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A Comprehensive Review of Artificial Intelligence-Based Hair and Scalp Disorder Detection

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Abstract

Problems of the scalp and hair, such as such conditions as alopecia, dandruff, psoriasis and fungus are common and affect a big number of individuals worldwide. Early identification of these problems and accurate diagnostic values is very important in ensuring that effective treatment of the problem can be administered and the results of the problem are not complicated by the passage of time. Scalp diseases in the past have been diagnosed by clinical inspection and dermoscopic evaluation undertaken by dermatologists. Nevertheless, the recent developments of Artificial Intelligence (AI) have presented novel opportunities of automated and effective disease detection. This review paper gives an account of Artificial Intelligence-based methods applicable in the detection and classification of hair and scalp ailments. The use of different machine learning and deep learning models is common, especially Convolutional Neural Networks (CNNs) to examine images of scales and determine disease patterns. These models have the ability of extracting key features like the hair density, the scalp texture and the follicle structure to identify various conditions of the scalp. The paper also presents the application of the image processing method, transfer learning models, and mobile-based diagnostic systems that can aid in automated scalp health monitoring. In spite of the good outcomes, the lack of datasets and clinical validation are also important issues. Altogether, Artificial Intelligence can be very promising in boosting the precision and efficiency of hair and scalp disorder detection, which will assist dermatologists and improve modern healthcare systems.

Keywords: **Artificial Intelligence, Hair Loss Detection, Scalp Disease, Deep Learning, CNN, Medical Image Processing.**

1. Introduction

A dermatological disorder that is typical among millions of individuals globally is hair and scalp disorders. Hair loss, itch, scalp psoriasis, fungal infections, and dandruff may be caused by such problems as alopecia, dandruff, seborrheic dermatitis, and scalp psoriasis. These disorders can not only affect the physical looks of a person but also can impact on the psychological state and self-esteem of an individual. Hair and scalp disorders are thus important to be detected early and their diagnosis done in order to be treated and prevent the occurrence of serious complications. Hair and scalp diseases are traditionally diagnosed using clinical examination that is conducted by dermatologists. Dermoscopy or trichoscopy are commonly used by medical experts to observe the scalp and the follicular hair in detail. Even though these methods are effective, they demand expert knowledge and equipment. Accessibility to dermatological specialists in most parts of the world particularly in the developing regions may be not easy thus complicating early diagnosis. Consequently, there is a growing necessity in the intelligent and automated systems that will help to detect and analyse the scalp disorders. Artificial Intelligence (AI) is a healthcare force in the recent years. Machine learning and deep learning, which are AI methods, have demonstrated substantial achievement in the analysis of medical images and detection of disease. Dee learning algorithms, including Convolutional Neural Networks (CNNs), can automatically detect salient information in images and the patterns which relate to different diseases. These models have extensively been applied in the diagnosis of skin diseases, detection of tumors as well as analysis of medical imaging data with a high level of accuracy. The recent literature has delved into the application of deep learning methods in the detection of scalp diseases using medical images. Roy et al. (2022) suggested a CNN-based system of detecting scalp diseases through the processing of medical image sets and proved that the deep learning models were capable of identifying patterns associated with scalp abnormalities and hair as

well [3]. In a similar way, Chowdhury et al. (2024) explored the application of deep neural networks to the diagnostic process of hair and scalp disease and emphasized the possibility of AI systems to enhance the accuracy of the diagnostic process in the field of dermatology [4]. Moreover, Kim (2023) created a scaling diagnosis algorithm on the basis of convolutional neural networks that realized scalp images and were used to recognize the abnormalities on the scalp, including dandruff and scalp inflammation [5]. AI use in dermatology has received significant interest due to the capability to work with large volumes of data and deliver quick diagnostic outcomes. It has been shown in multiple study reports that deep learning models are capable of classifying dermatological conditions as well as medical professionals can. As the digital images of scalps are available and new methods of calculation can be used, AI-based systems can be trained to identify patterns of hair density and changes in scalp texture, inflammation, and other visual features of scalp disorders. Moreover, automated diagnostic systems are created because of the combination of AI and computer vision and image processing methods. Such systems will be able to process images of the scalp that have been taken by digital cameras or smartphones and give preliminary diagnostic data. These smart systems can assist dermatologists to make clinical decisions and enhance the availability of scalp health monitoring services. Although these developments are achieved, AI-based hair and scalp disorder detection research is in its early stages. Numerous available studies are cantered on the general classification of skin diseases, whereas relatively little studies are cantered on definite scalp conditions. Such issues as lack of large datasets of annotated scalp images, differences in image quality, clinical validation are still serious concerns in the sphere. Accordingly, the purpose of this review paper is to give an all-inclusive review of the Artificial Intelligence-based methods in the detection of hair and scalp disorder. To diagnose scalp disease, the paper examines recent research contributions, widely used machine learning and deep learning techniques, and the importance of image processing techniques in the diagnosis process. Further, the research also indicates contemporary issues and explains future research prospects in the formation of more precise and credible AI scalp diagnostic systems.

1.1 Hair and scalp disorders overview

Hair and scalp disorders are common health conditions that affect people of all ages. These problems can influence not only the appearance of hair but also the health of the scalp. Hair plays an important role in protecting the scalp and maintaining body temperature, while the scalp provides the environment needed for healthy hair growth. When the scalp or hair follicles are affected by disease, it can lead to hair loss, itching, irritation, or other visible changes.

Many factors can contribute to hair and scalp disorders. These include genetic conditions, hormonal imbalance, poor nutrition, infections, stress, and environmental factors. In some cases, improper hair care practices or the excessive use of chemical products may also damage the scalp and hair follicles. Because of these reasons, hair problems are becoming increasingly common across different populations.

Some of the most frequently observed hair and scalp disorders include Alopecia Areata, which causes sudden patchy hair loss, and Androgenetic Alopecia, a hereditary condition that leads to gradual thinning of hair. Other common scalp conditions include Dandruff and Seborrheic Dermatitis, both of which can cause itching, irritation, and visible flakes on the scalp. Fungal infections such as Tinea Capitis can also affect hair follicles and may lead to hair breakage or hair loss, particularly in children.

Traditionally, dermatologists diagnose these disorders through physical examination of the scalp, patient medical history, and specialized tools such as dermoscopy. However, identifying certain scalp diseases can sometimes be difficult because many conditions share similar symptoms. Early diagnosis is important because untreated scalp disorders may worsen over time and can significantly affect a person's confidence and quality of life.

In recent years, technology has started to play an important role in assisting medical professionals in identifying hair and scalp problems more efficiently. Digital imaging and advanced computer-based analysis methods allow researchers to study scalp conditions in greater detail. These developments are encouraging the exploration of automated systems that can support dermatologists in detecting hair disorders at an early stage. Understanding the different types of hair and scalp disorders, their causes, and their effects is an important step toward developing effective diagnosis and treatment methods. Continuous research in this field is helping to improve awareness, early detection, and better management of these conditions.

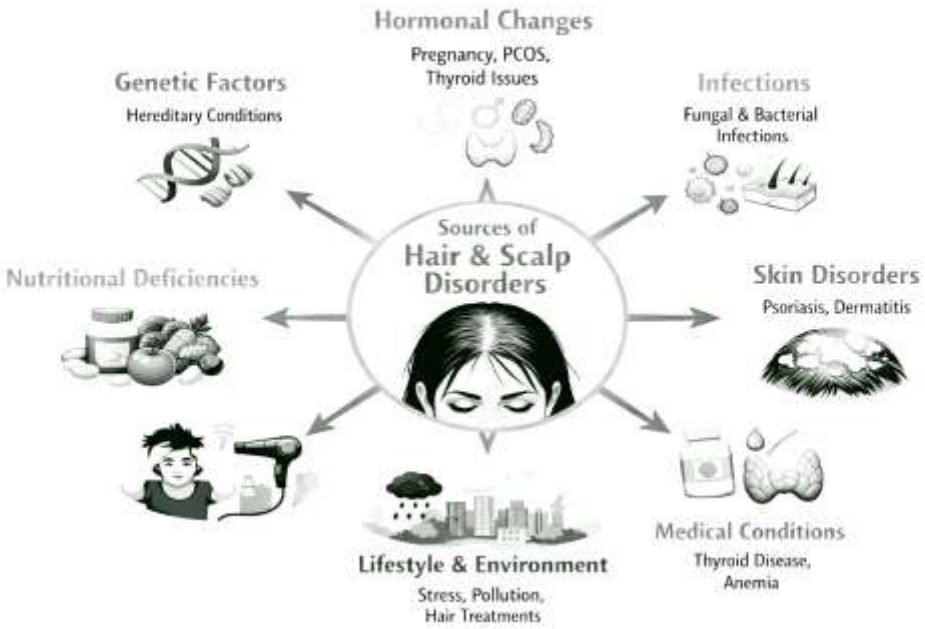

Fig 1: Sources of Hair & Scalp Disorder

1.2 Need for AI-Based Hair and Scalp Disease Detection

Diseases of the hair and scalp are extremely widespread and occur among individuals of various age groups. The symptoms are similar in many disorders like Alopecia Areata, Androgenetic Alopecia, Dandruff, and Seborrheic Dermatitis, and, therefore, it is a challenging task to make a diagnosis at an early stage. Dermatologists rely on visual examination as the main method of traditional diagnosis which is sometimes subjective and time-consuming. AI can be used to enhance detection of hair and scalp diseases by enhancing their accuracy and speed. AI-based systems are able to scan images of scalp and detect patterns that are not easily perceived by the human eye. Such systems would help dermatologists to make more accurate and quicker diagnosis. The other significant benefit of AI-based detection is accessibility. Access to dermatologists may not be easily available to many people particularly in remote regions. The preliminary screening and early detection of scalp disorders can be assisted by AI-powered devices and mobile applications. Early diagnosis enables the patient to seek treatment early enough before the condition degenerates to the severe stages. Consequently, AI application in the detection of hair and scalp diseases can help medical practitioners, enhance the accuracy of the diagnosis, and deliver more affordable healthcare services.

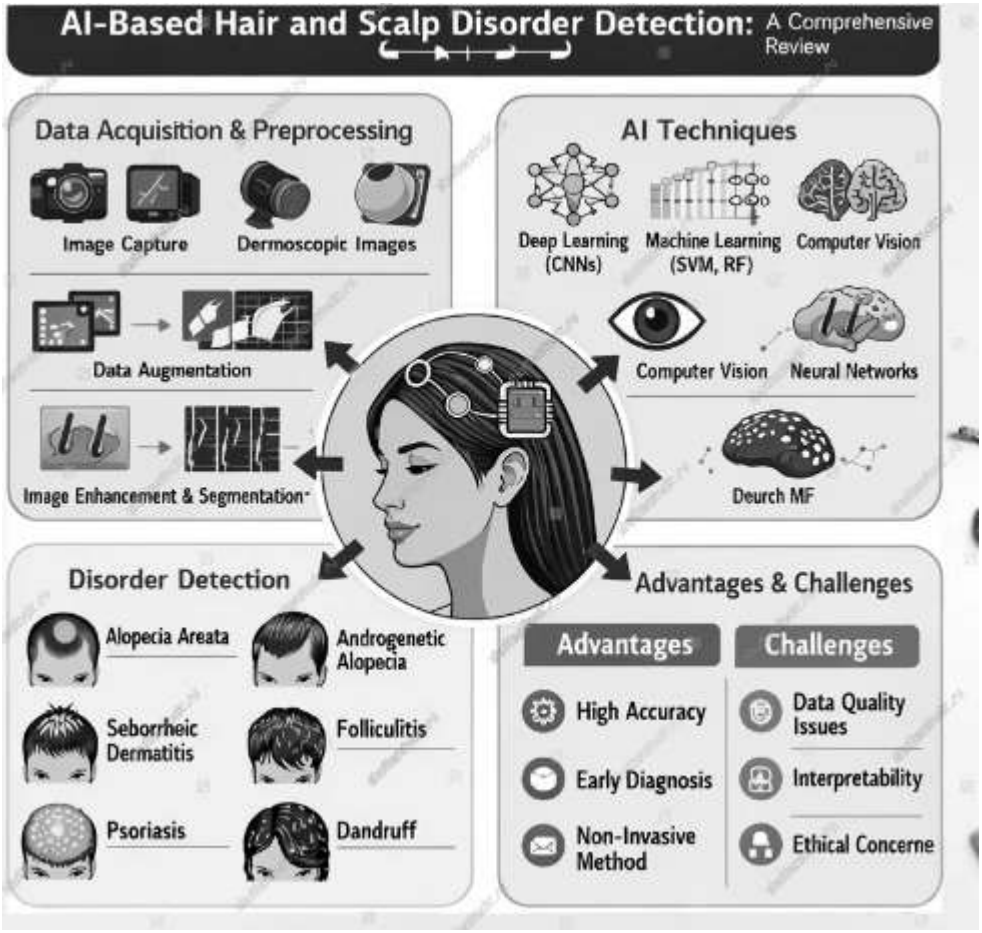

Fig 2: AI-Based Hair and Scalp Disorder Detection

2. Literature Review

Deep learning and Artificial Intelligence (AI) have brought revolutionary advancements in the medicine image analysis world (dermatology, scalp disease diagnosis). As machine learning methods develop, the automated system will be able to recognize scalp images and diagnose the disorder, including alopecia, dandruff, psoriasis, and folliculitis. These technologies are beneficial to the dermatologists in the sense that it enables quicker and correct diagnosis than the traditional manual examination approach. In recent research, convolutional neural networks (CNNs) have proven to be very useful in identifying hair and scalp diseases by means of image input. Scalp-based deep learning can automatically identify scalp features and identify various scalp disorders with high accuracy on scalp images [1][2]. It is also suggested in research that CNN-based diagnostic tools may be used to detect various diseases, including alopecia, psoriasis, and folliculitis, with the help of datasets of scalp images and through machine learning modelling [3]. The accuracy of the scalp disease detection systems has also been enhanced using deep neural networks. The recent studies introduced complex neural network architectures to extract dermatological images and help clinicians diagnose hair and scalp related diseases more accurately [4]. These models can learn the complicated patterns of medical images and thus early detect the hair-related conditions. The other significant field of study is on automated scalp diagnosis algorithms. The convolutional neural network that is surface-sensing was created to examine scalp conditions, including dandruff and erythema. The system involves image processing algorithms to analyse the scalp surface normalization and detects anomalies that can result into loss of hair or inflammation [5]. Hair follicle detection and hair density estimation have also been done using deep learning techniques. Research that adopted object detection algorithms like YOLO has revealed that AI models can automatically detect hair follicles in scalp images and estimate hair density, thus helping to assess the state of some hair loss condition severity [6]. Another emerging trend is the development of (web-based and mobile-based) scalp diagnosis systems. Scholars have suggested intelligent systems combining deep learning models and web applications to scan scalp images and report automated diagnosis results [7]. Such systems enable people to post images of their scalp and undergo initial health check-ups, without attending a health clinic. More recent research aimed at making more sophisticated deep learning models to analyse dermatological images has also been conducted.

Such systems apply convolutional neural network and computer vision to identify scalp diseases and help in the early diagnosis of hair disease [8]. Scalp analysis is also studied by the means of trichoscopic imaging. Learned deep learning models using trichoscopic images are capable of identifying early androgenetic alopecia and give precise results on the classification of hair loss patterns. Deep learning models have been confirmed with clinical studies on labeled images of the scalp on dermatology datasets [9]. Other researchers have suggested deep learning models combined with dermoscopy procedures to enhance the recognition of anomalies over the scalp. The models have the ability to detect various scalp diseases such as alopecia areata, seborrheic dermatitis and tinea capitus through the analysis of dermoscopic images of the scalp [10]. A number of papers emphasize the relevance of image preprocessing and feature extraction in enhancing the performance of AI based scalp diagnosis system. Image enhancement, noise removal, and segmentation are the techniques that can be employed to enhance the quality of images before sending the data to the deep learning models [11][12]. The transfer learning has also been extensively applied to enhance the performance of the deep learning models in cases where scarce scalp image datasets exist. ResNet, Efficient Net and VGGNet, which are pre-trained models, can be fine-tuned to the task of scalp disease classification [13][14]. Moreover, explainable artificial intelligence (XAI) methods are under investigation to make healthcare systems based on AI more transparent. Explainable models make clinicians aware of the manner in which the AI system arrives at predictions and enhance confidence in automated diagnostic systems [15]. The combination of AI and mobile health technologies and cloud computing has also increased the accessibility of scalp diagnosis systems. Healthcare solutions on cloud computing enable the processing of large amounts of data with feedback on scalp images in real-time [16][17]. Although there has been a considerable advancement, there is still a problem of creating a trustworthy AI-based scalp disease detection system. Small datasets, image quality differences, and inaccessibility to standardized databases of scalp images are significant problems of researchers [18][19]. In the recent past, there has also been interest in enhancing the dataset augmentation methods and generative frameworks in order to address the issue of data scarcity. Generative AI models can generate synthetic images of the scalp that can be used to train the deep learning algorithms [20]. On the whole, the existing studies prove that artificial intelligence and deep learning can be successfully applied to hair and scalp disease detection systems. As the AI-based diagnostic devices continue to develop with more sophisticated deep learning models, dataset creation, and clinical validation, they might become a significant part of the dermatology and healthcare systems of the future [21-30].

3. Discussion and Future Perspectives

According to the recent studies, the Artificial Intelligence (AI) approach and the deep learning methods have considerably helped to detect and classify the hair and scalp conditions. Most of the studies have used machine learning algorithms and convolutional neural networks (CNNs) to categorize scalp images and diagnose the following conditions alopecia, dandruff, psoriasis, and seborrheic dermatitis. These intelligent systems have demonstrated encouraging outcomes of precision, performance, and computer-aided diagnosis. Models can be used to identify various scalp conditions by using important features, namely, hair density, follicle distribution, scalp texture, and inflammation patterns, of which the models can be created using computer vision and image processing techniques. Regardless of these developments, there are various shortcomings of the current studies. It has one of the most significant limitations of its application due to the small size and poor annotation of scalp images datasets. Most studies use a small set of data or privately gathered data, which can decrease the generalization ability of AI models. The image quality, lighting conditions, and other scalp characteristics of different populations may also cause model variations. Also, there are AI models that act as a black box, i.e. their decision-making processes cannot be interpreted easily by clinicians. The inability to explain this may hinder the adoption of AI systems in medicine. A second significant research void is that there are no standardized assessment systems of AI-based scalp disease detection. Various research works employ various data sets, criteria of evaluation, and experiment environments, which makes it hard to compare the efficiency of various versions. Moreover, most of the suggested systems are only tested in laboratory settings and have not been proven in actual clinical settings. This explains the necessity of working with researchers, dermatologists, and healthcare institutions to create clinically reliable AI solutions. The future studies need to be oriented at creating bigger and more versatile scaled image databases which contain different types of hair, age and nationalities. The accuracy and transparency of diagnostic systems can be enhanced with the help of the state-of-the-art deep learning models, using transfer learning, and explainable AI approaches. Moreover, the combination of AI-based scalp analysis with mobile apps and cloud-based medical systems would be able to help monitor and identify scalp conditions at the earliest stage remotely. Altogether, AI-based technologies are highly promising to reshape the process of hair and scalp disorder diagnosis and treatment. As the data

availability, model interpretability, and clinical validation continue to develop, AI-based scalp diagnostic systems can be considered a useful tool to dermatologists, and can make healthcare services more accessible and efficient.

3.1 Real-Time Scalp Monitoring Systems

Real-time scalp monitoring systems are new technologies that are employed to constantly monitor the state of the scalp and hair follicles by means of high-end imaging equipment and smart algorithms. These systems record images of scalps using digital cameras, wearable devices or mobile phones and analyse them with the use of artificial intelligence. It is aimed at identifying the onset of scalp issues and keeping track of the progress. Such systems can be used to detect diseases such Alopecia Areata, Androgenetic Alopecia, Seborrheic Dermatitis and Dandruff at an early stage. Using the images and scalp parameters, the system will be able to monitor the hair density, inflammation of the scalp, the level of oil, and other significant factors. The monitoring on a real-time basis also enables the user and the healthcare professional to see the effectiveness of treatment. These systems together with mobile apps and cloud platforms can deliver timely notifications, personalized suggestions and remote dermatologist consultation. With the ongoing advances in technology, real-time scalp tracking systems can be significant to preventive care and customized care of hair.

3.2 AI-Driven Personalized Treatment

Real-time scalp monitoring systems are new technologies that are employed to constantly monitor the state of the scalp and hair follicles by means of high-end imaging equipment and smart algorithms. These systems record images of scalps using digital cameras, wearable devices or mobile phones and analyze them with the use of artificial intelligence. It is aimed at identifying the onset of scalp issues and keeping track of the progress. Such systems can be used to detect diseases such Alopecia Areata, Androgenetic Alopecia, Seborrheic Dermatitis and Dandruff at an early stage. Using the images and scalp parameters, the system will be able to monitor the hair density, inflammation of the scalp, the level of oil, and other significant factors. The monitoring on a real-time basis also enables the user and the healthcare professional to see the effectiveness of treatment. These systems together with mobile apps and cloud platforms can deliver timely notifications, personalized suggestions and remote dermatologist consultation. With the ongoing advances in technology, real-time scalp tracking systems can be significant to preventive care and customized care of hair.

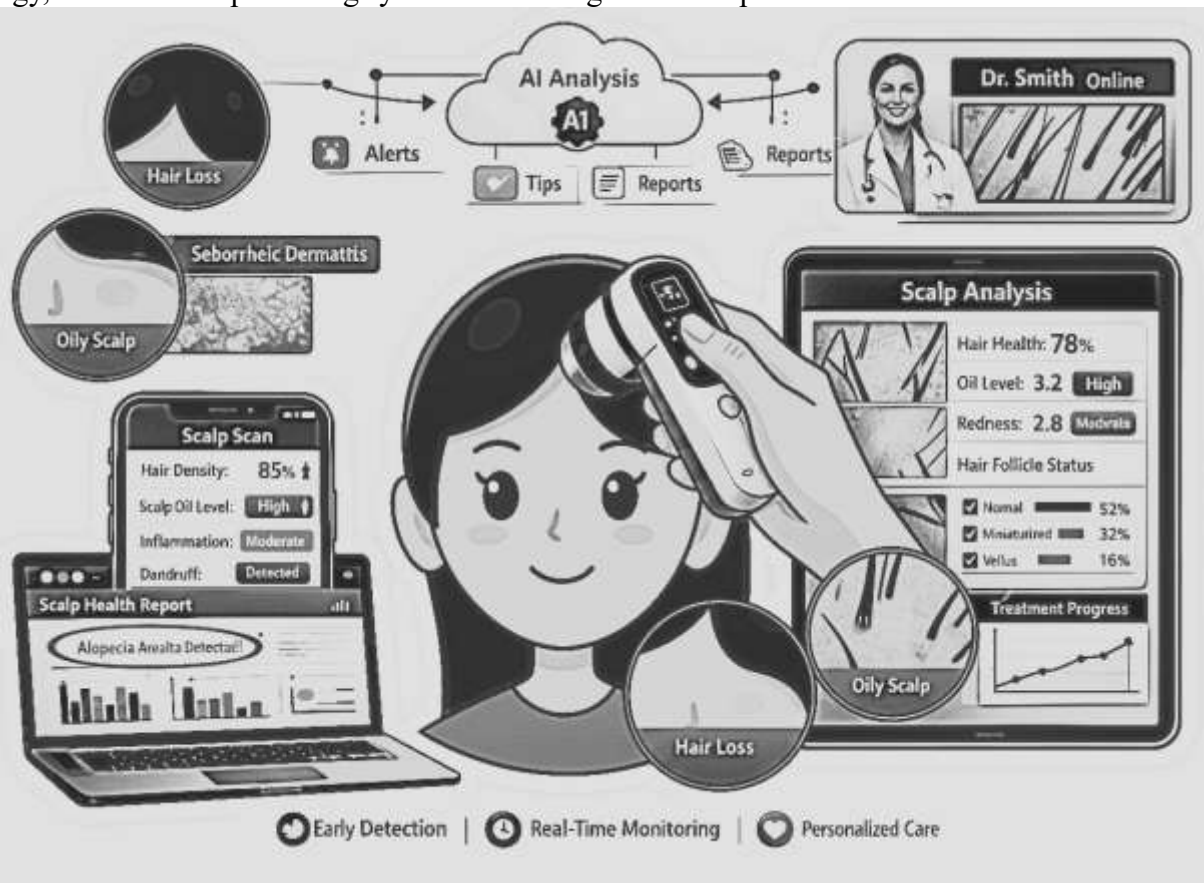

Fig 3 : Real-time scalp Monitoring System

4. Conclusion

This paper has described and reviewed in brief Artificial Intelligence-based methods of detecting hair and scalp disorders. The article is focused on the potential application of machine learning and deep learning technologies, specifically Convolutional Neural Networks (CNNs), to perform a scalp image analysis and detect a variety of hair and scalp disorders. These artificial intelligence solutions have demonstrated good outcomes in enhancing the quality and efficiency of skin diagnosis. The significance of image processing methods, computer-based diagnostic systems, and the combination of AI and healthcare technologies is also covered in the review. Even though a number of research studies reveal AI possibilities in scalp disease detection, it is still plagued by some issues, including lack of datasets and clinical validation. All in all, Artificial Intelligence can assist dermatologists and enhance the early diagnosis of hair and scalp disorders. To optimize the results of automated diagnosis of the scalp, future studies must be dedicated to the creation of more credible data sets and improved AI models.

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