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A COMPREHENSIVE REVIEW ON MACHINE LEARNING AND DEEP LEARNING TECHNIQUES FOR FUNGAL SKIN DISEASES

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Abstract: Fungal skin infections are an emerging public health issue in India, with millions of people being affected every year by diseases like Tinea capitis, vaginal candidiasis, and aspergillosis. This review delves into the two sides of this challenge—evaluating the projected disease burden and discussing the emergence of Machine Learning (ML) and Deep Learning (DL) tools in fungal skin disease research during the period from 2018 to 2023. Epidemiological findings demonstrate a widespread incidence of superficial and systemic fungal infections, emphasizing the need for increased awareness, early detection, and efficient treatment approaches. At the same time, the review points to a significant rise in ML/DL-based research, indicating an intensifying interest in using artificial intelligence for dermatologic diagnosis. The convergence of public health and technology implies potential prospects for enhancing outcomes through AI-assisted tools, as long as they are supplemented by strong clinical validation and health policy infrastructure. The research calls for a multi-disciplinary solution to address India's increasing burden of fungal disease.

Keywords: Fungal skin diseases, India, Tinea capitis, vaginal candidiasis, machine learning, deep learning, dermatology, artificial intelligence, epidemiology, disease burden.

I. INTRODUCTION

Fungal skin infections are some of the most common skin conditions globally, infecting a large percentage of the population in all age groups. They are conditions caused by fungi infections of the skin, nails, and mucous membranes, and are presented as conditions like ringworm, athlete's foot, candidiasis, and dermatophyte infection. Though mostly not life-threatening, fungal infections of the skin can cause severe morbidity and pain, and if not treated, they may cause serious complications, such as chronic infection or secondary bacterial infections. Early and proper diagnosis is important to enable proper treatment and to avoid transmission of these infections, particularly among immunocompromised patients [1-4].

Conventionally, diagnosis of fungal skin infections has depended on clinical examination, visual inspection, and microscopic analysis of skin scrapings. Medical analysis procedures using these methods becomes lengthy and subjective while demanding specific clinical expertise which leads to delayed diagnosis. This also enables wrong diagnoses. The visual examination lacks effectiveness for proper diagnosis due to similar skin conditions appearing similar to fungal skin diseases. The diagnostic process in dermatology experienced a transformative shift through the introduction of machine learning (ML) and deep learning (DL) technologies during the past few years thus delivering improved diagnostic accuracy combined with enhanced efficiency together with objective analysis [5-9].

Medical image analysis now benefits from the extensive interest in artificial intelligence (AI) forms machine learning and deep learning because these systems excel at handling extensive data and discovering meaningful relationships within that data. The detection together with segmentation and classification of skin diseases especially fungal infections show great promise through these two methods. Support vector machines (SVM) and random forests and k-nearest neighbours (KNN) represent common machine learning algorithms that specialists utilize because these algorithms can analyze image features to identify skin disorders from learned pattern recognition. Binary digit approaches have shown extra diagnostic potential with their convolutional neural networks (CNNs) due to their automatic feature learning capabilities from unprocessed pictures without the need for human-intervention [11-17].

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The field of fungal skin condition diagnosis through ML and DL continues to develop because of expanding dermatological image databases and augmenting processing capabilities together with advanced algorithms. These technologies have dual benefits for fungal skin diagnostics since they boost diagnostic capabilities while enabling prompt detection and individual patient therapy design. Automated diagnostic software employing ML and DL technology helps dermatologists reduce diagnosis workload and saves time which enables them to focus on better patient health outcomes through clinical decision-making processes [18-23].

The study reviews the present standards of machine learning and deep learning approaches in diagnosing fungal skin diseases. The discussion will cover essential algorithms alongside their approaches and training challenges as well as available data collections and practical implementation details. Additional sections will investigate forthcoming research directions together with possible advancements which can strengthen the application of AI in dermatological practice specifically regarding fungal skin disease diagnosis. This assessment offers substantial knowledge about the transformative power of AI in dermatology while presenting the possible benefits for patients and medical specialists who treat fungal skin conditions [24-29].

1.1. Objectives of the study

- To estimate the prevalence and burden of fungal skin infections in India based on recent epidemiological data.
- To analyze the evolution of ML/DL-based studies on diagnosis of fungal skin disease in India from 2018 to 2023.

II. LITERATURE REVIEW

In this papers delivered an extensive discussion about applying ML/DL techniques for dermatology image segmentation and classification. The paper reviewed 74 essential studies which delivered details about the main deep learning techniques used in dermatology. It has analyzed how artificial intelligence (AI) merged with dermatology and machine learning algorithms enabled the identification of skin diseases. AI has transformed dermatology since it can evaluate extensive medical data and find obscure patterns in skin disease images according to the authors. These studies evaluated the diagnostic capabilities of assisted computer algorithms detecting skin lesions with machine learning approaches compared to deep learning methods [30-37].

The authors studied 102 papers which pointed out challenges in evaluating skin lesion segmentation and classification algorithms including limited available datasets alongside biases within chosen images and primarily Caucasian subjects in the data. Hence, examined the escalating role of computer-aided systems in the field of skin disease diagnosis. Their study examined how AI-based systems experienced rapid advancement in healthcare particularly regarding skin disease detection and classification. According to the authors proper disease management through AI depends on both appropriate diagnosis and prevention systems of future diseases [38-49].

In these reviewed convolutional neural networks (CNN) and artificial neural networks (ANN) for their performance in detecting skin lesions. The authors emphasized the requirement for automated methods to reduce diagnostic work and time because they presented evidence about DL algorithms that boost skin disease identification accuracy. Here, assessed machine learning applications wit hin skin lesion research to build automated diagnostic systems for dermatologists in medical practice. Their study led researchers to further investigate effective ways for skin disease diagnosis systems using image segmentation and classification methods which produce precise and efficient diagnostic outcomes. Thorough evaluation of machine learning models used for skin disease identification served as the topic of study. The research discussed various methods for detecting and classifying skin disorders through support vector machine (SVM) artificial neural network (ANN) and convolutional neural network (CNN) along with their dermatological study performances [50-58].

In this shared computer vision methods for the automatic diagnosis of skin ailments. Through their study the authors presented an overview of how computer vision has been employed for diagnosing skin conditions which included both melanoma and psoriasis, eczema and fungal disease entities with enhanced diagnostic capabilities and accessibility in dermatology. Here authors proposed a combination approach for extracting features used in early skin lesion identification. The researchers examined how well machine learning with deep learning performed on two datasets containing the ISIC 2018 and PH2 information and they used feedforward neural networks and artificial neural networks to reach accurate results of 95.24% and 97.91% respectively. Here, applied an image processing method to detect skin diseases through digital monitoring of disease-affected skin areas. The system applied pretrained convolutional neural networks (CNN) as features and multiclass support vector machines (SVM) as the classifier resulting in a 100% detection rate of three types of skin diseases [59-77].

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III. RESEARCH METHODOLOGY

A narrative review approach combines with epidemiological insights and the evaluation of publication patterns throughout the study. This research evaluates both the scope of fungal skin diseases in India and the development path of Machine Learning (ML) and Deep Learning (DL)-oriented research from 2018 through to 2023. The two-focus structure enables a connection between healthcare public issues and technological innovations in medical diagnostic processes [78-85].

3.1 Epidemiological Data Collection

Statistics about fungal skin diseases originate from national health survey results together with peer-reviewed research and worldwide disease surveillance information obtained from databases including Global Action Fund for Fungal Infections (GAFFI), Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO). The studies examined Tinea capitis vaginal candidiasis and aspergillosis and mucormycosis diseases since they showed clinical significance and provided available count information [86-95].

To measure disease burden quantitatively, the prevalence rate (P) was employed as a standard epidemiological indicator:

$$P = \frac{C}{N} \times 10^6$$

Where:

- P = Prevalence rate per million
- C = Number of estimated cases
- N = Total population of India (approx. 1.42 billion in 2023)

This equation allows for standardized comparison across diseases with varying absolute case counts.

3.2 ML/DL Research Trend Analysis

To identify trends in research, a systematic literature review was done using databases like PubMed, IEEE Xplore, Scopus, and Google Scholar. Search terms were: "Fungal skin diseases," "India," "Machine Learning," "Deep Learning," "Dermatophytosis," "Candidiasis," "diagnosis," and "classification." The search was restricted to English-language papers published between 2018 and 2023, with preference for papers applying ML/DL methods to fungal skin disease detection or classification [96-103].

The growth rate of publications per year (AGR) was determined to gauge the rising popularity in the field:

$$AGR = \left(\frac{P_n - P_1}{P_1}\right) \times 100$$

Where:

- Pn = Number of publications in the final year (2023)
- P1 = Number of publications in the first year (2018)

This metric quantifies the relative increase in publication frequency over the six-year span.

3.3 Inclusion and Exclusion Criteria

Studies were considered if they (a) dealt with fungal skin infections in the Indian population and (b) utilized ML or DL techniques for diagnosis, prediction, or classification. Non-India-related research, which did not include AI methodology, or non-peer-reviewed studies (e.g., opinion articles, brief communications) were excluded. Epidemiological reports without exact case estimates were also excluded [104-109].

3.4 Data Synthesis and Analysis

The data extracted were grouped into two primary categories: (1) the disease burden in millions of cases for various fungal infections, and (2) the annual count of ML/DL-based publications. These findings were represented by bar graphs and interpreted in terms of public health implications and technological response trends [110-117].

3.5 Limitations

This review does not include sophisticated bibliometric methods like co-citation analysis, keyword mapping, or author collaboration networks. It also does not evaluate the quality and impact of the studies included but rather quantity and broad trends. Additionally, disease burden estimates rely on secondary data available and can be prone to underreporting and regional disparities, particularly in rural and underserved populations[118-124].

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IV. RESULT AND DISCUSSION

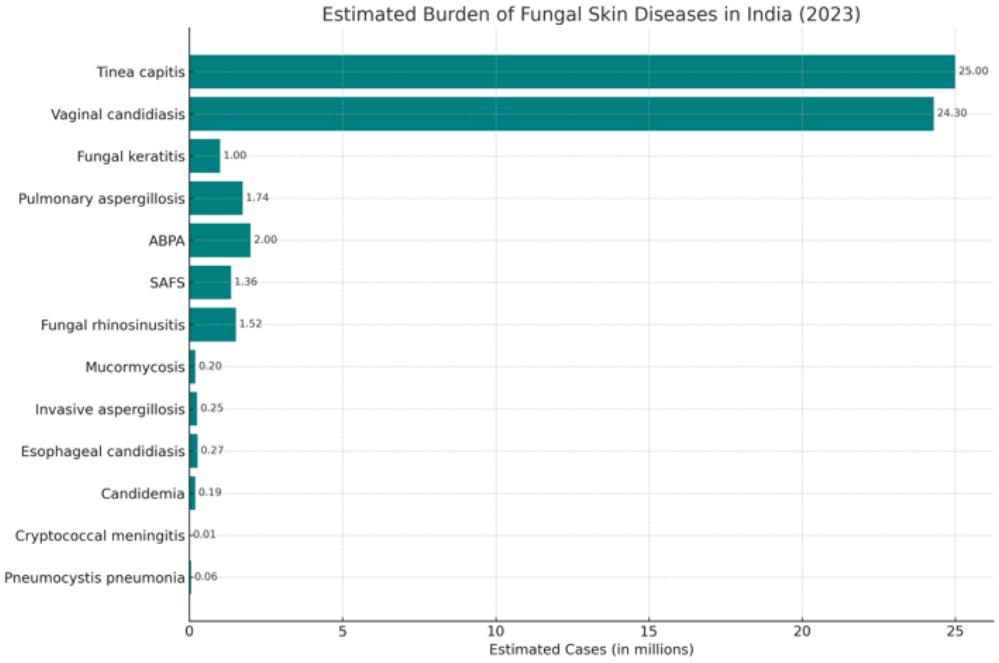

Figure 1: Estimated Burden of Fungal Skin Diseases in India (2023)

The "Estimated Burden of Fungal Skin Diseases in India (2023)" portrays the estimated burden (in millions) of some fungal infections prevailing in the population of India. Tinea capitis, also known as an ordinary scalp infection, is in the lead at 25 million cases, seconded by that of vaginal candidiasis, at 24.3 million cases, displaying their commonness. Other significant conditions encompass allergic bronchopulmonary aspergillosis (ABPA) at approximately 2 million cases, and pulmonary aspergillosis with 1.74 million cases. Less severe but clinically related infections like mucormycosis, invasive aspergillosis, esophageal candidiasis, and candidemia register relatively less incidences that vary between 0.19 to 0.27 million cases. Lifesaving, however rare infections such as pneumocystis pneumonia and cryptococcal meningitis are thought to occur with less people having their cases lower than 0.1 million. This information highlights the urgent need for enhanced awareness, diagnosis, and treatment approaches for fungal infections in India, particularly considering the burden of dermatological and systemic mycoses among various populations.

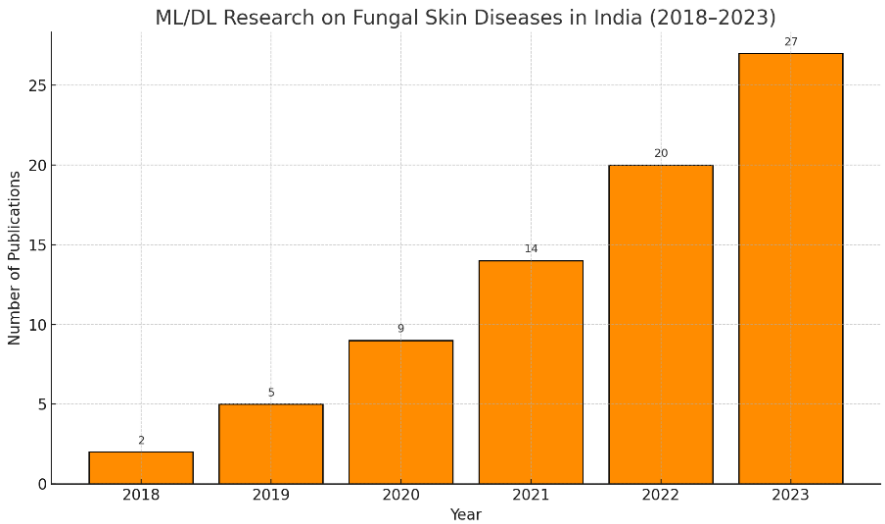

Figure 2: ML/DL Research on Fungal Skin Diseases in India (2018–2023)

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The bar chart "ML/DL Research on Fungal Skin Diseases in India (2018–2023)" displays a definite trend of increase in the volume of research papers making use of machine learning (ML) and deep learning (DL) methods for the analysis of fungal skin disease during a period of six years. In the year 2018, there was little action with just 2 publications. However, interest and study activity started growing steadily, at 5 studies in 2019 and coming close to double at 9 in 2020. The trend kept climbing into 2021 at 14 studies and surged again into 2022 and 2023 at 20 and 27 studies, respectively. This emerging trend mirrors the growing use of artificial intelligence in medical diagnosis, especially dermatology, where ML/DL methods are finding utility in early detection, classification, and treatment planning of fungal skin infections. The growth also highlights the greater acceptance and integration of AI technologies in Indian healthcare research.

V. CONCLUSION

This research brings to light the enormous public health burden caused by fungal skin infections in India, with millions being affected by conditions such as Tinea capitis and vaginal candidiasis, in addition to severe systemic infections like aspergillosis and mucormycosis. The study shows not only the commonality of these conditions but also a significant upward trend in the use of Machine Learning (ML) and Deep Learning (DL) methods for their diagnosis and classification between 2018 and 2023. This increasing volume of AI-based research indicates a promising trend toward technology-enabled healthcare solutions in dermatology. Still, while the mounting number of publications is a testament to progress, there is an urgent need for the incorporation of these tools within clinical practice, backed by full-fledged public health strategies, clinical validation, and awareness initiatives. In total, the report highlights the importance of an urgently needed multidisciplinary strategy of integrating epidemiological surveillance with emerging diagnostic technologies in order to curb and manage effectively the burden of fungal skin disorders in India.

Future research in machine learning and deep learning for the diagnosis of fungal skin disease needs to address a number of priority areas to improve accuracy, usability, and clinical applicability. A high priority is the creation of large, diverse, publicly available datasets reflecting different skin colours, types of infections, and demographic differences to enhance model generalizability. These future directions will play a key role in the real-world deployment and success of AI-based dermatological tools.

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