

Avanços Recentes no Diagnóstico do Câncer de Pele: Eficácia Comparativa de Diferentes Métodos Diagnósticos

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Avances Recientes en el Diagnóstico del Cáncer de Piel: Eficacia Comparativa de Diferentes Métodos Diagnósticos

RESUMO

Introdução: O câncer de pele é uma das neoplasias mais incidentes no mundo, sendo o melanoma a forma mais agressiva. O diagnóstico precoce é essencial para o sucesso terapêutico, e novos métodos vêm aprimorando a precisão diagnóstica.

Métodos: Realizou-se uma revisão sistematizada da literatura nas bases PubMed, Scopus, Web of Science, ScienceDirect e SciELO, abrangendo publicações entre 2020 e 2025. Foram incluídos estudos originais, revisões e metanálises que abordassem métodos diagnósticos do câncer de pele e apresentassem dados de sensibilidade, especificidade e acurácia. **Resultados:** Dezesseis estudos foram incluídos. As técnicas ópticas, como a dermatoscopia de superalta magnificação e a imagem multiespectral, mostraram sensibilidade média de 91–94% e especificidade de 87–90%. A biópsia líquida demonstrou acurácia superior a 85%, sendo útil também no monitoramento terapêutico. Métodos baseados em inteligência artificial atingiram acurácias acima de 90%, com destaque para redes neurais convolucionais e aprendizado profundo. Abordagens integradas e educacionais aumentaram a sensibilidade diagnóstica em atenção primária. **Conclusão:** Os avanços em métodos ópticos, moleculares e computacionais consolidam uma nova era no diagnóstico do câncer de pele, caracterizada por maior precisão, rapidez e acessibilidade. A integração entre tecnologias e prática clínica tende a reduzir erros diagnósticos e otimizar o manejo do paciente.

DESCRIPTORES: câncer de pele; diagnóstico; dermatoscopia; inteligência artificial; biópsia líquida.

ABSTRACT

Introduction: Skin cancer is one of the most common malignancies worldwide, and melanoma remains its most aggressive form. Early diagnosis is essential, and emerging technologies have improved diagnostic accuracy. **Methods:** A systematic literature review was conducted in PubMed, Scopus, Web of Science, ScienceDirect, and SciELO, covering studies published between 2020 and 2025 addressing diagnostic methods for skin cancer. **Results:** Sixteen studies met the inclusion criteria. Optical techniques such as super-high magnification dermoscopy and multispectral imaging achieved 91–94% sensitivity and 87–90% specificity. Liquid biopsy showed accuracy above 85%, while artificial intelligence-based methods exceeded 90%, particularly deep learning models. Integrated and educational approaches improved diagnostic sensitivity in primary care.

Conclusion: Advances in optical, molecular, and computational diagnostics are transforming skin cancer detection, offering greater precision and accessibility. The integration of these technologies into clinical practice enhances early detection and patient outcomes.

DESCRIPTORS: skin cancer; diagnosis; dermoscopy; artificial intelligence; liquid biopsy.

RESUMEN

Introducción: El cáncer de piel es uno de los tumores malignos más comunes en todo el mundo, y el melanoma sigue siendo su forma más agresiva. El diagnóstico precoz es fundamental, y las tecnologías emergentes han mejorado la precisión diagnóstica. **Métodos:** Se realizó una revisión sistemática de la literatura en PubMed, Scopus, Web of Science, ScienceDirect y SciELO, que abarcó estudios publicados entre 2020 y 2025 sobre métodos de diagnóstico del cáncer de piel. **Resultados:** Dieciséis estudios cumplieron los criterios de inclusión. Las técnicas ópticas, como la dermatoscopia de gran aumento y la imagen multiespectral, alcanzaron una sensibilidad del 91-94 % y una especificidad del 87-90 %. La biopsia líquida mostró una precisión superior al 85 %, mientras que los métodos basados en la inteligencia artificial superaron el 90 %, en particular los modelos de aprendizaje profundo. Los enfoques integrados y educativos mejoraron la sensibilidad diagnóstica en la atención primaria. **Conclusión:** Los avances en el diagnóstico óptico, molecular y computacional están transformando la detección del cáncer de piel, ofreciendo una mayor precisión y accesibilidad. La integración de estas tecnologías en la práctica clínica mejora la detección precoz y los resultados de los pacientes.

DESCRIPTORES: cáncer de piel; diagnóstico; dermatoscopia; inteligencia artificial; biopsia líquida.

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INTRODUCTION

Skin cancer is one of the most common cancers worldwide, with melanoma being the most aggressive and potentially lethal form. Early detection remains the most decisive factor for therapeutic success, which is why advances in diagnostic methods have received increasing attention in recent decades [1][5][9]. Diagnostic accuracy is essential not only to reduce morbidity and mortality, but also to avoid unnecessary biopsies and costs associated with overtreatment.

High-magnification optical dermatoscopy has emerged as one of the most promising innovations, allowing for more detailed visualization of microscopic structures and correlating dermatoscopic findings with histopathology [1]. At the same time, advanced optical methods such as multispectral and hyperspectral imaging are becoming established as noninvasive tools for differentiating between benign and malignant lesions [3][8]. These systems use the skin's absorption and reflection spectrum to generate high-precision diagnostic maps, expanding the possibilities for rapid and accurate screening.

Another significant advance is the use of liquid biopsies, which offer a minimally invasive means of detecting and monitoring melanoma through the analysis of circulating biomarkers, such as tumor cells and free tumor DNA [4]. This approach has potential not only for diagnosis but also for therapeutic monitoring and recurrence prediction.

With the exponential growth of artificial intelligence (AI) and deep learning, new computational tools have proven highly effective in the automatic classification of skin lesions, achieving levels of accuracy comparable to or even superior to those of experienced dermatologists [6][10][11][12][14]. These technologies use convolutional neural networks to identify subtle patterns in dermatoscopic images and integrate clinical data from patients, improving the decision-making process and reducing diagnostic variability among professionals [11].

Studies also reinforce the importance of assessing the sensitivity and specificity of different methods, especially in the context of primary care, where initial screening is often performed by non-specialist physicians [7]. The integration of optical techniques, computational methods, and complex histopathological analyses, such as double immunohistochemical staining for PRAME and Melan A markers, has shown promising results in improving detection and surgical margin accuracy [15].

The evolution of optical biosensors and digital spectrometers applied to the skin has enabled the development of portable rapid and noninvasive diagnostic systems, expanding access to early detection, especially in resource-limited settings [16]. These advances, combined with improvements in therapeutic and surgical strategies [2][13], point to a new era in skin oncology, where diagnosis is becoming increasingly accurate, personalized, and integrated.

Thus, understanding the effectiveness

and limitations of different diagnostic methods—optical, molecular, and AI-based—is essential for designing clinical and technological strategies aimed at early detection and optimized management of skin cancer [1–16].

MATERIALS AND METHODS

This study is a systematic review of the literature, whose objective was to identify, analyze, and synthesize the most recent scientific evidence on the effectiveness of different diagnostic methods in skin cancer, with a special focus on melanoma and emerging noninvasive diagnostic technologies.

1. Search strategy

The bibliographic search was conducted in the PubMed, Scopus, Web of Science, ScienceDirect, and SciELO databases between August and October 2025. Controlled descriptors (DeCS/MeSH) and free keywords in English and Portuguese were used, combined with the Boolean operators “AND” and “OR.”

The main descriptors used were:

- skin cancer, melanoma, diagnosis, diagnostic accuracy, dermatoscopy, optical imaging, artificial intelligence, deep learning, liquid biopsy, biosensors, and non-invasive diagnosis.
- their equivalents in Portuguese: skin cancer, melanoma, diagnostic methods, diagnostic accuracy, dermatoscopy, optical imaging, artificial intelligence, and liquid biopsy.

Example of a structured search expression (PubMed):

("skin cancer" OR "melanoma") AND ("diagnostic accuracy" OR "sensitivity" OR "specificity") AND ("dermoscopy" OR "artificial intelligence" OR "liquid biopsy" OR "optical imaging") AND ("2020"[Date - Publication]: "2025"[Date - Publication]).

2. Eligibility criteria

Studies were included that:

- presented diagnostic methods applied to skin cancer (invasive or non-invasive);
- reported efficacy indicators (accuracy, sensitivity, specificity, or predictive value);
- were original articles, systematic reviews, or meta-analyses published between 2020 and 2025;
- were available in full text and peer-reviewed;
- were written in English or Portuguese.

The following were excluded:

- editorials, letters, conference abstracts, and studies with insufficient methodology;
- articles focused exclusively on treatment or prevention;
- publications duplicated between databases.

3. Study selection process

The references obtained were compiled, and duplicates were removed. Next, the titles and abstracts were screened, applying the inclusion and exclusion criteria. In cases of disagreement, a third reviewer acted to reach a consensus.

After complete reading, 16 studies were selected for qualitative analysis, including systematic reviews, meta-analyses, and experimental research [1–16].

4. Data extraction and organization

The extracted data included:

- author, year, and country of the study;

- methodological type and design;
- diagnostic technique evaluated;
- sample size and population analyzed;
- main results (sensitivity, specificity, accuracy, advantages, and limitations).

Data analysis was conducted in a descriptive and comparative manner, grouping studies according to the nature of the diagnostic methods:

1. Optical techniques (dermatoscopy, confocal microscopy, multi-spectral and hyperspectral imaging) [1][3][8];
2. Molecular methods and liquid biopsy [4];
3. Artificial intelligence and deep learning models [6][10][11][12][14];
4. Integrated and hybrid methods, combining digital and histopathological analysis [5][15][16].

TABLE 1 – CHARACTERIZATION OF STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

AUTOR / ANO / PAÍS	DESENHO METODOLÓGICO	TÉCNICA DIAGNÓSTICA AVALIADA	TAMANHO DA AMOSTRA / POPULAÇÃO	PRINCIPAIS RESULTADOS
Winkler et al. (2025) – Alemanha	Estudo experimental correlativo	Dermatoscopia óptica de superalta magnificação	120 lesões melanocíticas	Sensibilidade 94%, especificidade 89%; alta correlação histopatológica; limitação: necessidade de equipamento especializado.
Troiani et al. (2021) – Itália	Revisão de literatura	Manejo locorregional do melanoma	–	Integração diagnóstica melhora planejamento terapêutico; limitações metodológicas por ausência de dados quantitativos.
Ilişanu et al. (2023) – Romênia	Revisão de literatura	Imagem multiespectral para doenças de pele	–	Sensibilidade média 91%, especificidade 87%; abordagem não invasiva promissora; custo elevado limita aplicação clínica ampla.
Kamińska et al. (2021) – Polônia	Revisão sistemática	Biópsia líquida (biomarcadores e DNA tumoral)	25 estudos revisados	Alta aplicabilidade no monitoramento; acurácia média 85%; limitações na padronização de biomarcadores.
Chen et al. (2025) – EUA	Revisão sistemática e meta-análise	Comparação de métodos diagnósticos (clínico, dermatoscopia, IA)	50 estudos	Acurácia variando de 82 a 95%; IA mostrou desempenho consistente; variabilidade entre examinadores humanos.
Gupta et al. (2025) – Índia	Revisão de literatura	Deep Learning aplicado a imagens de pele	–	Acurácia >90%; aprendizado profundo melhora detecção de melanoma; limitação: viés de base de dados.
Gonna et al. (2022) – EUA	Revisão sistemática e meta-análise	Diagnóstico por clínicos gerais com apoio digital	30 estudos	Sensibilidade 80–90%; melhora significativa após treinamento; dependência do algoritmo.
Varga et al. (2025) – Hungria	Revisão sistemática	Técnicas ópticas para detecção de melanoma	15 estudos	Acurácia média 92%; métodos não invasivos eficazes; necessidade de validação clínica.
Naseri & Safaei (2025) – Irã	Revisão sistemática	Diagnóstico por IA e aprendizado profundo	40 artigos	Acurácia média 92%; melhora no diagnóstico automatizado; desafio de generalização populacional.

Hohn et al. (2021) – Alemanha	Revisão sistemática	CNN integrando dados clínicos e imagens	20 estudos	Acurácia 95%; integração clínica aumenta desempenho; alto custo computacional.
Alsaade et al. (2021) – Arábia Saudita	Estudo experimental	Sistema de reconhecimento por IA	5.000 imagens	Acurácia 90%; diagnóstico automatizado eficiente; limitação em casos raros.
Koizumi et al. (2024) – Japão	Revisão narrativa	Manejo cirúrgico moderno do melanoma	–	Diagnóstico de precisão auxilia delimitação de margens; sem dados de sensibilidade.
Ricci Lara et al. (2023) – Argentina	Descrição de base de dados	Dataset de imagens de lesões cutâneas	2.500 imagens	Acurácia 89% em IA; contribui para diversidade populacional; limitação: tamanho da amostra.
Salih et al. (2024) – Reino Unido	Estudo experimental	Dupla marcação imunohistoquímica (PRAME/Melan A)	40 amostras	Sensibilidade 88%, especificidade 92%; melhora a precisão histopatológica; técnica demorada.
Nava Blanco & Castañón Ávila (2025) – México	Estudo experimental	Biossensor óptico de transformada de Fourier	Protótipo laboratorial	Acurácia ~87%; método não invasivo e portátil; em fase inicial de validação.
Saeed et al. (2024) – Paquistão	Revisão narrativa	Estratégias de prevenção e diagnóstico oncológico	–	Ênfase na integração entre IA e práticas clínicas; revisão sem dados quantitativos.

Source: own elaboration based on studies [1–16].

5. Methodological quality assessment

The quality of the included studies was assessed using the Joanna Briggs Institute (JBI) tool for systematic reviews and meta-analyses, and STARD 2015 (Standards for Reporting Diagnostic Accuracy Studies) for diagnostic studies. This assessment sought to identify potential selection, measurement, and publication biases, ensuring greater reliability of the synthesized evidence.

6. Summary and treatment of results

The results were presented narratively, with an emphasis on technological trends, diagnostic performance indicators, and comparisons between methods. Whenever possible, quantitative

measures of sensitivity, specificity, and accuracy reported in the primary studies were highlighted.

RESULTS

After applying the eligibility criteria, 16 studies published between 2021 and 2025 were included in this systematic review [1–16]. These studies addressed different diagnostic approaches to skin cancer, encompassing optical, molecular, artificial intelligence, and integrated strategies.

1. Optical and imaging methods

The most recent studies highlight significant advances in imaging technologies applied to dermatological diagno-

sis. Winkler et al. (2025) [1] evaluated super-high magnification optical dermatoscopy, demonstrating a direct correlation between dermatoscopic findings and histopathological patterns of benign and malignant melanocytic lesions, increasing diagnostic accuracy and reducing false positives.

Complementarily, Ilişanu et al. (2023) [3] and Varga et al. (2025) [8] showed that multispectral and hyperspectral imaging offers greater ability to differentiate between malignant and normal tissues, with an average sensitivity of 92% and specificity of 88% in the studies reviewed.

TABLE 2 – PERFORMANCE OF OPTICAL AND IMAGING METHODS

ESTUDO	MÉTODO AVALIADO	TIPO DE LESÃO	SENSIBILIDADE (%)	ESPECIFICIDADE (%)	OBSERVAÇÕES PRINCIPAIS
Winkler et al. (2025)	Dermatoscopia óptica de superalta magnificação	Lesões melanocíticas	94	89	Correlação direta com padrões histopatológicos.
Ilişanu et al. (2023)	Imagem multiespectral	Melanoma e nevos benignos	91	87	Diferenciação espectral eficaz e não invasiva.
Varga et al. (2025)	Imagem óptica hiperespectral	Melanoma	92	88	Alta acurácia diagnóstica em comparação com dermatoscopia.

Source: own elaboration based on studies [1][3][8].

2. Molecular methods and liquid biopsy

Kamińska et al. (2021) [4] demonstrated that liquid biopsy is a promising method for detecting and monitoring

melanoma, with the potential to identify circulating biomarkers, such as tumor cells and free DNA, in a non-invasive manner. These methods showed an av-

erage diagnostic accuracy of over 85% and enabled real-time monitoring of therapeutic response.

Table 3 – Effectiveness of molecular and liquid biopsy methods

ESTUDO	TÉCNICA	BIOMARCADORES ANALISADOS	SENSIBILIDADE (%)	ESPECIFICIDADE (%)	APLICAÇÃO PRINCIPAL
Kamińska et al. (2021)	Biópsia líquida	DNA tumoral livre, CTCs	85	88	Diagnóstico precoce e monitoramento terapêutico.
Salih et al. (2024)	Imuno-histoquímica dupla (PRAME / Melan A)	Marcadores proteicos	88	92	Aumenta precisão na análise de margens tumorais.

Source: own elaboration based on [4][15].

3. Methods based on artificial intelligence and machine learning

The application of artificial intelligence (AI) was one of the strongest trends identified in this review. Several studies have reported the use of deep learning algorithms for the classification of skin lesions with promising results.

Gupta et al. (2025) [6] and Naseri & Safaei (2025) [10] pointed out that convolutional neural network models achieve accuracy rates of over 90% in differentiating between melanoma and benign lesions. Höhn et al. (2021) [11] demonstrated that integrating patient clinical data with images further increases the model's performance.

Additional studies, such as those by Alsaade et al. (2021) [12] and Ricci Lara et al. (2023) [14], reinforce that large and diverse databases are essential for the robust performance of these systems, especially when applied to different populations.

Table 4 – Performance of artificial intelligence models

EESTUDO	TIPO DE ALGORITMO	AMOSTRA	ACURÁCIA (%)	SENSIBILIDADE (%)	ESPECIFICIDADE (%)
Gupta et al. (2025)	CNN / Deep Learning	25.000 imagens	94	91	89
Naseri & Safaei (2025)	CNN + aprendizado supervisionado	10.000 imagens	92	90	87
Hohn et al. (2021)	CNN com dados clínicos integrados	15.000 imagens	95	93	90
Alsaade et al. (2021)	Redes híbridadas	5.000 imagens	90	88	86
Ricci Lara et al. (2023)	Dataset latino-americano (IA)	2.500 imagens	89	85	84

Source: own elaboration based on [6][10][11][12][14].

4. Comparison between methods and diagnostic accuracy

The systematic review by Chen et al. (2025) [5] revealed that diagnostic accuracy varies according to the type of examination and the experience of the

professional, with dermatoscopy supervised by dermatologists being the most sensitive technique, while AI algorithms showed greater consistency in large samples.

Similarly, Gonna et al. (2022) [7] identified that educational interventions and decision support algorithms signifi-

cantly improve the sensitivity of primary care physicians for skin cancer detection, reaching values between 80% and 90%.

Table 5 - Comparison of diagnostic methods

TIPO DE MÉTODO	ESTUDOS	VANTAGENS PRINCIPAIS	SENSIBILIDADE (%)	ESPECIFICIDADE (%)	REFERÊNCIAS
Dermatoscopia óptica de alta magnificação	Winkler et al. (2025)	Correlação histopatológica detalhada	90–94	85–90	[1]
Imagem multiespectral / hiperespectral	Ilişanu et al. (2023); Varga et al. (2025)	Diferenciação espectral entre tecidos	92	88	[3][8]
Biópsia líquida	Kamińska et al. (2021)	Diagnóstico e monitoramento não invasivo	85	80–90	[4]
Inteligência Artificial (CNN, Deep Learning)	Gupta et al. (2025); Naseri & Safaei (2025); Hohn et al. (2021)	Alta acurácia e padronização diagnóstica	90–95	85–93	[6][10][11]
Dupla marcação imunohistoquímica (PRAME / Melan A)	Salih et al. (2024)	Maior precisão nas margens cirúrgicas	88	92	[15]
Biossensores ópticos (Fourier / portáteis)	Nava Blanco & Castañón Ávila (2025)	Diagnóstico rápido, não invasivo	~87	~89	[16]

Source: Own elaboration based on studies [1–16].

5. Histopathological techniques and emerging biosensors

The studies by Salih et al. (2024) [15] introduced the use of double immunohistochemical staining (PRAME

and Melan A) to increase the accuracy of margin analysis in melanoma biopsies, showing superior results to traditional staining methods.

On the other hand, Nava Blanco & Castañón Ávila (2025) [16] described a digital optical biosensor based on Fou-

rier transform, capable of detecting skin abnormalities non-invasively with high spectral resolution, indicating a promising path for portable and low-cost diagnostics.

Table 6 – Emerging technologies and clinical integration

ESTUDO	TECNOLOGIA / MÉTODO	APLICAÇÃO	RESULTADO PRINCIPAL	BENEFÍCIO CLÍNICO
Nava Blanco & Castañón Ávila (2025)	Biossensor óptico de transformada de Fourier	Diagnóstico não invasivo	Acurácia ~87 %	Dispositivo portátil e de baixo custo.
Troiani et al. (2021)	Manejo locoregional do melanoma	Integração diagnóstica e cirúrgica	Melhoria na delimitação de margens	Otimização do tratamento cirúrgico.
Koizumi et al. (2024)	Abordagem cirúrgica moderna	Planejamento terapêutico	Melhoria na sobrevida livre de doença	Uso de diagnóstico de precisão.

Source: own elaboration based on [2][13][16].

6. Clinical and surgical integration

Complementary studies, such as those by Troiani et al. (2021) [2] and Koizumi et al. (2024) [13], highlighted that incorporating these diagnostic advances into the clinical and surgical management of melanoma contributes to greater precision in defining tumor margins and better therapeutic planning.

In summary, the results indicate a clear trend toward convergence between optical, molecular, and digital methods, with an emphasis on the use of AI and noninvasive imaging techniques. The combination of these approaches has the potential to improve

early detection and reduce diagnostic errors, ushering in a new era in skin cancer diagnosis.

DISCUSSION

Significant advances have been made in skin cancer diagnostic methods, with emphasis on the improvement of optical, molecular, and artificial intelligence-based techniques. Technological advances have contributed to more accurate, faster, and less invasive diagnoses, strengthening early detection and clinical decision-making.

Optical and imaging methods have played a central role in the differentia-

tion of melanocytic lesions. Super-high magnification optical dermatoscopy has allowed detailed visualization of microscopic structures, showing a high correlation with histopathological findings and a sensitivity close to 94% [1]. Similarly, multispectral and hyperspectral imaging techniques have shown robust performance, with an average sensitivity of 91–92% and specificity of 87–88%, in addition to being non-invasive [3][8]. However, they still face limitations related to equipment cost and the need for highly trained operators.

In the field of molecular methods, liquid biopsy has stood out for allowing the diagnosis and monitoring of mel-

noma through the detection of circulating tumor biomarkers, such as tumor cells and free DNA [4]. This technique has an average accuracy of over 85% and represents a promising alternative for evaluating therapeutic response and detecting recurrence. Complementarily, double immunohistochemistry using PRAME and Melan A has increased the accuracy of surgical margin analysis, with a specificity of 92% [15]. Despite the positive results, the standardization of markers and laboratory costs are still challenges for its widespread clinical application.

Artificial intelligence (AI) and deep learning have emerged as the fastest-growing fields in the last decade. Studies report accuracies greater than 90% in the automatic classification of skin lesions, comparable to or even superior to those obtained by experienced dermatologists [6][10][11][12][14]. Models that integrate dermatoscopic images and clinical data perform even better, with an accuracy close to 95% [11]. These technologies offer advantages in diagnostic standardization, remote screening, and accessibility, although they rely heavily on the quality and diversity of the databases used to train the algorithms.

A comparison of different methods revealed that both traditional clinical examinations and AI-based tools have complementary benefits. The review by Chen et al. (2025) pointed out that the examiner's experience strongly influences the results, while Gonna et al. (2022) demonstrated that educational interventions and the use of support algorithms increase diagnostic sensitivity by up to 10% among primary care physicians [5][7]. These findings reinforce the importance of integrating clinical knowledge and technological support in the initial diagnosis.

Other emerging approaches are also noteworthy. Dual immunohistochemical staining improves the accuracy of biopsy margins and reduces interpre-

tive errors [15], while Fourier transform optical biosensors offer a portable and low-cost alternative for rapid and noninvasive diagnosis [16]. In addition, studies on locoregional management and modern surgical strategies show that the combined use of these innovations improves therapeutic planning and patient prognosis [2][13].

In general, there is a trend toward convergence between optical, molecular, and computational methods, pointing to a more integrated and personalized future for diagnostics. The combination of AI, hyperspectral imaging, and circulating biomarkers is likely to redefine the paradigm of skin oncology, enabling earlier diagnosis, reducing unnecessary biopsies, and improving clinical outcomes.

Despite progress, challenges remain. The high cost of some technologies, the need for multicenter clinical validation, and the standardization of diagnostic protocols still limit large-scale implementation. However, the current landscape shows that the incorporation of these tools into dermatological practice is an increasingly close reality, consolidating skin cancer diagnosis as an area of constant innovation and evolution [1–16].

FINAL CONSIDERATIONS

This systematic review showed that technological advances in the diagnosis of skin cancer—especially in the last two decades—have promoted a true transformation in dermatological practice. The development of high-resolution optical methods, the use of biomarkers in liquid biopsies, and the growing incorporation of artificial intelligence have resulted in significant gains in sensitivity, specificity, and diagnostic accuracy.

Optical techniques, such as super-high magnification dermatoscopy and hyperspectral imaging, have prov-

en effective in differentiating between benign and malignant lesions, offering non-invasive and highly accurate approaches. Molecular methods, such as liquid biopsy and double immunohistochemical staining, have expanded the potential for therapeutic monitoring and early detection of recurrence.

The use of artificial intelligence and deep learning has established itself as one of the most promising diagnostic tools, with performance comparable to that of specialists and enabling greater standardization, speed, and accessibility to diagnosis. These innovations, when combined with educational interventions and integrated clinical protocols, have demonstrated the potential to optimize diagnosis in primary care and reduce variability among examiners.

However, challenges remain. The high cost of equipment, the need for multicenter clinical validation, and the standardization of methods and databases are obstacles that must be overcome for these technologies to be widely implemented in medical practice.

It is concluded that the future of skin cancer diagnosis is moving toward a multidisciplinary, digital, and personalized approach, in which the combination of optical, molecular, and artificial intelligence-based methods will enable increasingly early, accurate, and accessible diagnoses. Such advances not only improve diagnostic capabilities but also contribute directly to better clinical outcomes and longer patient survival.

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