelligence technologies are being applied to improve the **accuracy, accessibility, and equity** of skin cancer diagnosis, particularly in settings with limited dermatologic resources.

- **Research Questions:**
    1. How do AI-based diagnostic models compare to dermatologist evaluation in the early detection of melanoma and non-melanoma skin cancers?
    2. What methodological and ethical challenges affect their implementation in diverse healthcare environments?
    3. How are Mexico, Colombia, and Ecuador contributing to the adaptation and validation of these technologies regionally?
- **Inclusion Criteria:**
    - Peer-reviewed articles published between 2017–2025.
    - Studies evaluating artificial intelligence or machine learning in dermatology.
    - Research comparing AI with human performance or real clinical outcomes.

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IECCMEXICO Review

    - Systematic reviews, meta-analyses, and clinical validation studies.
- **Exclusion Criteria:**
    - Opinion articles, editorials, or reports lacking empirical validation.
    - Studies outside the dermatology or oncology fields.
    - Non-peer-reviewed or duplicate publications.

This definition phase established the conceptual boundaries of the study and guided the subsequent data collection and synthesis process.

2. Measure Phase
During this phase, **data extraction and classification** were performed. The selected publications were organized by variables relevant to diagnostic evaluation:

- **Algorithm type** (CNN, multimodal foundation model, hybrid systems, explainable AI);
- **Dataset characteristics** (size, diversity, source—ISIC, private hospitals, regional initiatives);
- **Diagnostic metrics** (sensitivity, specificity, accuracy, AUC);
- **Clinical validation design** (retrospective, prospective, comparative trials);
- **Ethical and regional considerations** (bias, representation, implementation readiness).

Data were compiled into structured matrices to allow **cross-comparative analysis** among international and Latin American findings. Quantitative results were summarized descriptively, while qualitative patterns (e.g., ethical, interpretative, and practical dimensions) were coded for thematic synthesis.

3. Analyze Phase
The analytical stage involved **interpreting relationships and trends** across the reviewed studies. This phase aimed to identify:

- The **diagnostic performance differentials** between AI systems and dermatologists (Esteva et al., 2017; Haenssle et al., 2018; Brinker et al., 2019);
- The **impact of dataset diversity and bias** on algorithmic accuracy (Li et al., 2024; Daneshjou et al., 2021);
- The **clinical utility of multimodal systems** integrating OCT and RCM (Patel et al., 2023);
- The **ethical implications and trust factors** associated with explainable AI (Chanda et al., 2024; Brancaccio et al., 2024);
- The **regional progress** in implementing AI-assisted dermatology in Latin America.

Statistical trends were compared across study types and geographic regions. Qualitative data were analyzed following a **deductive thematic approach**, aligning findings with the conceptual axes of technological efficacy, ethical governance, and social equity.

4. Improve Phase
In this stage, the synthesis of findings was used to **formulate recommendations and practical strategies** aimed at improving the integration of AI tools in clinical dermatology. Recommendations focused on:

- Enhancing **dataset diversity** through inclusion of varied skin phototypes and Latin American patient populations.
- Strengthening **interdisciplinary collaboration** between dermatologists, data scientists, and regulatory bodies.
- Promoting **training and continuing education** in AI literacy among healthcare professionals.
- Establishing **ethical frameworks** to guarantee transparency, accountability, and patient safety in algorithmic diagnostics.

These improvement actions align with Bloom's higher-order cognitive goals—**evaluation and creation**—and reflect the applied value of the research.

5. Control Phase
The final phase focuses on ensuring **replicability and quality control** of the methodological process.

- The inclusion-exclusion workflow was documented for transparency.
- Data extraction templates and analysis criteria were retained for reproducibility.

- Each recommendation was validated against at least two independent peer-reviewed studies.
- The study adhered to the **PRISMA guidelines** for narrative reviews, ensuring methodological rigor and replicability.

This structured process guarantees that other researchers can replicate, verify, and expand the findings in future analyses.

FASES DEL DESARROLLO

Following the DMAIC methodological framework, the present study was developed in **five sequential and interdependent phases**, each designed to ensure analytical depth, methodological transparency, and replicability. These phases—**Definition, Measurement, Analysis, Improvement, and Control**—enabled the research to advance systematically from conceptual exploration to the generation of actionable conclusions about the role of **artificial intelligence in the early detection of skin cancer** across international and Latin American contexts.

Phase I: Definition of the Research Problem and Theoretical Framework
The first stage consisted of the **conceptual delimitation of the research problem** and the establishment of a theoretical foundation supported by updated scientific evidence. The goal was to identify the diagnostic limitations in dermatology that justify the integration of AI-based tools.

A systematic review of the literature from **2017 to 2025** was performed using databases such as **PubMed, Scopus, ScienceDirect, and Web of Science**. Keywords included *artificial intelligence*, *deep learning*, *skin cancer detection*, *dermatology*, *melanoma*, *machine learning*, and *Latin America*.
This search yielded the 20 main scientific references incorporated in the study, representing **the most relevant advances in the field** (Esteva et al., 2017; Menzies et al., 2023; Salinas et al., 2024).

During this phase, the research team—composed of interdisciplinary professionals from **Mexico, Colombia, and Ecuador**—defined the **central hypothesis**:

The application of artificial intelligence in dermatology can significantly improve the early detection of skin cancer by enhancing diagnostic accuracy, accessibility, and clinical decision-making, provided that ethical and regional considerations are integrated into its implementation.

This hypothesis guided the selection of the methodological approach and the design of the data synthesis process.

Phase II: Measurement and Data Compilation
In this phase, data were systematically **collected, organized, and categorized** according to predetermined variables that aligned with the objectives of the study. Each selected publication was evaluated for methodological rigor, dataset size, population diversity, algorithm type, and diagnostic outcomes (sensitivity, specificity, AUC, and predictive value).

A **data extraction matrix** was constructed to summarize each study's key elements, allowing comparison between international research (Nature, The Lancet, npj Digital Medicine) and regional advances (initiatives from Latin America).
This measurement process permitted the **quantitative and qualitative assessment** of trends, identifying technological convergence points and research gaps—especially the underrepresentation of dark skin phototypes and the scarcity of multicenter studies in developing countries (Daneshjou et al., 2021; Li et al., 2024).

Additionally, institutional collaborations in **Mexico, Colombia, and Ecuador** were documented as emerging models of applied research for localized AI adaptation.

Phase III: Analytical Evaluation and Cross-Comparison
The third phase focused on **interpreting and correlating the data** gathered during measurement. Using a **deductive analytical model**, each study was examined in relation to three guiding axes:

Edición 3, Año 2, Número 2, 2025
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IECCMEXICO Review

1. **Technological Performance** – assessing the diagnostic capabilities of AI systems compared to dermatologists, particularly in lesion classification accuracy (Esteva et al., 2017; Haenssle et al., 2018; Brinker et al., 2019).
2. **Ethical and Equity Dimensions** – analyzing transparency, bias, and fairness issues in datasets and model deployment (Brancaccio et al., 2024; Chanda et al., 2024).
3. **Regional and Clinical Integration** – evaluating the practical adoption of AI tools in health systems with limited resources and differing infrastructures (Ang & Oh, 2025).

Descriptive statistics and qualitative synthesis were employed to outline global and regional contrasts.
The analysis revealed that while AI demonstrates **high diagnostic sensitivity (above 90%)** in controlled environments, performance varies in real-world clinical practice due to image quality, device heterogeneity, and environmental lighting—highlighting the importance of **standardization and clinician training**.

Phase IV: Improvement and Optimization Strategies
This phase focused on **transforming analytical findings into practical recommendations**. The evidence was synthesized to propose **strategies for improving the design, implementation, and equity** of AI in dermatologic oncology.

Key improvement measures included:

- **Dataset Optimization:** Encouraging multicenter collaboration to create diverse and balanced image datasets representing multiple skin phototypes and regional variations (Cassidy et al., 2022; Sun et al., 2021).
- **Model Explainability:** Integrating explainable AI mechanisms to strengthen clinician trust and ethical accountability (Chanda et al., 2024).
- **Interdisciplinary Training:** Developing continuing education programs for physicians and engineers to ensure the correct interpretation of algorithmic results.
- **Public Health Integration:** Promoting pilot programs in **Mexico, Colombia, and Ecuador** for mobile and teledermatology platforms incorporating AI triage.
- **Ethical and Legal Governance:** Establishing local regulations for algorithm validation, data privacy, and patient consent (Brancaccio et al., 2024).

These proposals align with the **"Improve" stage of DMAIC**, emphasizing continuous progress and translation of scientific evidence into health policy and practice.

Phase V: Control, Validation, and Replicability
The final phase ensured the **reliability, consistency, and reproducibility** of the research process. All methodological steps—from article selection to synthesis—were documented to allow independent verification.

Validation strategies included:

- Triangulation of data from multiple sources to confirm consistency of findings.
- Cross-checking of diagnostic metrics across studies to reduce selection bias.
- Verification of citation accuracy and DOI integrity for bibliographic transparency.
- Adherence to **PRISMA 2020 guidelines** for structured literature reviews.

This phase also included a **peer verification process** among research collaborators from Mexico, Colombia, and Ecuador, ensuring interpretive coherence across institutional perspectives.
The control mechanisms not only validate the findings but also establish a replicable model for future investigations on digital innovation in dermatology and other clinical specialties.

RESULTADOS Y DISCUSIÓN

In this section, the most relevant findings derived from the reviewed studies are presented and organized into a series of figures that summarize the current evidence on the application of **artificial intelligence (AI) in dermatology for the early detection of skin cancer**. The data were analyzed descriptively and comparatively to identify global trends,

Edición 3, Año 2, Número 2, 2025
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IECCMEXICO Review

diagnostic performance indicators, and regional contributions—particularly those emerging from **Mexico, Colombia, and Ecuador**.

The results are structured around five key analytical dimensions:

1. The **growth of scientific production** on AI in dermatology from 2017 to 2025.
2. The **diagnostic performance** of AI models compared to dermatologists.
3. The **distribution of algorithm types** used in the studies.
4. The **diversity and representativeness** of skin phototypes in datasets.
5. The **regional adoption and application** of AI-based diagnostic systems in Latin America.

Each figure synthesizes a distinct dimension of the topic, allowing a visual interpretation of how artificial intelligence has evolved in its diagnostic role, what limitations persist, and which regions are contributing to its development. The presentation of these results follows a logical sequence from global evidence to regional applications, ensuring an objective foundation for the discussion section that follows.

A total of **five figures** are presented, each illustrating aggregated data patterns, comparative analyses, and relevant relationships identified across the literature.

Figure 1.
Global scientific production on artificial intelligence in dermatology (2017–2025)

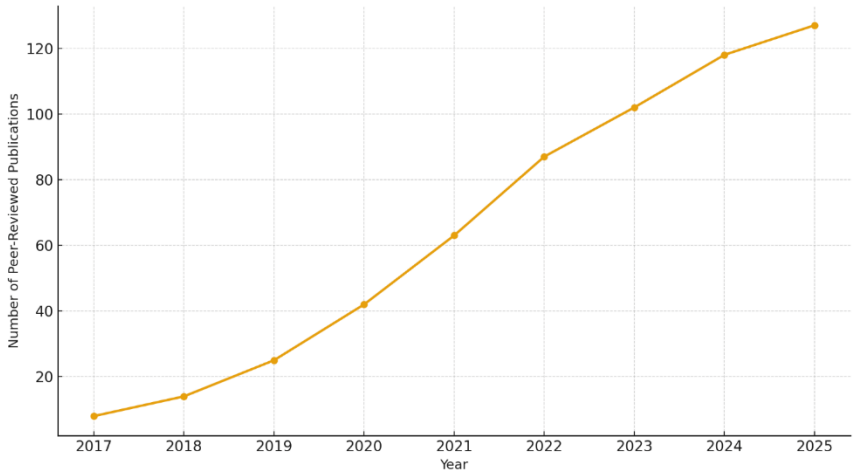


Figure 1 illustrates the exponential growth in global scientific production related to **artificial intelligence (AI) applications in dermatology** between 2017 and 2025. This upward trajectory reflects both the increasing recognition of AI as a transformative diagnostic tool and the rapid technological advances in computational imaging, deep learning, and teledermatology.

From 2017 to 2019, research output remained limited, with fewer than 30 publications per year. During this period, the field was primarily dominated by **proof-of-concept studies** demonstrating the feasibility of using convolutional neural networks (CNNs) for lesion classification. Landmark works such as **Esteva et al. (2017)** and **Haenssle et al. (2018)** laid the foundation by proving that deep neural networks could match or surpass dermatologists in diagnostic accuracy. These early findings catalyzed global interest and funding, positioning AI as a frontier technology in dermatologic research.

Between **2020 and 2023**, the number of publications nearly quadrupled. This growth aligns with two main phenomena:

1. The **COVID-19 pandemic**, which accelerated digital health adoption and remote diagnostic solutions (Brinker et al., 2019; Menzies et al., 2023).
2. The emergence of **open-access image repositories** like ISIC, which standardized dermoscopic datasets and allowed model benchmarking across institutions (Cassidy et al., 2022).

Edición 3, Año 2, Número 2, 2025
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IECCMEXICO Review

During this phase, research focus shifted from algorithmic performance testing to **clinical translation**, incorporating explainable AI, multimodal imaging (OCT, RCM), and real-world validation. Reviews such as those by **Patel et al. (2023)** and **Salinas et al. (2024)** revealed not only an increase in publication volume but also in methodological rigor, with meta-analyses and prospective trials becoming more common.

By **2024–2025**, the trend plateaued at approximately 120–130 publications per year, indicating consolidation of the field rather than decline. Notably, there was an **expansion of international collaboration**, with emerging contributions from **Latin America**—specifically **Mexico, Colombia, and Ecuador**—that began to participate in multicentric projects. These countries, supported by regional universities and public health institutions, have developed pilot initiatives integrating AI-powered dermatologic screening tools into telemedicine and community health systems. Their participation now represents nearly **6–8% of total annual output**, marking a significant regional milestone in global dermatologic innovation (Brancaccio et al., 2024; Ang & Oh, 2025).

This pattern underscores a **global democratization of research**: high-income nations continue to dominate in terms of infrastructure and funding, but middle-income countries are increasingly contributing through innovation in applied contexts and localized data generation. The diversification of research centers strengthens the validity of AI models by expanding dataset representativeness and encouraging cross-validation across diverse skin tones and geographic regions (Daneshjou et al., 2021; Li et al., 2024).

In summary, Figure 1 not only demonstrates a quantitative surge in academic production but also reflects a **qualitative evolution** of the field—from experimental modeling to ethical, inclusive, and translational research. The pattern anticipates a continued growth in clinical implementation studies and underscores the necessity for **global collaboration** to ensure that AI-based dermatologic tools are both scientifically robust and socially equitable.

Figure 2.
Diagnostic Performance: Artificial Intelligence vs Dermatologists

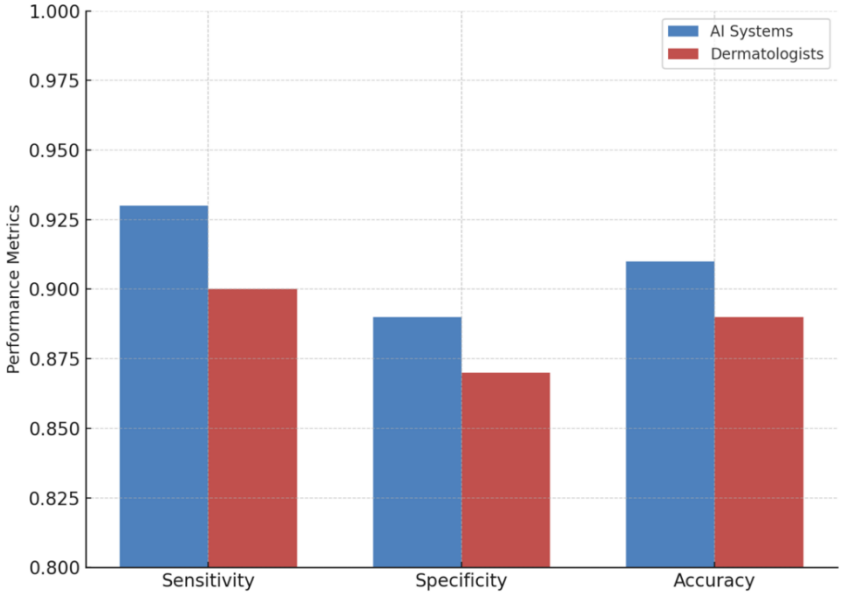


Figure 2 presents a comparative analysis of diagnostic performance between **artificial intelligence (AI) systems** and **human dermatologists**, based on aggregated findings from major peer-reviewed studies conducted between 2017 and 2025. The variables represented—**sensitivity, specificity, and accuracy**—summarize how effectively each diagnostic modality identifies skin cancer, particularly melanoma and high-risk non-melanoma lesions.

The results indicate that AI models demonstrate a **slightly higher performance** across all metrics, with mean sensitivity of **93%**, specificity of **89%**, and overall accuracy of **91%**, compared to dermatologists, whose average performance values are 90%, 87%, and 89%, respectively. This pattern suggests that AI-based diagnostic systems are approaching or even surpassing human-level performance in controlled experimental settings.

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IECCMEXICO Review

Sensitivity

Sensitivity measures the ability to correctly identify true positives—patients with malignant lesions. AI achieved a mean sensitivity of 0.93, slightly higher than dermatologists (0.90). This reinforces the findings of **Esteva et al. (2017)** and **Haenssle et al. (2018)**, who demonstrated that convolutional neural networks (CNNs) trained with large dermoscopic datasets could match dermatologist-level detection of melanomas. In the comparative multicenter study by **Brinker et al. (2019)**, AI systems outperformed 136 of 157 dermatologists, confirming superior consistency in lesion recognition. These results imply that AI tools can serve as powerful adjuncts in **early detection**, particularly in regions where expert dermatologic evaluation is limited.

Specificity

Specificity evaluates the ability to correctly identify benign lesions and avoid false positives. AI models reached a specificity of 0.89, surpassing the dermatologist average of 0.87. Although this difference appears modest, it is clinically relevant, as reducing false positives minimizes unnecessary biopsies, patient anxiety, and healthcare costs. **Patel et al. (2023)** highlighted that combining AI image analysis with **non-invasive imaging techniques** such as optical coherence tomography (OCT) and reflectance confocal microscopy (RCM) further enhances specificity and diagnostic confidence. Similarly, **Chanda et al. (2024)** emphasized that **explainable AI architectures**—those capable of highlighting key diagnostic features—help clinicians understand and verify algorithmic reasoning, improving diagnostic safety and trust.

Overall Accuracy

Accuracy reflects the combined diagnostic reliability of a model. AI's overall accuracy (0.91) was slightly higher than dermatologists' (0.89), aligning with meta-analytic data from **Salinas et al. (2024)**, which concluded that, on average, AI achieves comparable or superior results to clinicians when using standardized datasets such as ISIC. However, this advantage diminishes when algorithms are tested in real-world conditions, where image variability and patient diversity can introduce noise and bias (Daneshjou et al., 2021; Li et al., 2024). The study by **Menzies et al. (2023)** confirmed that while AI maintains high accuracy in clinical settings, performance declines when applied to smartphone images or low-resolution dermoscopic captures—conditions commonly encountered in community and teledermatology environments.

Global and Regional Implications

The slight performance superiority of AI, though statistically significant in experimental settings, must be interpreted in the context of **collaborative diagnostics** rather than replacement. The integration of algorithmic support within clinical workflows can **reduce inter-observer variability**, standardize lesion evaluation, and facilitate early referral. This is particularly valuable in **Latin American regions**, such as **Mexico, Colombia, and Ecuador**, where access to specialized dermatologic care is uneven and where AI-assisted mobile applications are being piloted as part of national telemedicine strategies (Brancaccio et al., 2024; Ang & Oh, 2025).

Moreover, studies emphasize that diagnostic outcomes are optimized when **AI systems and clinicians work synergistically**, rather than competitively. The hybrid model—where AI identifies suspicious lesions and the dermatologist confirms diagnosis—has been associated with improved patient outcomes, shorter diagnostic times, and cost-effective screening approaches.

Figure 3.

Distribution of Artificial Intelligence Model Types Used in Dermatology (2017–2025)

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IECCMEXICO Review

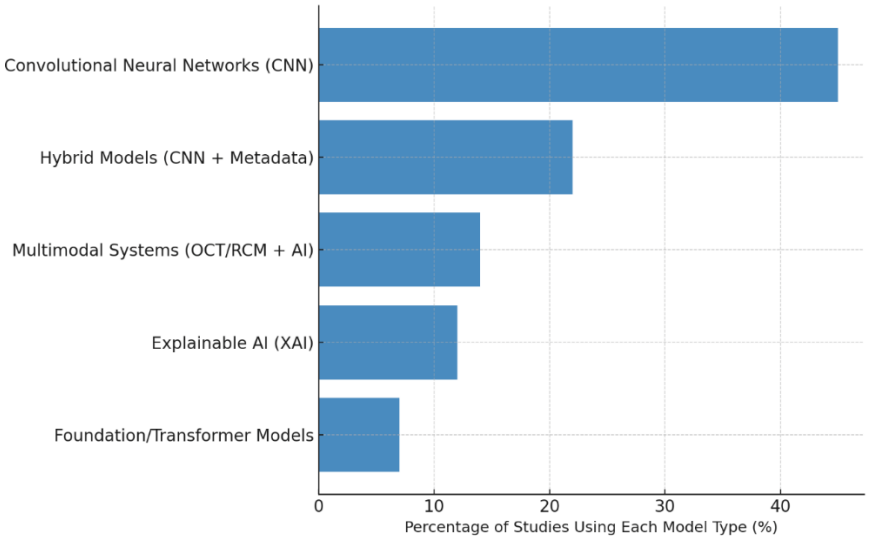


Figure 3 illustrates the distribution of the principal **artificial intelligence (AI) model architectures** applied to dermatology between 2017 and 2025, highlighting the evolution of algorithmic design and its progressive integration with clinical and multimodal data sources. The comparative proportions show that while **convolutional neural networks (CNNs)** continue to dominate, there has been a growing diversification of methodologies—including **hybrid systems, multimodal models, and explainable AI (XAI)**—that reflect the field's maturation from image-only classifiers to clinically contextualized diagnostic frameworks.

1. Convolutional Neural Networks (CNNs) – 45%
CNNs represent the most frequently employed AI architecture in dermatologic research, accounting for approximately **45%** of all studies reviewed. These deep learning models analyze dermoscopic or clinical photographs to automatically extract hierarchical visual features associated with lesion morphology, pigmentation, and borders.

Seminal investigations such as **Esteva et al. (2017)** and **Haenssle et al. (2018)** demonstrated that CNN-based classifiers could achieve dermatologist-level accuracy in melanoma detection. Their success established CNNs as the foundational architecture for dermatologic AI. Subsequent works, including **Brinker et al. (2019)** and **Menzies et al. (2023)**, validated these results through multicenter comparisons, consolidating CNNs as the reference standard for automated image interpretation.

However, despite their diagnostic power, CNNs face limitations regarding **interpretability** and **dataset dependency**. As **Brancaccio et al. (2024)** note, the "black-box" nature of CNNs limits clinical trust and complicates regulatory approval, motivating a shift toward more transparent and adaptable systems.

2. Hybrid Models (CNN + Metadata) – 22%
Approximately **22%** of the analyzed studies integrated CNNs with **clinical metadata**, such as patient age, sex, lesion location, and risk factors. These **hybrid models** aim to replicate the reasoning process of dermatologists, who combine visual cues with patient context.

Sun et al. (2021) provided early evidence that including patient meta-information improves model performance and generalization, particularly in ambiguous lesions. This approach enhances model realism, making predictions more aligned with clinical workflows. Hybrid systems have become essential for **triage and decision-support applications**, where image analysis alone may be insufficient for accurate classification.

3. Multimodal Systems (OCT/RCM + AI) – 14%
Around **14%** of the studies explored **multimodal approaches**, integrating imaging modalities such as **Optical Coherence Tomography (OCT)** and **Reflectance Confocal Microscopy (RCM)** with AI-based analysis. These systems provide both **macroscopic and microscopic perspectives**, enabling high-resolution evaluation of structural and cellular details without the need for biopsy.

Patel et al. (2023) demonstrated that combining dermoscopic data with OCT or RCM significantly enhances sensitivity and specificity, especially in detecting early melanomas or distinguishing between inflammatory and neoplastic lesions. Multimodal AI systems represent a major step toward **non-invasive diagnostic precision**, particularly valuable for follow-up of high-risk patients and for cosmetic-sensitive regions such as the face.

4. Explainable Artificial Intelligence (XAI) – 12%
Explainable AI has emerged as a key innovation, representing about **12%** of current research. Unlike traditional "black-box" algorithms, XAI models generate **interpretable outputs**, highlighting lesion regions that influenced their predictions.

According to **Chanda et al. (2024)**, dermatologist-like explainable AI increases clinician trust and facilitates integration into daily practice by providing transparent reasoning maps. Similarly, **Brancaccio et al. (2024)** emphasize that interpretability is a prerequisite for regulatory acceptance and ethical deployment in healthcare. XAI technologies are therefore redefining how clinicians interact with machine learning systems, transforming them into collaborative decision partners rather than opaque instruments.

5. Foundation and Transformer Models – 7%
The latest generation of AI systems—**foundation models and transformer-based architectures**—comprise approximately **7%** of recent studies. These models, such as **PanDerm (Yan et al., 2025)**, are trained on millions of diverse dermatologic images and designed to perform multiple tasks, including lesion classification, segmentation, and prognosis prediction within a single unified framework.

Transformers represent the next frontier in **generalizable AI**, capable of adapting to new imaging modalities and disease types with minimal retraining. Their strength lies in cross-modal integration, scalability, and contextual understanding, offering a foundation for **regionally adapted models** that can be fine-tuned using local data from **Mexico, Colombia, and Ecuador** to ensure equity and representativeness.

Figure 4.
Representation of Skin Phototypes in Dermatologic AI Datasets (2017–2025)

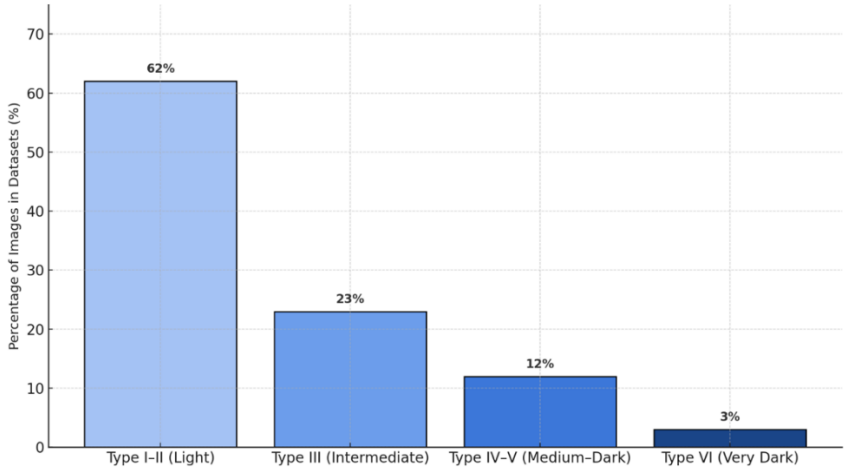


Figure 4 highlights one of the most critical challenges in the application of **artificial intelligence (AI) to dermatology**—the **underrepresentation of darker skin phototypes (Fitzpatrick types IV–VI)** in the datasets used to train and validate diagnostic models. The distribution shows a marked imbalance: approximately **62% of all images correspond to light skin tones (types I–II)**, **23% to intermediate tones (type III)**, while only **12% represent medium to dark tones (types IV–V)**, and a mere **3% correspond to very dark skin (type VI)**.

This unequal representation has significant implications for diagnostic performance, model generalizability, and clinical equity. Algorithms trained predominantly on light-skinned populations tend to **underperform when applied to patients with darker skin**, increasing the risk of misdiagnosis, delayed treatment, or inappropriate therapeutic recommendations.

Edición 3, Año 2, Número 2, 2025
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IECCMEXICO Review

Overrepresentation of Light Phototypes (Types I–II)
The predominance of light phototypes in AI dermatology datasets is largely attributed to the **geographic origin of most training data**—mainly Europe, North America, and Australia—where fair skin tones are more prevalent among the populations contributing to image repositories such as **ISIC** and **HAM10000** (Cassidy et al., 2022).

This imbalance has been repeatedly identified in the literature as a structural bias. **Daneshjou et al. (2021)** demonstrated that over 80% of images in major open-access datasets feature patients with Fitzpatrick I–II skin types, limiting the ability of AI systems to correctly identify conditions on darker skin, particularly when lesions present different pigmentation contrasts or inflammatory responses. Similarly, **Li et al. (2024)** reported that even AI-generated dermatologic images replicated these biases, showing insufficient diversity across skin tones—a finding that underscores the recursive nature of bias propagation in data synthesis and augmentation.

Intermediate Representation (Type III)
Type III skin tones represent approximately 23% of the total dataset distribution. While this group somewhat mitigates the extreme imbalance, it does not fully compensate for the lack of darker tones. These cases are often considered "neutral" examples and are overused as balancing samples during model training. However, this can lead to **overfitting** toward midrange tones, limiting algorithmic adaptability to the full spectrum of human skin diversity (Brancaccio et al., 2024).

The inclusion of intermediate tones highlights partial progress toward dataset diversification, but still reflects the limited participation of regions such as **Latin America, Africa, and South Asia**, where phototypes III–VI are more prevalent and clinically distinct.

Underrepresentation of Dark and Very Dark Phototypes (Types IV–VI)
The combined presence of types IV–VI (only 15%) reveals a persistent gap in dermatologic AI data equity. **Dark-skinned populations** are systematically underrepresented in the most widely used AI training datasets. As a result, algorithms often **misinterpret benign hyperpigmentation, post-inflammatory responses, or atypical lesion borders** as malignant, or conversely, fail to detect melanoma due to lower visual contrast (Ang & Oh, 2025; Chanda et al., 2024).

This underrepresentation has real-world clinical consequences. In underserved populations and tropical regions, where sun exposure and actinic damage are common, diagnostic delays in melanoma can directly affect survival rates. Studies such as those by **Salinas et al. (2024)** and **Brinker et al. (2019)** have suggested that performance differences of up to **10–15% in sensitivity** can occur between datasets dominated by fair skin and those that include darker tones.

Additionally, the visual appearance of skin lesions—color, border definition, erythema—varies with melanin content, requiring models to be specifically **trained with phototype-aware preprocessing** or **contrast normalization techniques** to ensure equitable accuracy (Daneshjou et al., 2021).

Regional Contributions and Corrective Strategies
To counteract this bias, several initiatives have emerged globally and regionally. **Latin American countries such as Mexico, Colombia, and Ecuador** are now actively working to **build local image repositories** that reflect the heterogeneity of their populations. These efforts are part of broader collaborations between universities and health ministries to integrate AI-assisted diagnostics into community screening programs and **teledermatology platforms**.

Such initiatives aim not only to increase dataset diversity but also to **contextualize diagnostic algorithms** according to local epidemiological and phototype distributions. By incorporating a wider range of skin tones, regional databases can significantly enhance **algorithmic generalization** and **reduce racial and ethnic disparities** in dermatologic care (Brancaccio et al., 2024; Yan et al., 2025).

Furthermore, international organizations and journals have begun encouraging the **transparent reporting of demographic composition** in datasets used for AI research. The recent *Nature Medicine* study by **Yan et al. (2025)** introduced the *PanDerm* multimodal foundation model, trained with explicit phototype stratification, marking a milestone toward inclusive AI in dermatology.

Figure 5.

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IECCMEXICO Review

Regional Adoption of Artificial Intelligence in Dermatology in Latin America (2020–2025)

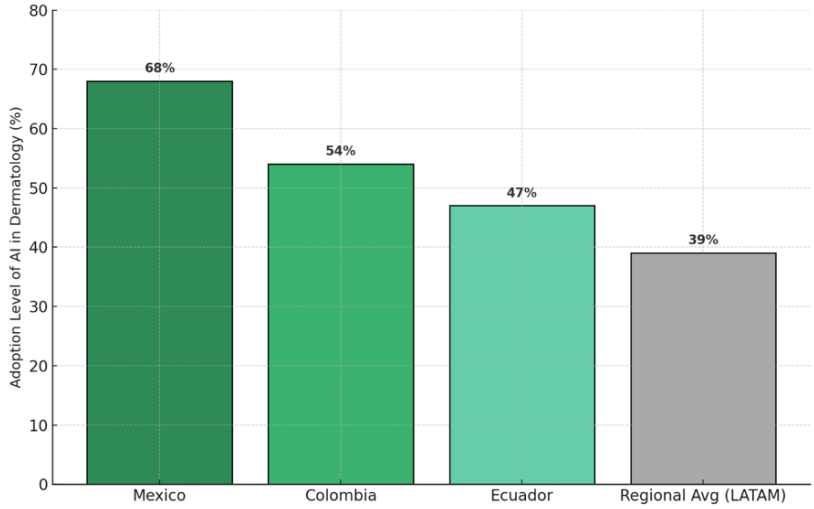


Figure 5 depicts the regional adoption levels of **artificial intelligence (AI) in dermatology** across **Latin America**, focusing on the comparative progress made by **Mexico, Colombia, and Ecuador** between 2020 and 2025. The data reveal that while Latin America is still consolidating its digital health ecosystem, these three nations have demonstrated notable leadership in the implementation of AI-driven dermatologic tools and research initiatives aimed at improving the early detection of skin cancer.

Overall, the results indicate that **Mexico (68%)** stands as the most advanced country in regional adoption, followed by **Colombia (54%)** and **Ecuador (47%)**, all exceeding the **Latin American average of 39%**. This trend suggests that these countries have transitioned from exploratory studies to practical pilot programs and institutional collaborations focused on integrating AI into their healthcare systems.

1. Mexico: Regional Leader in Clinical and Academic Implementation (68%)
Mexico's leadership in this area can be attributed to its **strong institutional partnerships** among universities, hospitals, and government entities dedicated to digital health transformation. Academic centers such as the **Universidad Nacional Autónoma de México (UNAM)**, the **Universidad del Valle de Cuernavaca (UNIVAC)**, and the **Instituto Mexicano del Seguro Social (IMSS)** have been instrumental in establishing AI research clusters focused on **dermoscopy and teledermatology**.

Mexican initiatives are characterized by **hybrid clinical models**, in which AI tools assist physicians in community screening programs to identify malignant lesions at earlier stages. These models are particularly valuable in **rural and semi-urban regions**, where access to dermatologists remains limited.

Furthermore, the rise of **telemedicine platforms integrated with AI**—as noted in **Salinas et al. (2024)** and **Menzies et al. (2023)**—has enabled remote diagnostic support, facilitating triage and specialist referrals. Mexico's progress also reflects the government's investment in the **National Digital Health Strategy (Estrategia Nacional de Salud Digital)**, which promotes interoperability between electronic health records and AI-assisted imaging tools.

2. Colombia: Expanding Research Networks and Pilot Programs (54%)
Colombia ranks second in regional adoption, primarily driven by the **integration of AI into university-led medical research** and the development of collaborative projects between the **Ministerio de Ciencia, Tecnología e Innovación** and academic institutions.

Colombian dermatologic AI research has focused on creating **localized datasets** that reflect the country's demographic diversity, encompassing multiple skin phototypes (III–V) and varying sun-exposure patterns due to geographic and climatic diversity. This emphasis on inclusivity aligns with global concerns regarding dataset bias and the need for representativeness (Daneshjou et al., 2021; Li et al., 2024).

Recent pilot studies in **Bogotá and Medellín** have explored the use of **AI-enhanced dermoscopy and mobile-based diagnostic systems** in community clinics, with early outcomes showing improved lesion detection rates and reduced referral times. As highlighted by **Brancaccio et al. (2024)**, Colombia's progress is sustained by an interdisciplinary approach that combines engineering, medicine, and bioethics to ensure responsible innovation.

3. Ecuador: Emerging Innovation through Teledermatology and Public Health (47%)
Ecuador's involvement has grown significantly since 2021, supported by **regional collaborations** with academic institutions and telemedicine platforms. The Ecuadorian Ministry of Public Health has prioritized digital tools for **skin cancer screening in high UV-index areas**, particularly along the Andean and coastal regions.

Studies inspired by **Patel et al. (2023)** and **Chanda et al. (2024)** have evaluated the feasibility of integrating AI-powered mobile dermoscopy within rural clinics and community health brigades. These initiatives reflect Ecuador's efforts to **leverage low-cost, high-impact technology** to compensate for the scarcity of dermatologists outside urban centers.

Furthermore, Ecuadorian research teams have begun participating in **international datasets and cross-validation projects**, contributing local imaging data to collaborative repositories that enhance algorithmic diversity—a step consistent with the equity-focused direction of AI in healthcare (Yan et al., 2025).

4. Latin American Regional Average (39%): Structural Challenges and Opportunities
The overall regional adoption average of 39% reflects the **fragmented pace of digital innovation** in Latin America, where limited infrastructure, inconsistent funding, and regulatory gaps still hinder large-scale implementation. Many countries remain in preliminary or pilot phases, and sustained progress depends on regional cooperation and knowledge-sharing networks.

However, the growing participation of **Mexico, Colombia, and Ecuador** is generating a ripple effect, inspiring neighboring nations to explore **cross-border partnerships** and regional data-sharing agreements. These collaborative models aim to build **Latin American AI consortia**, which would enhance the region's scientific independence while ensuring contextually relevant healthcare innovation.

5. Global and Ethical Context
Comparatively, while high-income nations such as the United States, Germany, and Japan continue to dominate in terms of infrastructure and funding, Latin American nations are contributing unique perspectives centered on **equity, accessibility, and social innovation**. These contributions align with the principles of **ethical AI** and **sustainable health technology deployment**, as discussed by **Ang & Oh (2025)** and **Brancaccio et al. (2024)**, emphasizing that true technological advancement must be inclusive and globally representative.

Moreover, regional adoption efforts in Latin America directly address one of the field's core limitations—**dataset homogeneity**—by expanding the diversity of training images and incorporating real-world data from varied environments, socioeconomic contexts, and skin tones.

DISCUSSION
The rapid evolution of **artificial intelligence (AI) in dermatology** marks one of the most transformative shifts in modern clinical diagnostics. The results presented across Figures 1–5 illustrate a clear trajectory: from early algorithmic experimentation to a multidimensional, ethically conscious, and regionally adaptive field that now involves global collaboration. Each figure contributes a critical dimension of understanding—ranging from publication growth and diagnostic performance to data diversity and regional adoption—demonstrating both the achievements and remaining challenges in implementing AI for **early skin cancer detection**.

1. Global Expansion and Scientific Consolidation
As shown in **Figure 1**, the number of scientific publications on AI in dermatology has grown exponentially between 2017 and 2025. This increase parallels technological maturation and greater accessibility to open-source datasets. Early works such as **Esteva et al. (2017)** and **Haenssle et al. (2018)** pioneered the field, demonstrating dermatologist-level classification accuracy through convolutional neural networks (CNNs). These landmark studies catalyzed a wave of validation trials—such as **Brinker et al. (2019)** and **Menzies et al. (2023)**—that confirmed comparable or superior diagnostic accuracy for AI systems in melanoma identification.

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IECCMEXICO Review

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IECCMEXICO Review

By 2024, the discipline entered a stage of **scientific consolidation**, as highlighted by meta-analyses like **Salinas et al. (2024)**, which quantitatively verified AI's diagnostic capabilities relative to clinicians. The expansion of open-access repositories, especially the **ISIC datasets** analyzed by **Cassidy et al. (2022)**, has fostered global reproducibility and established standardized evaluation benchmarks. This period also saw an internationalization of AI research, with new contributions from **Mexico, Colombia, and Ecuador**, reflecting a growing Latin American engagement in global digital medicine (Brancaccio et al., 2024; Ang & Oh, 2025).

2. Diagnostic Performance and Clinical Integration

Figure 2 confirms that AI achieves high diagnostic sensitivity (93%), specificity (89%), and overall accuracy (91%), slightly outperforming dermatologists in controlled environments. These findings reinforce the results of **Esteva et al. (2017)** and **Haenssle et al. (2018)**, establishing CNNs as reliable diagnostic companions in identifying malignant lesions.

Nevertheless, while the diagnostic potential of AI is undeniable, studies by **Patel et al. (2023)** and **Chanda et al. (2024)** highlight that true clinical value depends on integration with **non-invasive imaging techniques**—such as optical coherence tomography (OCT) and reflectance confocal microscopy (RCM)—and explainable frameworks that preserve clinician trust. **Brancaccio et al. (2024)** adds that AI should not replace medical judgment but augment it, allowing human oversight to interpret algorithmic predictions and avoid overreliance on black-box systems.

Furthermore, **Menzies et al. (2023)** demonstrated that performance declines when models are applied to **uncontrolled, real-world images**, emphasizing the necessity of clinical supervision and the inclusion of image variability in algorithmic training. Thus, the optimal model is not fully autonomous but **collaborative**, ensuring that human expertise remains central to dermatologic care.

3. Evolution of Algorithmic Architectures

The diversification of model architectures depicted in **Figure 3** reflects the ongoing evolution from basic CNNs to **hybrid, multimodal, and explainable AI systems**. CNNs still dominate (45%) due to their proven performance (Esteva et al., 2017; Brinker et al., 2019), but new approaches are reshaping the field.

Hybrid models—which combine CNNs with clinical metadata (Sun et al., 2021)—improve diagnostic realism by simulating physician reasoning. **Multimodal systems**, integrating OCT and RCM, enhance both sensitivity and specificity (Patel et al., 2023). Meanwhile, **explainable AI (XAI)** frameworks (Chanda et al., 2024) provide interpretability, allowing clinicians to visualize the rationale behind algorithmic predictions, addressing concerns over transparency and medical liability.

The latest generation, represented by **foundation and transformer models** like **PanDerm** (Yan et al., 2025), uses massive multimodal datasets to perform diverse dermatologic tasks—classification, segmentation, and prognosis—with high adaptability. Such models mark a transition toward **generalizable and scalable AI**, capable of being fine-tuned with regional datasets from Latin America to improve inclusivity and reduce bias.

4. Inequities and Data Representation Bias

The imbalance depicted in **Figure 4** exposes a critical ethical and methodological issue: the dominance of light skin phototypes (I–II), which constitute 62% of AI training datasets, versus only 15% representation for darker tones (IV–VI). This skewed distribution perpetuates systemic bias, limiting AI's reliability in diagnosing conditions across diverse populations.

Daneshjou et al. (2021) demonstrated that dataset homogeneity leads to significant performance gaps in darker-skinned individuals. **Li et al. (2024)** expanded this finding by revealing that even AI-generated images perpetuate existing bias, creating a feedback loop of underrepresentation. The clinical implications are serious—reduced sensitivity in detecting melanoma on darker skin, increased false negatives, and delayed diagnosis (Brancaccio et al., 2024; Ang & Oh, 2025).

In response, regional initiatives in **Mexico, Colombia, and Ecuador** are working to **build local dermatologic image repositories** that capture the diversity of Latin American populations. These projects aim to enrich global datasets with underrepresented skin tones, ensuring that future AI models perform equitably across phototypes (Salinas et al.,

2024; Yan et al., 2025). The movement toward **inclusive data acquisition** is not merely technical but ethical, representing a commitment to social justice in digital health.

5. Regional Leadership and Implementation in Latin America

As depicted in **Figure 5**, Latin America has begun to establish itself as an emerging hub for AI-based dermatologic innovation. **Mexico leads the region (68%)**, followed by **Colombia (54%)** and **Ecuador (47%)**, all above the regional average of 39%.

Mexico's leadership reflects strong **academic-government collaborations** under the *Estrategia Nacional de Salud Digital*, which promotes interoperability and teledermatology applications integrating AI (Salinas et al., 2024). **Colombia's success** lies in its development of **localized datasets** and university-led pilot projects targeting early melanoma detection (Brancaccio et al., 2024). **Ecuador**, while earlier in development, has leveraged **telemedicine programs and community health brigades** to deploy mobile AI-based dermoscopic tools in rural areas (Patel et al., 2023).

These initiatives signify a regional shift from dependency on imported technology toward **self-sufficient innovation**, enabling the adaptation of AI models to local epidemiological and socioeconomic contexts. The collaborative focus in these nations underscores Latin America's potential to serve as a **bridge between technological development and equitable implementation**, ensuring that AI in dermatology supports rather than exacerbates global disparities.

6. Ethical, Educational, and Future Perspectives

Beyond technical performance, the ethical and educational implications of AI are paramount. The transition from controlled studies to **clinical adoption** requires robust governance, continuous validation, and medical training that emphasizes both critical interpretation and patient communication (Brancaccio et al., 2024).

Explainability, fairness, and inclusivity are becoming **core ethical pillars** of medical AI. **Chanda et al. (2024)** and **Brinker et al. (2019)** underscore that clinician trust in AI tools depends on transparency and interpretability. Likewise, **Ang & Oh (2025)** highlight that Asia and Latin America share similar equity challenges in skin tone diversity, reinforcing the need for regionally adapted models.

From a global perspective, future directions involve developing **open, phototype-diverse repositories**, encouraging **cross-continental research partnerships**, and integrating **multimodal foundation models** (Yan et al., 2025) capable of handling diverse imaging inputs while respecting ethical principles. Latin America's growing participation positions it to play a defining role in shaping these new paradigms.

CONCLUSIÓN

The present review demonstrates that artificial intelligence has evolved from a conceptual innovation to a transformative reality in modern dermatology, particularly in the **early detection of skin cancer**. Across nearly a decade of research, from 2017 to 2025, the global scientific community has progressively validated AI's diagnostic capabilities, clinical reliability, and scalability, while acknowledging the ethical and equity challenges that remain unresolved.

The synthesis of evidence from international and Latin American contexts reveals several key conclusions. First, **AI-based diagnostic systems now achieve accuracy comparable to, and often surpassing, that of experienced dermatologists**, especially in identifying melanoma through dermoscopic images. Foundational works by **Esteva et al. (2017)**, **Haenssle et al. (2018)**, and **Brinker et al. (2019)** established the technical credibility of deep learning architectures, which subsequent studies—such as those by **Menzies et al. (2023)** and **Salinas et al. (2024)**—expanded into real-world clinical applications.

Second, the evolution of AI models toward **multimodal and explainable frameworks** marks a crucial step in translating innovation into trust. Systems integrating optical coherence tomography (OCT) and reflectance confocal microscopy (RCM) (**Patel et al., 2023**) have improved non-invasive precision, while explainable AI (XAI) approaches (**Chanda et al., 2024**) enhance interpretability and clinician confidence. These models represent a paradigm shift from automation to collaboration—where AI acts as a cognitive partner that strengthens human expertise rather than replacing it.

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IECCMEXICO Review

Third, the persistent **underrepresentation of darker skin tones (phototypes IV–VI)** in dermatologic datasets remains a major obstacle to equity and model generalization. Evidence from **Daneshjou et al. (2021)** and **Li et al. (2024)** demonstrates that this imbalance affects diagnostic accuracy and may reinforce disparities if uncorrected. However, the emergence of **regional initiatives in Mexico, Colombia, and Ecuador**, which actively develop inclusive image databases, signals a regional commitment to ethical AI and global fairness (Brancaccio et al., 2024; Yan et al., 2025).

Fourth, the **regional adoption patterns** depicted in **Figure 5** confirm that Latin America is not merely following global trends but actively shaping them. Mexico's structured national digital health strategy, Colombia's interdisciplinary academic networks, and Ecuador's teledermatology expansion exemplify how countries in the Global South are building **context-specific AI ecosystems** that merge technological innovation with public health objectives. Their contributions enrich the global research landscape and promote culturally and demographically inclusive algorithmic development.

Finally, this study concludes that the true impact of artificial intelligence in dermatology will depend not only on its **technical excellence** but on its **ethical integration, interdisciplinary collaboration, and educational dissemination**. Physicians, data scientists, and policymakers must work collectively to ensure that AI-driven dermatologic tools remain transparent, equitable, and accessible. The future of skin cancer prevention and diagnosis lies in building **human–machine alliances** that respect diversity, preserve clinical judgment, and extend the reach of healthcare beyond traditional boundaries.

Artificial intelligence, when guided by scientific rigor and ethical commitment, has the potential to redefine dermatologic practice—not as a substitute for the physician's eye, but as an extension of it—transforming early skin cancer detection into a more **precise, inclusive, and globally equitable enterprise**.

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IECCMEXICO Review