

## DERMATOSCOPY AND ARTIFICIAL INTELLIGENCE IN THE REPUBLIC OF KAZAKHSTAN: EFFECTIVENESS AND LEGITIMACY

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This paper provides a comprehensive analysis of the evolution of dermoscopy and the integration of artificial intelligence within clinical practice, specifically addressing early skin cancer detection in the Republic of Kazakhstan. Given that skin lesions remained among the top three oncological pathologies in the country between 2012 and 2022, objective screening is now a national priority. The study involved a multi-stage search across international repositories, resulting in a selection of twenty-six representative sources, including randomized controlled trials and meta-analyses.

The findings trace the methodological transformation from the qualitative scales of the 1990s to the current era of digital dominance. Contemporary data confirm the technological superiority of convolutional neural networks, which demonstrate area under the curve values ranging from 0.86 to 0.99, often exceeding expert performance. While early observations focused on morphological structures, the current focus has shifted toward deep learning and total digital monitoring, despite persistent risks associated with real-world artifacts and out-of-distribution data.

The analysis confirms a paradigm shift toward hybrid intelligent systems. In Kazakhstan, this process is supported by national strategic concepts and the Law on Artificial Intelligence, integrated into the 2026 health legislation. However, implementation at the primary healthcare level requires overcoming the lack of local datasets that account for regional skin phototypes. This study establishes a roadmap for technology integration, emphasizing that clinical validation and international cooperation are vital factors for improving patient survival rates during medical digital transformation.

*Key words:* dermoscopy; melanoma; artificial intelligence; deep learning; diagnosis computer-aided

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### INTRODUCTION

The modern dynamics of malignant neoplasms in the Republic of Kazakhstan pose challenges to the healthcare system that require not only clinical but also deep technological transformation. Skin lesions occupy a special place among oncopathologies, demonstrating steady growth over the last decade. Retrospective epidemiological studies from 2012 to 2022 show that skin cancer consistently ranks among the three most common cancers in the country [1]. Despite the visual accessibility of lesions, early-stage diagnosis of melanoma and other neoplasms remains associated with several subjective difficulties, often leading to prolonged diagnostic intervals and reduced patient survival.

Amid increasing pressure on specialized oncology services, it becomes critically important

to identify tools capable of objectifying primary screening at the primary healthcare level (PHC). In this context, the strategic response of the state has been the accelerated development of digital medicine. This policy was further reinforced by the approval of the Artificial intelligence (AI) Development Concept for 2024 – 2029, which identified the implementation of intelligent systems in healthcare as a priority modernization vector [2]. This document laid the methodological foundation for the transition from traditional medical image analysis to automated clinical decision support systems.

However, the implementation of such innovations requires not only technical readiness but also clear legal legitimation. A fundamental step in this direction was the adoption in 2025 of the specialized Law «On Artificial Intelligence» dated

November 17, 2025 No. 230-VIII ZRK, which for the first time established the legal status of algorithms and defined the framework of liability for their use in socially significant sectors, including healthcare [3].

These provisions are harmoniously integrated into the overall architecture of the national healthcare system through the Code «On Public Health and the Healthcare System» (as amended in 2026), which guarantees patients access to high-technology diagnostic methods while simultaneously regulating requirements for cybersecurity and the protection of personal data [4].

Thus, Kazakhstan has established a full ecosystem enabling the transition of neural network algorithms from experimental development to real clinical practice. Given this regulatory and legal framework, a detailed analysis of the technological component of these changes is warranted. The article therefore presents a literature review of the evolution of dermatoscopy and a comparative assessment of deep learning algorithm performance.

## MATERIALS AND METHODS

The systematic literature review was conducted on publications from 1990 to 2025, focusing on the evolution of dermatoscopy and the application of deep learning algorithms for skin cancer diagnosis. Searches were performed in *PubMed*, *Scopus*, *Web of Science*, and *Google Scholar* using keywords: «dermatoscopy», «melanoma», «deep learning», «CNN skin cancer diagnosis», «artificial intelligence dermatology» in both English and Russian, as well as local context terms such as «Kazakhstan oncology AI».

Twenty-six original studies and meta-analyses were selected (including works by Stolz, Argenziano, Kittler, Dinnes, Haenssle, etc.), meeting inclusion criteria: randomized controlled trials, prospective cohort studies, or systematic reviews with quantitative metrics (sensitivity, specificity, AUC). Case reports, expert opinions without data, and publications without dermatoscopic images were excluded. Data were structured chronologically (1990 – 2022 for dermatoscopy; 2022 – 2025 for AI) and summarized in comparative tables of model performance metrics (AUC, sensitivity, specificity).

Statistical analysis included qualitative synthesis without pooled meta-analysis due to methodological heterogeneity. Study quality was assessed using AMSTAR-2 for reviews and QUADAS-2 for diagnostic studies. Kazakhstan's regulatory framework (AI Concept 2024 – 2029, AI Law 2025, Health Code 2026) was integrated to contextualize implementation.

### **The emergence of dermatoscopy as a diagnostic method: a conceptual breakthrough (1990 – 2002)**

The history of modern skin tumor diagnostics underwent a fundamental transformation at the turn

of the century. Prior to the widespread adoption of epiluminescence microscopy (dermoscopy), the diagnosis of pigmented lesions was limited to unaided visual inspection, inevitably leading to high subjectivity and frequent diagnostic errors. The period from 1990 to 2002 can rightly be considered the «golden age» of methodological development, when fragmented expert observations were transformed into clear diagnostic algorithms supported by an evidence base.

The first attempt to translate intuitive structural analysis into the language of mathematics and logic was made by W. Stolz and colleagues (1994). Their proposed ABCD rule addressed clinicians' complaints about the excessive complexity of morphological descriptions. The authors offered an elegant solution: to quantify asymmetry, border irregularity, color variation, and lesion architecture using a semi-quantitative scale [5]. This approach not only simplified the clinician's work but also brought dermatoscopy out of specialized research laboratories into broad outpatient practice, creating a unified «diagnostic code» for specialists of varying levels.

However, the ergonomic design of algorithms alone was insufficient to convince the conservative medical community of the need for methodological change. Statistical validation was required. In 2001, a landmark paper by G. Argenziano and H. Pehamberger in *Lancet Oncology* established dermatoscopy not merely as a «useful adjunct» but as a critical tool for detecting melanoma at the in situ stage [6]. The researchers demonstrated that the ability to verify sub-microscopic epidermal architecture enables the detection of malignant growth long before it becomes apparent on visual inspection.

The debate over the method's validity was settled by a meta-analysis led by H. Kittler in 2002. Their findings ultimately legitimized instrumental diagnostics, confirming a multiple-fold increase in the sensitivity and specificity of examinations [7]. A crucial outcome of this period was the acknowledgment of the «human factor»: the accuracy of the instrument was shown to depend directly on the operator's expertise. This observation triggered a surge in educational programs and ultimately laid the groundwork for the emergence of digital analysis systems. By the early 2000s, dermatoscopy had officially achieved the status of a «gold standard», forming a foundation without which modern dermato-oncological practice would be unthinkable.

### **Evolution of criteria (2003 – 2010): when numbers replaced intuition**

By the early 2000s, dermatoscopy faced a «translation problem»: different schools used their own terminology to describe the same structures, creating chaos in both training and diagnostics. A turning point in overcoming this Babel-like confusion was the Consensus Net meeting, the results of which

G. Argenziano and colleagues published in 2003 [8]. This work effectively standardized the conceptual framework of modern dermato-oncology.

Experts not only agreed on terminology but also formalized a two-step diagnostic algorithm that is still taught as the foundation today. In the first step, the clinician must clearly exclude non-melanocytic lesions (seborrheic keratosis, basal cell carcinoma, angiomas), while in the second step, they examine the morphology of melanocytic lesions in detail for malignancy risk [8]. The introduction of a unified visual code allowed the method to achieve international standardization, transforming the subjective «this is how I see it» into a reproducible protocol.

Alongside linguistic standardization, the seeds of the digital revolution began to take root. While dermoscopy was initially regarded as purely a manual optical tool, by the late 2000s concepts of digital monitoring and early machine analysis entered professional discourse. In 2009, S. M. Rajpara and colleagues presented a large systematic review in the *British Journal of Dermatology*, which at the time seemed almost futuristic.

The authors conducted the first serious inventory of AI capabilities relative to classical dermoscopy. Their conclusions were sobering: digital image processing and early automated systems already demonstrated sensitivity comparable to expert assessment but suffered from low specificity [9]. Rajpara's work became an important «bridge», linking Argenziano's classical morphology to the future era of neural networks, and highlighted the decade's central challenge: how to teach a machine not only to recognize patterns but also to understand the clinical context.

By the end of the decade, it was widely acknowledged that a physician's expertise is not intuition but the ability to rapidly correlate complex dermoscopic structures with histological predictions.

### **Revision of the evidence base: the era of big data (2010 – 2018)**

By 2010, dermoscopy had earned considerable credibility, but for full inclusion in national protocols, a rigorous audit of accumulated data was necessary. The first major «stress test» came from the meta-analysis by M. E. Vestergaard published in *British Medical Journal*. The researchers drew a clear line under debates on the instrument's value: the data convincingly demonstrated that relying solely on visual inspection at the expense of instrumental examination consciously reduced patients' chances for early tumor detection [10].

A more comprehensive inventory of evidence was provided by J. Dinnes in the 2018 Cochrane review. The results of this monumental work made an important correction to professional understanding: the dermatoscope is not a magical lens but a high-precision instrument whose effectiveness sharply

declines outside the clinical context. The authors showed that the combination of «patient history + dermoscopic pattern» yields significantly better results than any attempt to interpret the image in isolation [11]. This approach was further reinforced by H. A. Haenssle and colleagues in *JAMA Dermatology*, establishing contemporary sensitivity and specificity standards that continue to guide leading oncology centers when developing clinical guidelines [12].

### **The phenomenon of melanoma in situ: beyond the obvious (2018 – 2021)**

Once the diagnosis of invasive forms became routine, professional interest shifted toward the «gray zone» – melanoma *in situ* (MIS). At this stage, the limits of the method become evident, as the boundary between benign atypia and early malignancy becomes nearly transparent.

In 2018, A. Lallas and colleagues attempted to codify this diagnostic complexity. In their work published in *JAMA Dermatology*, they identified markers that enabled clinicians to «grasp» an MIS diagnosis: primarily, architectural abnormalities of the pigment network and areas of regression, which had previously often been attributed to phenotypic variation [13]. These criteria prompted physicians to reconsider seemingly «innocuous» lesions lacking overt signs of aggression.

The final note of this period came with P. Guitera's reflections (2021) on the limits of melanoma predictability. Her study in *Dermatologic Surgery* served as an important reminder of the biological cunning of the tumor: even with perfect mastery of diagnostic algorithms, variability in early forms leaves room for error [14]. These findings effectively legitimized the need for dynamic monitoring and the concept of a «digital skin passport», making them essential elements of modern strategies for managing high-risk patients.

### **Revision of diagnostic standards: numbers versus intuition (2021)**

By 2021, the scientific community had moved beyond debates about the value of the dermatoscope itself. The focus had shifted to a more complex question: how much weight should each morphological feature carry in the final assessment. A large meta-analysis by J. Dinnes, published in *JAMA Dermatology*, effectively drew a line under years of discussion. The authors confirmed an obvious yet crucial point: the method's potential is directly limited by the specialist's expertise. Without expert training, even the most advanced instrument cannot guarantee breakthroughs in diagnostic accuracy, although overall sensitivity in the melanocytic sector has reached peak levels in recent years [15]. This peak performance has been further challenged by deep learning systems; for instance, Esteva et al. demonstrated that CNNs could achieve a level of classification parity with board-certified dermatologists

[31]. Similarly, large-scale benchmarks involving over 150 specialists have shown that AI algorithms can consistently match or even exceed human diagnostic sensitivity in controlled settings [34, 38].

In the same year, L. Ferrante di Ruffano and colleagues attempted to deconstruct conventional diagnostic algorithms. Rather than repeatedly describing «classic patterns», they conducted rigorous validation of individual features. They found that several markers long considered suspicious actually have low specificity. This differentiated approach allowed clinicians to finally exclude secondary features – the so-called «morphological noise» that often led to overdiagnosis – and focus on high-specificity markers of malignancy [16].

#### **Expansion into primary care and digital monitoring (2019 – 2022)**

A significant ideological shift occurred at the turn of the decade, as dermoscopy ceased to be the exclusive domain of specialized oncology clinics. F. M. Walter's work (2019) highlighted a critical vector: transferring screening to primary care. Data published in *BMJ Open* clearly demonstrated that if a general practitioner or primary care physician is trained in basic teledermoscopy, the pathway from a suspicious lesion to biopsy is drastically shortened, while unnecessary surgical interventions sharply decline [17].

A logical continuation of this process was the development of the «digital footprint» concept. In 2022, C. Rosendahl and colleagues effectively declared the end of static diagnostics. They demonstrated that a single image of a lesion provides only an instantaneous snapshot, which may not fully reflect the biological nature of the process. The future lies in total digital mapping (Total Body Photography) and long-term monitoring. This approach enables the early detection of so-called «ugly ducklings» at a stage when their atypia is not yet identifiable by any classical algorithm, but growth dynamics already reveal malignant potential [18]. This shift from one-time consultation to continuous digital surveillance represents the culmination of the modern dermatological screening system.

#### **The era of algorithmic assistance: AI as assistant and challenge (2022 – 2024)**

The past three years in dermato-oncology have been marked by «digital determinism». While physicians previously relied on their own eyes and reference manuals, today decision support systems (CDSS) based on deep learning have come to the forefront. The success of these systems is largely attributed to the emergence of massive, high-quality open-source repositories, most notably the HAM10000 dataset, which provided the necessary scale for training robust neural architectures [32]. Furthermore, the adoption of deep learning ensembles has proven superior to single-model approaches

in recognizing complex melanoma patterns [33]. In 2022, T.J. Brinker and his team presented in the *International Journal of Biomedical Imaging* a comprehensive perspective on how neural networks are transforming image analysis. They emphasized that AI no longer merely «guesses» diagnoses, but is capable of detecting patterns that the human eye misses due to biological perceptual limitations [19].

However, the transition to machine-based analysis has not been as smooth as techno-optimists predicted. In 2023, V. J. Mar and colleagues, in *Cancers*, raised the challenging question of the clinical relevance of these systems. Their study demonstrated that high algorithmic accuracy «in the lab» often collides with the variability of real-world images – so-called «real-world artifacts» (such as hair, gel bubbles, or varying illumination). The authors stressed that CDSS should not replace the physician, but function as a «second opinion» tool, reducing cognitive load during mass screening [20]. Research by Tschandl et al. reinforces this, showing that the highest diagnostic accuracy is achieved through human-computer collaboration, rather than relying on either in isolation [35]. However, technical barriers remain: for example, the presence of surgical skin markings in images can significantly confound CNN predictions, leading to potential false positives [36]. Moreover, recent scoping reviews highlight a critical lack of transparency and potential bias in AI datasets, particularly regarding skin tone representation, which remains a key challenge for global implementation [37].

By 2024, the discussion shifted toward integrating AI into live clinical workflows. H.A. Haenssle and colleagues, in their landmark publication in *British Journal of Dermatology*, reported results from testing the latest decision-support systems. The key conclusion of this period: maximum effectiveness is achieved only in symbiosis, where the final judgment rests with the specialist who can evaluate patient history, not just pixels on a screen [21].

Concurrently, S. Saeed's 2024 review in *Cureus* highlighted ethical and legal aspects of this «digital race». The authors pointed out the «black box» problem – the inability to fully understand which features the neural network relied on to reach its verdict. This underscores the modern understanding of dermoscopy as a high-tech hybrid, where traditional morphology meets machine learning power, yet patient responsibility remains firmly human [22].

The current research landscape focuses on meta-analysis of data, where operational characteristics of convolutional neural networks (CNNs) – such as sensitivity, specificity, and AUC (Area Under the Curve, a standard metric for evaluating binary classification in medicine, dermatology, machine learning, and statistics) – are compared against traditional clinical assessments. Such integration is critical for understanding the

boundaries of technological applicability: it identifies scenarios where AI assistance significantly improves diagnostic accuracy, while highlighting technological barriers that hinder full integration into daily practice.

The table 1 summarizes findings from the most representative international studies, reflecting the current balance of power between neural network solutions and expert clinicians.

and clinical reports over recent years demonstrates a clear transition from isolated use of dermatoscopes to systematic population-based monitoring.

The South Kazakhstan Medical Academy (Shymkent) was among the pioneers in substantiating the role of dermatoscopy in the differential diagnosis of nevi and malignant skin neoplasms. Researchers V. V. Khvan and D. T. Arybzhhanov emphasized the

**Table 1** – Comparative diagnostic performance of artificial intelligence and dermatologists in dermoscopic detection of skin neoplasms

Study	Comparative Analysis	Study Results
Haenssle et al. (Man against machine) 2018 [23]	Diagnostic performance of a deep learning CNN for dermoscopic melanoma recognition compared with assessments by 58 dermatologists	CNN AUC 0.86 vs Derm AUC 0.79
Liu et al. 2025 [24]	Systematic review and meta-analysis of 19 studies: comparing sensitivity and specificity of AI and clinical skin lesion diagnosis	AI AUC 0.99 vs Derm AUC 0.96
Brinker et al. ( <i>Melanoma classification</i> ) 2019 [25]	Comparison of CNN performance with 157 dermatologists in dermoscopic melanoma classification	CNN outperformed most dermatologists in sensitivity and specificity, demonstrating higher diagnostic efficacy
Combalia et al. (Out-of-distribution) 2022 [26]	Analysis of AI models on dermoscopic images, including out-of-distribution scenarios and artifact effects	Compared with dermatologists, AI outperformed experts in most categories but performed significantly worse on out-of-distribution data, especially for diagnoses absent from training
Esteva et al. (2017) [31]	CNN vs 21 dermatologists	CNN achieved parity with all tested experts across all tasks.
Tschandl et al. (2020) [35]	Human-computer collaboration	AI-based support improved the diagnostic accuracy of both experts and novices.
Daneshjou et al. (2021) [37]	Scoping review of AI bias	Identified significant under-representation of dark skin tones in major datasets (like HAM10000).

Analysis of these studies convincingly demonstrates that deep learning algorithms can match and often exceed dermatologists' diagnostic accuracy in dermoscopic skin lesion recognition. The current stage of technological development marks a shift from demonstrating superiority in experimental settings to understanding the real clinical boundaries for AI application.

### **Geography and scientific–practical framework of dermatoscopy development in kazakhstan**

The modern architecture of dermatological services in Kazakhstan has been shaped through the integration of non-invasive imaging technologies into the activities of the country's largest regional medical clusters. An analysis of publication trends

diagnostic potential of devices such as the Heine Delta 20 for verifying specific morphological features, which is particularly important under conditions of high solar radiation in the southern regions of the country [27].

In parallel, specialists from the State Medical University of Semey proposed considering dermatoscopy as an essential component of early screening programs. In the works of A. K. Akhmetova and colleagues, it is highlighted that implementing dermatoscopy at the primary examination stage significantly improves the diagnostic precision of melanocytic lesions while reducing the proportion of unnecessary surgical interventions [28].

A new vector of development has been the expansion of clinical indications for dermatoscopy,

as reflected in the research conducted at the West Kazakhstan Marat Ospanov Medical University (Aktobe c.). In a 2025 review, G. M. Iztleuova and co-authors demonstrated the effectiveness of dermatoscopy not only in oncodermatology but also as an objective tool for monitoring therapeutic outcomes in various skin pathologies [29]. This indicates the transition of dermatoscopy into the category of routine clinical practice for Kazakhstani dermatologists.

The culmination of this evolution has been represented by policy documents and analytical reviews presented at the IX Eurasian Congress of Dermatology, as well as in leading scientific journals. Contemporary data confirm that Kazakhstan is systematically implementing global standards for early melanoma detection, employing a comprehensive approach ranging from specialist training to high-technology total body mapping of skin neoplasms [30].

Despite the evident progress in the scientific and theoretical foundation, the actual implementation of the method in the routine clinical practice of Kazakhstan faces a complex set of structural challenges that significantly reduce the effectiveness of early diagnosis.

One of the most pressing problems remains the sharp contrast in the level of equipment among healthcare institutions. While metropolitan research and clinical centers and leading private clinics in Almaty and Astana utilize expert-class systems (for example, digital mapping systems such as FotoFinder), at the level of regional dermatovenerologic dispensaries the primary tools remain conventional handheld dermatoscopes. Such a «digital divide» effectively blocks the creation of nationwide databases and the full development of teledermatology, which is particularly essential for patients living in rural and remote regions.

Alongside the technological deficit, there remains a critical dependence of diagnostic accuracy on the individual experience of the specialist. To date, Kazakhstan's healthcare system has not approved a unified national standard for the description of dermatoscopic findings. Physicians currently apply heterogeneous assessment algorithms (ranging from the ABCD rule to Menzies' method or the 7-point checklist). The absence of a standardized reporting format inevitably generates discrepancies in the interpretation of morphological structures, thereby disrupting continuity between dermatological and oncological services.

Specialist training in this field is often discrete and fragmented in nature. In residency curricula, dermatoscopy is allocated an insufficient number of academic hours, and the lack of a mandatory state certification system specifically for this method compels physicians to rely on short-term commercial training courses. Such an approach does not always

guarantee adequate mastery of the competencies required to detect rare and atypical forms of melanocytic tumors, thereby confirming the need for a systemic revision of educational standards.

### RESULTS

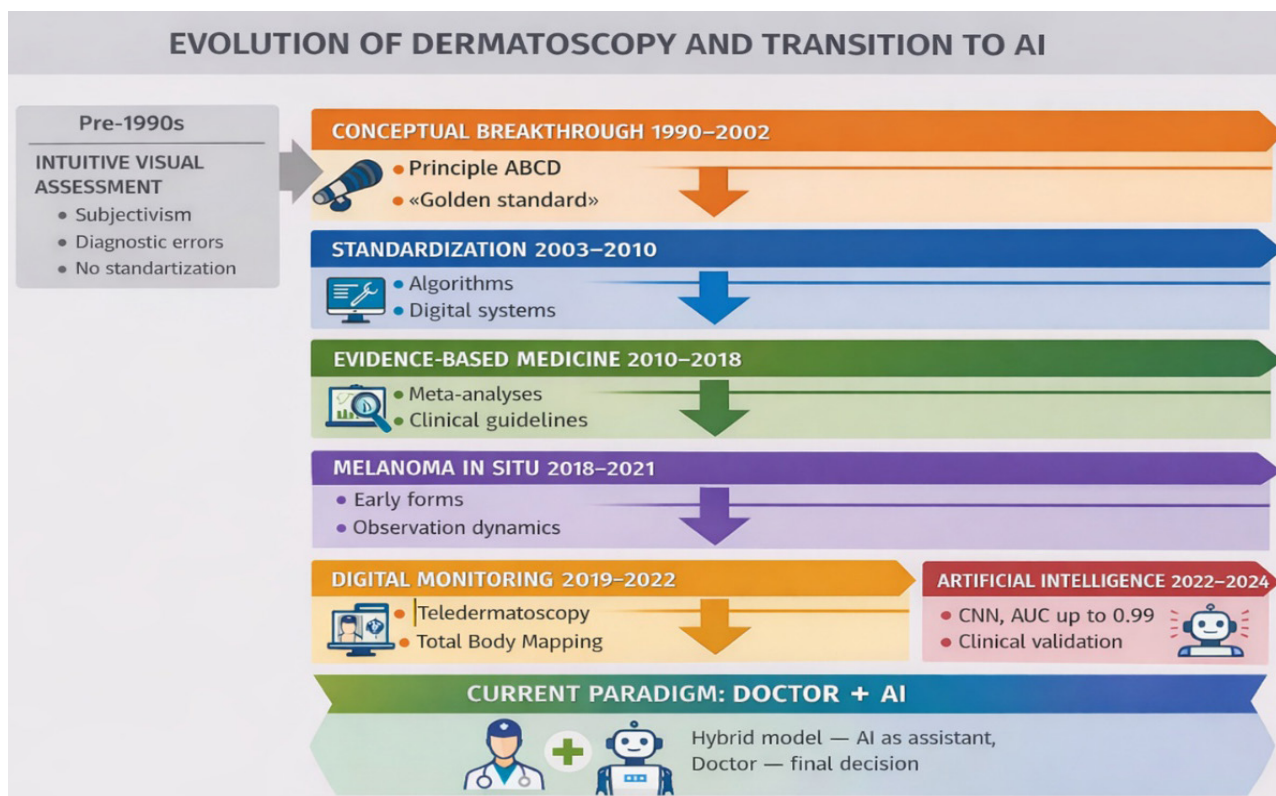
The dynamics of the data presented above clearly illustrate the transformation of dermoscopy (fig. 1): from subjective visual interpretation to a high-tech system integrating machine learning algorithms. The foundation of this process was laid during 1990 – 2002, when the development of the ABCD rule and its verification in early melanoma diagnosis finally standardized the examination procedure. The subsequent period (2003 – 2010) was marked by rigorous systematization of criteria and the implementation of a two-step diagnostic protocol, which not only unified international approaches but also laid the groundwork for the first attempts at digital image processing.

Results from large-scale meta-analyses conducted between 2010 and 2018 effectively legitimized instrumental examination as an essential component of screening. A key conclusion from this period was the recognition of the decisive role of clinical context: physician expertise remained primary in the interpretation of observed structures. Later, research focus shifted toward the detection of melanoma in situ and the implementation of dynamic monitoring strategies. This transition drove the adoption of total digital skin mapping, significantly reducing the «diagnostic interval» and minimizing the risk of errors in managing complex patients.

At the current stage (2022 – 2024), the main vector has become the expansion of deep learning. Although neural networks demonstrate accuracy comparable to expert levels under experimental conditions (AUC up to 0.99), real-world practice reveals several limitations. Variability in skin phototypes and the presence of image artifacts prevent full autonomy of the machines. Consequently, the prevailing concept today is that of a hybrid model: artificial intelligence is regarded solely as a clinical decision support system (CDSS), where the authority for the final diagnosis and legal responsibility remains with the clinician.

### DISCUSSION

Analysis of the accumulated data indicates a profound transformation in methodology: from attempts to formalize morphological features in the 1990s to the current stage of «algorithmic determinism». Although convolutional neural networks (CNNs) demonstrate impressive AUC performance (0.86 – 0.99 vs. 0.79 – 0.96 for experts) in several controlled trials, extrapolating these figures to the clinical context of Kazakhstan requires caution. For the domestic healthcare system, where



**Figure 1** – Evolution of dermatoscopy and transition to AI

skin neoplasms have consistently ranked among the top three oncology pathologies over the past decade (2012 – 2022), the critical barrier remains the «diagnostic gap» at the primary care level (PCU).

It is important to acknowledge that laboratory superiority of AI is often mitigated under real-world clinical conditions. The problem of «noise» factors – such as lighting artifacts, hair coverage, or specifics of immersion gel application – leads to a 15-20% reduction in model specificity. In this context, the findings of Haenssle (2024) and Brinker (2019) confirm the indispensable role of clinical context: the combination of patient history and skin phototype remains decisive. For the Kazakhstani population, dominated by Fitzpatrick phototypes III-IV, direct integration of Western solutions (based on the ISIC Archive) carries a latent risk of false-negative outcomes, underscoring the necessity for local algorithm validation.

From a regulatory perspective, the adoption of the AI Law in 2025 and the update of the Health Code in 2026 have established a legitimate framework for the use of clinical decision support systems (CDSS). However, without national randomized controlled trials (RCTs), these norms risk remaining largely declarative. The observed digitalization gap (less than 5% adoption of teledermatology in Kazakhstan versus 30% in EU countries) reflects structural lag that cannot be overcome merely by copying foreign software.

A priority development vector lies in creating a national repository of dermoscopic images (targeting over 10,000 verified cases). Pilot testing of adapted CNN models within regional centers, particularly at the Karaganda Oncology Dispensary, could provide the foundation to translate the theoretical potential of artificial intelligence into a tangible reduction in melanoma mortality in Kazakhstan.

## CONCLUSION

An analysis of the dynamics of the above-mentioned literature clearly illustrates the transformation of dermatoscopy: from subjective visual interpretation to a high-tech system integrating machine learning algorithms. The journey from Stolz's intuitive criteria to neural network-based analysis indicates a fundamental shift: today, clinicians diagnose not just a «spot», but a complex digital pattern. Comparative performance of CNNs, confirmed by international meta-analyses, leaves little doubt about their technical superiority in certain scenarios. Nevertheless, high AUC values in laboratory testing do not automatically guarantee clinical success, where imaging artifacts and biological variability of tumors continue to influence outcomes.

For the Republic of Kazakhstan, the integration of AI is moving from «technical curiosity» to a realm of strict legal responsibility. The 2025 AI Law clearly defines the rules of engagement: the algorithm remains

a supportive tool and does not replace the clinician's judgment. The main challenge today is reducing reliance on Western datasets. Without validation of AI systems on local clinical material that accounts for the population's skin phototype characteristics, the risk of diagnostic distortions remains unacceptable. Therefore, the future of the method in Kazakhstan lies in establishing a hybrid model, where digital transformation and teledermoscopy networks are strictly regulated by biological safety and medical ethics standards, leaving the final diagnostic authority in the hands of the clinician.

#### Author contributions:

Y. R. Pak – literature search and analysis, writing – original draft preparation.

G. S. Kayupova – supervision, final approval of the version to be published

I. L. Pak – critical revision of the draft for intellectual content and final editing.

M. S. Askarov – critical revision of the draft for intellectual content and final editing.

T. S. Bekeyev – development of the structure and conceptual framework of the review

#### Conflict of interest:

No conflict of interest declared.

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Received 23.05.2025

Sent for revision 14.06.2025

Accepted 31.07.2025

Published online 30.03.2026

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### ДЕРМАТОСКОПИЯ И ИСКУСТВЕННЫЙ ИНТЕЛЛЕКТ В РЕСПУБЛИКЕ КАЗАХСТАН: ЭФФЕКТИВНОСТЬ И ЛЕГИТИМНОСТЬ

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В статье представлен комплексный анализ эволюции дерматоскопии и интеграции искусственного интеллекта в клиническую практику с особым акцентом на раннее выявление рака кожи в Республике Казахстан. Учитывая, что в период с 2012 по 2022 год поражения кожи входили в тройку лидеров онкологических патологий в стране, объективный скрининг признан национальным приоритетом. Исследование включало многоэтапный поиск в международных репозиториях, в результате которого было отобрано двадцать шесть репрезентативных источников, включая рандомизированные контролируемые испытания и метаанализы.

Результаты позволяют проследить методологическую трансформацию от качественных шкал 1990-х гг. к нынешней эпохе цифрового доминирования. Современные данные подтверждают технологическое превосходство сверточных нейронных сетей, которые демонстрируют значения площади под кривой (AUC) в диапазоне от 0,86 до 0,99, часто превосходя показатели экспертов. Если ранние наблюдения были сосредоточены на морфологических структурах, то в настоящее время фокус сместился в сторону глубокого обучения и тотального цифрового мониторинга, несмотря на сохраняющиеся риски, связанные с артефактами реального мира и данными, выходящими за пределы обучающей выборки.

Анализ подтверждает смену парадигмы в сторону гибридных интеллектуальных систем. В Казахстане этот процесс поддерживается национальными стратегическими концепциями и Законом об искусственном интеллекте, интегрированным в законодательство о здравоохранении 2026 года. Однако внедрение на уровне первичной медико-санитарной помощи требует преодоления проблемы нехватки локальных наборов данных, учитывающих региональные фототипы кожи. Данное исследование формирует дорожную карту интеграции технологий, подчеркивая, что клиническая валидация и международное сотрудничество являются жизненно важными факторами для повышения показателей выживаемости пациентов в условиях цифровой трансформации медицины.

*Ключевые слова:* дерматоскопия; меланома; искусственный интеллект; глубокое обучение; компьютерная диагностика

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### **ҚАЗАҚСТАН РЕСПУБЛИКАСЫНДАҒЫ ДЕРМАТОСКОПИЯ ЖӘНЕ ЖАСАНДЫ ИНТЕЛЛЕКТ: ТИІМДІЛІГІ МЕН ЗАҢДЫЛЫҒЫ**

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Бұл мақалада дерматоскопия эволюциясына және клиникалық практикаға жасанды интеллектіні интеграциялауға, соның ішінде Қазақстан Республикасында тері обырын ерте анықтау мәселесіне кешенді талдау жасалған. 2012 – 2022 жылдар аралығында тері зақымданулары еліміздегі онкологиялық патологиялардың алғашқы үштігіне енгенін ескере отырып, объективті скрининг ұлттық басымдық ретінде танылды. Зерттеу барысында халықаралық репозиторийлерде көпсатылы іздеу жұмыстары жүргізіліп, нәтижесінде жиырма алты репрезентативті дереккөз, соның ішінде рандомизацияланған бақыланатын сынақтар мен мета-талдаулар іріктеліп алынды.

Зерттеу нәтижелері 1990-жылдардағы сапалық шкалалардан қазіргі цифрлық үстемдік дәуіріне дейінгі методологиялық трансформацияны бақылауға мүмкіндік береді. Заманауи мәліметтер қисық астындағы аудан (AUC) мәндері 0,86-дан 0,99-ға дейінгі диапазонды көрсететін және жиі сарапшылардың көрсеткіштерінен асып түсетін конволюциялық нейрондық желілердің технологиялық артықшылығын

растайды. Ерте кезеңдегі бақылаулар морфологиялық құрылымдарға негізделсе, қазіргі уақытта фокус нақты әлемдегі артефактілер мен оқыту таңдамасынан тыс деректерге байланысты сақталып отырған тәуекелдерге қарамастан, терең оқыту мен толық цифрлық мониторингке ауысты.

Талдау гибриді интеллектуалды жүйелерге қарай парадигманың өзгергенін айқындайды. Қазақстанда бұл процесс ұлттық стратегиялық тұжырымдамалармен және 2026 жылғы денсаулық сақтау заңнамасына интеграцияланған «Жасанды интеллект туралы» Заңмен қолдау табады. Дегенмен, алғашқы медициналық-санитарлық көмек деңгейінде енгізу үшін аймақтық тері фототиптерін ескеретін жергілікті деректер жиынтығының тапшылығы мәселесін шешу қажет. Бұл зерттеу технологияларды интеграциялаудың жол картасын қалыптастырады және медицинаның цифрлық трансформациясы жағдайында пациенттердің өміршеңдік көрсеткіштерін арттыру үшін клиникалық валидация мен халықаралық ынтымақтастық маңызды факторлар екенін көрсетеді.

*Кілт сөздер:* дерматоскопия; меланома; жасанды интеллект; терең оқыту; компьютерлік диагностика