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# ARTIFICIAL INTELLIGENCE-ASSISTED TRICHOSCOPY IN HAIR DISORDERS: CURRENT APPLICATIONS, CLINICAL UTILITY, AND FUTURE PERSPECTIVES

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**ABSTRACT**
Hair and scalp disorders are commonly assessed through visual examination, serial photography, and trichoscopy. Although trichoscopy offers a non-invasive view of follicular and perifollicular structures, its interpretation may vary according to clinician experience, image quality, and examination protocols. Artificial intelligence (AI), including machine learning, deep learning, and computer vision, may help convert selected elements of trichoscopic assessment into more objective and reproducible measurements. This review summarizes the current role of AI-assisted trichoscopy in the diagnosis, follow-up, and individualized management of hair disorders.
A narrative review with a structured literature search was conducted. Publications addressing AI, trichoscopy, alopecia, scalp disorders, dermatological image analysis, teledermatology, and precision medicine were considered. The reviewed literature suggests that the most immediately applicable use of AI in trichology is not autonomous diagnosis, but automated quantification of hair and scalp parameters, including hair density, shaft diameter, follicular unit count, miniaturization, and longitudinal change. These tools may support assessment of androgenetic alopecia, alopecia areata, cicatricial alopecias, and selected inflammatory or infectious scalp conditions. However, diagnostic and predictive models remain limited by heterogeneous datasets, inconsistent image acquisition, limited external validation, and unresolved ethical and regulatory issues.
At present, AI-assisted trichoscopy should be viewed as an adjunct to dermatological evaluation. Future progress will depend on diverse datasets, standardized imaging, explainable algorithms, secure data handling, and clinical validation demonstrating measurable benefit for patients and clinicians.

**KEYWORDS**
Artificial Intelligence, Trichoscopy, Alopecia, Hair Disorders, Machine Learning, Teledermatology

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## 1. Introduction

Hair disorders are an important clinical problem in dermatology because they affect not only physical appearance but also patients' psychological well-being, social functioning, and quality of life. Alopecia may be scarring or non-scarring, and its etiology includes androgen-dependent, autoimmune, inflammatory, infectious, drug-induced, and environmental mechanisms [4,5,26]. The most common conditions include androgenetic alopecia, alopecia areata, telogen effluvium, and various forms of cicatricial alopecia [1,4,5]. Early and accurate diagnosis is clinically important because diagnostic delay may lead to disease progression, ineffective treatment, or irreversible follicular destruction, particularly in scarring alopecias [5,25].

Trichoscopy, defined as dermoscopy of the hair and scalp, is currently one of the basic non-invasive diagnostic tools in trichology [1,4,5]. It allows assessment of hair density, hair shaft diameter, miniaturization, follicular openings, perifollicular erythema, perifollicular scaling, exclamation mark hairs, black dots, yellow dots, and signs of scarring [4,5,25]. Therefore, trichoscopy supports differential diagnosis, evaluation of disease activity, monitoring of treatment response, and selection of the optimal biopsy site in suspected cicatricial alopecia [5].

Despite its clinical value, conventional trichoscopic assessment remains partly subjective. Its accuracy depends on clinician experience, image quality, examination standardization, and the ability to compare images over time [1,2,5]. In routine practice, objective assessment of disease progression and treatment response may be challenging, especially when precise comparison of hair density, shaft diameter, follicular unit count, miniaturization, or scalp involvement is required [1,2,3]. In this context, increasing attention has been directed toward artificial intelligence as a tool supporting trichoscopic and microscopic hair image analysis [1,2,24].

AI is increasingly used in dermatology, particularly in medical image analysis [6,16,21]. Dermatology is highly dependent on visual pattern recognition; therefore, methods such as machine learning, deep learning, convolutional neural networks, and computer vision may support lesion classification, image segmentation, disease severity assessment, and treatment monitoring [6,16]. In hair disorders, the potential of these methods results from the need for pattern recognition, quantitative evaluation of hair parameters, and longitudinal monitoring [1,2,24].

At present, the most clinically advanced applications of AI in trichology are tools that enable automated and reproducible measurement of hair parameters, including hair density, shaft diameter, follicular unit count, and the proportion of terminal to thinner hairs [1,2]. Strictly diagnostic and predictive models, although promising, still require further validation, standardization, and evaluation in real-world dermatological practice [1,2,3,24].

AI in trichology may increase examination objectivity, improve measurement reproducibility, facilitate treatment monitoring, and support personalized therapy [1,2,23,26]. Image-based tools may also be useful in teledermatology and remote patient monitoring, particularly where access to dermatology specialists is limited [9,10,11,12,13]. However, these technologies also raise important challenges, including the lack of standardized datasets, data bias, limited model interpretability, variable image quality, data privacy, legal and ethical concerns, and the need for physician oversight in the diagnostic process [1,2,9,11,14,19,20,22].

The aim of this review is to summarize current applications of AI-assisted trichoscopy in the diagnosis and monitoring of hair disorders, with particular emphasis on clinical utility, limitations, and future perspectives.

## 2. Materials and Methods

This review was designed as a narrative synthesis supported by a structured search strategy. Its purpose was to summarize how artificial intelligence is being applied to trichoscopy, scalp imaging, quantitative hair assessment, treatment monitoring, teledermatology, and precision-oriented management of hair disorders [1,2,8,9,24,26].

PubMed was used as the primary database. Search terms were combined around four main concepts: artificial intelligence technologies, hair and scalp disorders, image-based dermatological assessment, and remote or digital care. The terms included artificial intelligence, machine learning, deep learning, computer vision, trichoscopy, alopecia, hair disorders, scalp disorders, microscopic hair imaging, teledermatology, and dermatological image analysis. Additional review articles and systematic reviews were identified when they provided relevant background on dermatological imaging, inflammatory skin diseases, cicatricial alopecias, alopecia areata, patient perspectives, ethical issues, or precision therapeutics [1–18,24–26].

The search focused mainly on English-language publications from 2021 to 2026, reflecting the rapid growth of AI-related dermatology literature during this period. Recent reviews, systematic reviews, meta-analyses, clinical studies, and articles describing practical or translational applications were prioritized [1,2,3,6,8,14,24]. Publications on the broader technological basis of medical image analysis and on barriers to implementation were included when they were relevant to the interpretation or clinical translation of AI-assisted trichoscopy [9,10,11,16,19,20,22].

Studies and reviews were considered eligible if they addressed at least one of the following areas: AI-based or computer vision-based analysis of hair disorders; trichoscopy, microscopic hair imaging, scalp photography, or quantitative hair assessment; AI in dermatological image interpretation; AI applications in inflammatory or autoimmune skin diseases, especially alopecia areata; teledermatology, mHealth, digital health, or remote monitoring; or ethical, legal, technical, and social issues related to the use of AI in dermatology [1–3,6–11,19,24,26].

Articles were excluded if they were unrelated to dermatology or trichology, were purely technical without a clinically relevant component, did not involve imaging or medical data analysis, or consisted only of expert opinion without adding meaningful context to the review question.

Full-text articles were analyzed in greatest detail when available, particularly those addressing AI in hair disorders, dermatological image analysis, teledermatology, cicatricial alopecias, inflammatory skin diseases, precision medicine, and patient perceptions of AI or telemedicine [1–18]. Additional PubMed records without accessible full text were used as supplementary sources based on their titles, abstracts, and bibliographic information, mainly to support background discussion, limitations, and future directions [19–30].

The extracted information was organized thematically rather than statistically. The synthesis focused on five domains: trichoscopy and AI-based hair assessment, disease-specific applications, clinical utility and digital health, limitations and ethical issues, and future perspectives. Because the included publications differed substantially in design, populations, imaging methods, algorithms, and outcomes, a meta-analysis was not performed.

## 3. Results and Thematic Synthesis

### 3.1. Trichoscopy and AI in Hair Disorder Assessment

Trichoscopy is one of the core non-invasive diagnostic methods used in hair disorders. It enables assessment of hair shafts, follicular openings, inflammatory signs, scaling, vascular structures, miniaturization, and scarring [1,4,5]. In clinical practice, it helps differentiate non-scarring alopecias, such as androgenetic alopecia, alopecia areata, and telogen effluvium, from scarring alopecias, in which permanent follicular damage and loss of follicular openings occur [4,5]. Early recognition of scarring alopecias is particularly important, as delayed treatment may result in irreversible hair loss [5,25].

Despite its usefulness, trichoscopic interpretation remains partly subjective. The assessment depends on clinician expertise, image quality, magnification, lighting, documentation method, and the ability to compare images over time [1,2,5]. Reproducible evaluation of quantitative parameters, such as hair density, shaft diameter, miniaturization, follicular unit count, and alopecic area size, is especially challenging [1,2,3]. These elements create a natural field for AI application, as they can be analyzed using computer vision, machine learning, and deep learning methods [1,2,6,24].

In dermatology, AI has developed primarily in image analysis, as the specialty relies heavily on visual pattern recognition [6,16,21]. Convolutional neural networks and other deep learning models may support classification, segmentation, and quantitative assessment of clinical, dermoscopic, trichoscopic, and microscopic images [6,16]. In hair disorders, the most relevant applications currently involve automated repetitive measurements, including hair counting, density assessment, shaft diameter measurement, miniaturization detection, and longitudinal comparison [1,2,24].

AI may support image analysis at several stages, from image quality control and segmentation of hair shafts or follicular units to the generation of quantitative clinical reports [1,2,24]. Microscopic hair imaging adds another layer to this workflow because image acquisition, structural representation, artifact handling, and clinical interpretation all influence the final output [24]. AI-based approaches in this area may be most useful when they are developed as part of a standardized pipeline rather than as isolated image classifiers. Such systems could improve objectivity, reduce interobserver variability, and facilitate treatment monitoring [1,2,24].

### 3.2. Disease-Specific Applications

In androgenetic alopecia, AI may support assessment of follicular miniaturization, hair density, shaft diameter, and the proportion of terminal to thinner hairs [1,2,4,26]. These parameters are relevant for both diagnosis and monitoring, as they help evaluate disease progression and treatment response. Automated image analysis may be particularly useful for detecting subtle changes that are difficult to assess visually, especially in early disease or during long-term treatment [1,2,23].

In alopecia areata, AI applications focus on disease activity and lesion extent. Trichoscopy can identify exclamation mark hairs, black dots, broken hairs, yellow dots, and short regrowing hairs [1,3,7]. Computer vision methods may support segmentation of alopecic patches, estimation of affected scalp area, and monitoring of hair regrowth [3]. This may be relevant both in clinical practice and in trials evaluating emerging therapies, including Janus kinase inhibitors [3,7,8,26].

In cicatricial alopecias, AI is less developed but potentially valuable. Conditions such as frontal fibrosing alopecia, lichen planopilaris, and discoid lupus erythematosus require early detection of active inflammation because treatment primarily aims to prevent irreversible follicular destruction [5,25]. Algorithms could support identification of features such as loss of follicular openings, perifollicular erythema and scaling, hyperkeratosis, and scarring areas [5,25]. In the future, integration of trichoscopic data with histopathology and digital pathology may be useful, including for selecting the optimal biopsy site [5,24].

AI may also be relevant in other scalp and hair conditions, including telogen effluvium, PCOS-related hair loss, scalp psoriasis-associated alopecia, and superficial fungal infections [15,27,29]. In these conditions, its role is currently more supplementary but may include photographic documentation, hair density assessment, monitoring of inflammatory changes, and support for differential diagnosis [4,15,29].

### 3.3. Clinical Utility and Digital Health

The main current clinical value of AI-assisted trichoscopy lies in improving objectivity and reproducibility. Algorithms may perform measurements according to consistent rules, generate numerical outputs, and facilitate comparison of results across follow-up visits [1,2,24]. This is especially important in chronic hair disorders, where improvement is often gradual and early treatment effects may be difficult to detect during routine examination [1,4,23].

AI may support treatment monitoring by assessing changes in hair density, shaft diameter, the proportion of terminal hairs, alopecic patch size, and signs of active inflammation [1,2,3]. It may also improve the quality of clinical trials, as automated or semi-automated measurement tools reduce dependence on individual evaluators and facilitate comparison of data across centers [1,3,23].

Another promising direction is treatment personalization. Future AI systems may combine trichoscopic findings with clinical history, laboratory markers, genetic information, environmental exposures, and patient-reported data to support more individualized therapeutic decisions [8,23,26]. Early work on AI-guided hair loss management illustrates this concept by linking scalp image analysis with patient questionnaires, but these approaches should be interpreted cautiously until independently validated in larger and more diverse clinical populations [23].

Integration of AI with teledermatology may further improve access to care. Teletrichology, understood as remote diagnosis and monitoring of hair disorders, may use a store-and-forward model in which patients submit scalp images and clinical data for later assessment [9,10,13]. AI may support image quality control, preliminary image analysis, longitudinal comparison, and prioritization of cases requiring urgent consultation [1,2,9,24]. This may be particularly relevant in regions with limited access to dermatologists [10,12,13].

From the patient perspective, digital tools may facilitate disease tracking, improve understanding of treatment effects, and support adherence [2,11,23]. However, physician oversight, transparent communication about the role of AI, and protection of medical data are essential [11,19,30].

### 3.4. Challenges, Limitations, and Ethical Issues

The main limitations of AI-assisted trichoscopy relate to data quality, image standardization, external validation, model interpretability, and data security [1,2,19,24]. Many AI models are trained on limited datasets from single centers, involving small numbers of patients, skin phototypes, hair types, and imaging devices [1,2,3,24]. This may limit algorithm performance in external populations and increase the risk of bias [14,19,30].

Lack of standardized image acquisition is particularly important in trichology. Trichoscopic images may vary in magnification, lighting, device angle, sharpness, scaling, sebum, cosmetic products, and artifacts [1,2,24]. These differences can affect hair counting, diameter measurement, and miniaturization assessment. Therefore, algorithm development should be accompanied by standardized image acquisition and reporting protocols [1,2,24].

Annotation quality is another key issue. AI models learn from expert-labeled images, but many trichoscopic features are subtle and dependent on evaluator expertise [1,5,6]. Inconsistent annotations may lead to learning of inaccurate or ambiguous patterns [6,16,24].

Interpretability remains a major challenge. Many deep learning models function as "black box" systems, limiting clinician trust and making it difficult to determine whether the algorithm relies on clinically meaningful image features [19,20,22]. Explainable AI methods, such as heat maps, may improve transparency but do not replace critical dermatological interpretation [20,22]. Future systems should present not only outputs but also confidence levels, analysis limitations, and indications for further specialist evaluation [20].

Ethical issues include data privacy, cybersecurity, informed consent, diagnostic inequity, and legal responsibility [9,11,19,30]. Patients should know whether their data will be analyzed by AI, stored, or used for algorithm training [19,30]. It is also essential to avoid models that perform less accurately in underrepresented populations [14,19,30].

At present, AI should be regarded as a clinical decision-support tool rather than an autonomous diagnostic system [1,11,19]. Final interpretation should remain with the physician, who integrates medical history, clinical examination, trichoscopy, additional tests, and patient preferences [1,5,19].

### 3.5. Future Perspectives

The future of AI-assisted trichoscopy will likely depend on integrating image analysis with clinical, histopathological, laboratory, molecular, and patient-reported data [1,8,24,26]. Multimodal models may support more comprehensive assessment of hair disorders, prediction of disease course, and treatment personalization [8,23,26].

Precision medicine is a particularly promising direction. In androgenetic alopecia, hormonal, genetic, inflammatory, and environmental factors may be relevant, while alopecia areata is primarily driven by autoimmune mechanisms and cytokine pathways [7,8,26]. Integration of imaging data with biological information could support patient stratification and targeted therapy selection [8,26].

AI may also improve clinical trials in hair disorders by standardizing endpoints and enabling automated assessment of hair density, shaft diameter, alopecic area, and regrowth [1,2,3,24]. Teletrichology may facilitate long-term monitoring outside the clinic, provided that image acquisition is standardized, data are protected, and dermatological supervision is maintained [9,10,11,13,19].

A key requirement for future development is the creation of large, multicenter, diverse, and well-annotated trichoscopic datasets [1,2,3,24]. These datasets should include different alopecia types, skin phototypes, hair structures and colors, age groups, and imaging devices [1,2,19,24]. Only then will it be possible to develop models with greater generalizability and lower risk of bias [14,19,30].

## 4. Discussion

AI-assisted trichoscopy is an emerging approach within digital dermatology and trichology. Based on the available literature, its most convincing current value is the automation of quantitative and reproducible measurements rather than independent diagnostic decision-making [1,2,24]. This distinction is clinically important: many hair disorders evolve gradually, and small changes in density, shaft caliber, or follicular miniaturization may be difficult to judge consistently by visual inspection alone [1,2,4].

The most practical applications involve automated trichoscopic measurements. In androgenetic alopecia, AI may assist in evaluating hair density, miniaturization, and shaft diameter [1,2,26]. In alopecia areata, it may support patch segmentation, assessment of disease activity, and monitoring of regrowth [3,7,8]. In cicatricial alopecias, the most relevant future application may be detection of active inflammation and support in selecting biopsy sites [5,25]. Therefore, the utility of AI should not be considered uniform across all hair disorders; rather, it depends on disease mechanism, image type, and clinically relevant endpoints.

At the same time, current evidence does not support the use of AI as an autonomous diagnostic tool in trichology. Diagnostic and predictive models remain largely investigational, and their clinical translation is limited by small datasets, lack of image standardization, insufficient external validation, and risk of bias [1,2,3,19,24]. In clinical practice, AI may support dermatologists but should not replace medical history, clinical examination, expert trichoscopic interpretation, or histopathological assessment when indicated [1,5,19].

Data quality and representativeness remain central challenges. AI models in dermatology often perform well in experimental settings but may show reduced performance in real-world clinical populations [14,17,19]. In trichology, this issue is particularly complex because image appearance depends not only on skin phototype but also on hair color, density, structure, and grooming practices [1,2,24]. Underrepresentation of different skin tones and hair types may lead to diagnostic inequity and reduced generalizability [19,30].

Model interpretability is another important issue. In medicine, clinicians need to understand the basis of algorithmic outputs, especially when these outputs may influence diagnostic or therapeutic decisions [19,20,22]. Explainable AI methods, including heat maps, may help determine whether a model focuses on clinically meaningful image areas, but they still require expert interpretation [20,22].

Digital health and teletrichology may improve access to care, especially in regions with limited availability of dermatologists [9,10,12,13]. Combining AI with telemedicine may support triage, chronic disease monitoring, and treatment-response assessment outside the clinic [9,11]. However, remote assessment of hair disorders requires high-quality images, standardized acquisition procedures, data protection, and clearly defined clinical responsibility [9,10,19].

From the patient perspective, AI-based tools may improve disease documentation, facilitate understanding of treatment progress, and shorten time to specialist assessment [11,23]. Nevertheless, patients often expect AI to be used under physician supervision rather than as a substitute for medical care [11,19]. Responsible implementation should therefore include patient education, transparent communication, informed consent, and privacy protection [11,19,30].

Future development will likely move toward multimodal models integrating trichoscopic images with clinical, histopathological, laboratory, molecular, and patient-reported data [1,8,24,26]. Such systems may support precision medicine, prediction of treatment response, and more individualized therapeutic decisions [8,23,26].

Overall, AI-assisted trichoscopy should be understood as a developing decision-support approach. Its near-term role is most likely to be in measurement, documentation, follow-up, and workflow support, rather than in replacing clinical diagnosis [1,2,24]. Wider adoption will require large and diverse datasets, standardized imaging protocols, external validation, interpretable outputs, secure data governance, and clear legal and ethical frameworks [1,3,19,24,30]. The most realistic model is a collaborative one, in which AI improves objectivity and efficiency while the dermatologist remains responsible for final interpretation and treatment planning [1,11,19,20].

## 5. Conclusions

AI-assisted trichoscopy represents a promising but still evolving approach to the assessment of hair disorders. Its strongest current application is the automated quantification of hair and scalp parameters, including hair density, shaft diameter, follicular unit count, miniaturization, and change over time [1,2,24].

In androgenetic alopecia, AI may support assessment of miniaturization and treatment monitoring; in alopecia areata, it may assist in patch segmentation and regrowth evaluation; and in cicatricial alopecias, it may potentially help detect active inflammation and guide biopsy site selection [1,3,5,25,26]. These applications are clinically relevant because hair disorders often require long-term follow-up, while conventional visual assessment may be subjective and dependent on clinician experience [1,4,5].

Despite this potential, AI should not currently be positioned as an independent diagnostic substitute for dermatologists. Diagnostic and predictive models in hair disorders still require external validation, standardized imaging, larger and more diverse datasets, and testing in real-world clinical environments [1,2,3,19,24]. Data bias, model interpretability, patient privacy, legal responsibility, and informed consent remain central issues for safe implementation [11,19,20,22,30].

The most appropriate implementation model is the use of AI as a clinical decision-support tool. In this model, the algorithm performs reproducible measurements, analyzes images, and identifies trends, while the dermatologist interprets the results in the context of medical history, clinical examination, trichoscopy, histopathology when needed, and patient preferences [1,5,11,19]. Such an approach may improve objectivity, efficiency, and personalization while preserving patient safety and clinical accountability.

Further development of AI-assisted trichoscopy should focus on multicenter datasets, standardized image acquisition, explainable AI, multimodal data integration, and evaluation of the impact of these tools on real clinical decisions and treatment outcomes [1,8,19,22,24,26]. If these conditions are met, AI may become an important component of modern trichology, supporting earlier diagnosis, more precise monitoring, and more personalized management of hair disorders.

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