SS Journal of Interconnected Education and Life Sciences (SSJIELS)
ISSN: 3107-6351 | Vol. 02, Issue-02, May-August, 2026 | pp. 35-52

Early-Onset Alopecia in Gen Z And Gen Alpha: Pathologies, Biomarkers, Etiological Insights, AI-Enhanced Hair Restoration (FUE, FUT, Hair Patches), and Machine Learning–Driven Psychosocial Management in Youth

Yash Srivastav[1*], Stuti Verma[2], Kamini Prajapati[1], Sandeep Prakash[1], Rajeev Kumar[2], Anubha Dhuriya[2], Anup Kumar Sirbaiya[3]

[1] D.K.R.R Pharmacy College (Dev Kumari Rajaram Pharmacy Shikshan Sansthan), Amberpur, Sitapur (Uttar Pradesh), India. 261303
[2]Aryakul college of Pharmacy and Research, Sitapur Uttar Pradesh, India. 261303
[3]K.P. Singh Memorial Institute of Pharmacy, Sitapur, U.P, India.

***Corresponding Author E-mail: yashsrv.108@gmail.com**

Abstract

Early onset alopecia has gained momentum as a dermatologic issue amongst Generation Z and Generation Alpha owing to its rising incidence and considerable clinical as well as psychosocial ramifications. In this review, we will be summarizing the latest human clinical evidence available on the epidemiology, classification, etiology, biomarkers, AI-assisted hair restoration, and psychosocial management using machine learning of early onset alopecia. These studies indicate that genetic predisposition, hormonal imbalance, nutritional deficiency, autoimmune conditions, stress, environment, and behavior contribute significantly to this condition. Recent developments in biomarkers, artificial intelligence (AI), deep learning, and precision dermatology have helped with earlier detection and classification of this disease along with a better treatment plan. Human clinical evidence has also proved the efficacy of FUE, FUT, hair patches, PRP, LLLT, exosomes therapy, and combination therapies for hair restoration. In addition to these, various applications of machine learning technology, including digital counseling, chatbots, and individual prediction of mental health issues, have also been considered in the context of overcoming the psychological burden linked to the development of early-onset alopecia. While promising in terms of their potential, these technologies still face problems of standardization, long-term validation, and proper ethical application. To conclude, this review stresses the need for combining biomarkers, artificial intelligence, regenerative therapy, and psychosocial interventions to create a patient-tailored management strategy for early-onset alopecia.

Keywords: Early-onset Alopecia; Generation Z and Generation Alpha; Artificial Intelligence; Biomarkers; Hair Restoration; Machine Learning.

Received: May 18, 2026 **Revised: June 20, 2026** **Accepted: July 19, 2026** **Published: August 10, 2026**

DOI: https://doi.org/10.64474/3107-6351.Vol2.Issue2.3

https://ssjiels.nknpub.com/1/issue/archive

1. INTRODUCTION

Early Onset Alopecia has become a rising public health issue among generation Z (people who were born around 1997-2012) and generation alpha (those people who have been born since 2013), as more and more teenagers and young adults are experiencing early onset hair fall. It is a health problem that was earlier associated only with middle-aged and older individuals; however, it is now being recognized in younger individuals due to the collective effects of genetic susceptibility, hormonal imbalances, nutritional deficiencies, autoimmune problems, chronic stress, environmental toxins, poor health habits, and metabolic disturbances [1]. Hair fall at this age may have negative effects on self-esteem, body image, academic success, social interaction, and overall quality of life, making early diagnosis and effective management increasingly important.

Figure 1: Alopecia[2]

The current progress in dermatology, molecular biology, regenerative medicine, and digital health technologies has greatly contributed to the knowledge regarding the pathophysiologic mechanisms of early-onset alopecia. Biomarker studies have found a number of biomarkers which may be useful as diagnostic or prognostic markers, among which one may include serum ferritin, vitamin D, zinc, dihydrotestosterone (DHT), inflammatory cytokines, microRNA, and genetic polymorphism related to hair follicle biology[3]. At the same time, the quick development of artificial intelligence (AI), machine learning (ML), deep learning, computer vision, and digital trichoscopy technologies has greatly changed clinical practice through improving the ability to classify disease, analyze images of the scalp, predict treatments, and create individual treatment plans. Additionally, regenerative therapies such as Platelet-Rich Plasma (PRP), Low-Level Laser Therapy (LLLT), Follicular Unit Extraction (FUE), Follicular Unit Transplantation (FUT), hair patch technology, exosomes, and AI-based surgical planning are available now.

1.1 Background Information and Context

Early-onset alopecia is a cluster of various types of hair problems that manifest themselves in early hair loss in the period from childhood to early adulthood. The different types of hair disorders include androgenetic alopecia, alopecia areata, telogen effluvium, traction alopecia, scarring alopecia, and nutritional alopecia. In recent times, human-based research on the disorder has found several different risk factors that interact together to bring about the condition, such as heredity, hormonal imbalance, micronutrient deficiency, immunity problems, environmental exposure, stress, and poor lifestyle habits[4]. On the other hand, breakthroughs in artificial intelligence, molecular diagnostics, regenerative medicine, and digital health technologies present new possibilities for early detection, precision medicine, and management of the disorder. Early-onset alopecia now stands out as an area for interdisciplinary research.

1.2 Objectives of the Review

The main aims of this review include:

- To provide an overview of the current human-based literature on the epidemiology, pathophysiology, and classification of early-onset alopecia in Generation Z and Generation Alpha.
- To evaluate the etiology and new biomarkers of disease development, progression, and response to treatment.
- To investigate recent innovations in artificial intelligence, machine learning, deep learning, and precision dermatology for the diagnosis and treatment of early-onset alopecia.
- To evaluate the clinical efficacy of AI-assisted hair restoration therapies such as Follicular Unit Extraction (FUE), Follicular Unit Transplantation (FUT), hair patch therapy, PRP, LLLT, exosome therapy, and combined therapy based on human clinical studies.

1.3 Importance of the Topic

The significance of early-onset alopecia in healthcare practice has grown over time due to its increasing incidence, complex causes, and its adverse consequences for both the physical and psychological wellbeing of younger patients[5]. Premature hair loss influences not only the aesthetics of individuals, but their emotional wellbeing, academic achievements, and social interactions. The recent advances in biomarkers, artificial intelligence, regenerative medicine, and precision dermatology have made it possible to develop improved approaches to diagnosing and treating early-onset alopecia. Moreover, the application of machine learning in psychosocial assessment and digital healthcare has increased the number of tools that can be used in the process of managing alopecia, since it helps to take care not only of the clinical, but also of the mental aspects of this disorder. For all these reasons, a detailed review of current human-based evidence regarding early-onset alopecia is necessary[6].

1. EARLY-ONSET ALOPECIA IN GEN Z AND GEN ALPHA

Early-onset alopecia has now become a growing public health problem amongst Generation Z and Generation Alpha due to the increased incidences of the problem and its adverse physical, psychological, and social impacts on individuals suffering from it. New human-based clinical trials have shown that hair fall in adolescents and young people is not only due to genetic reasons like hereditary androgenic alopecia, but now there are many other causes including nutritional deficiency, hormonal imbalances, immune problems, psychological stresses, environmental pollution, unhealthy lifestyle, and metabolic problems[7]. The human-centred research conducted by dermatologists, trichologists, endocrinologists, psychologists, and adolescent participants stresses the significance of early diagnosis, biomarker analysis, personalization of treatment, and multidisciplinary treatment approaches for prevention of disease.

2.1 Epidemiology and Global Burden of Early-Onset Alopecia

In recent epidemiological studies, there has been an incremental rise in the prevalence of early onset alopecia among adolescents and young adults in both developed and developing nations[8]. Majority of the studies used cross-sectional survey methods, hospital-based observational studies, prospective cohort studies, and systematic review studies on children, adolescents, and young adults in order to ascertain the prevalence, age group, gender distribution, and risk factors of the disease. It has been proven from the results of these studies that androgenetic alopecia is more common among male adolescents, whereas telogen effluvium and diffuse alopecia are common among female adolescents. Moreover, human clinical trials have revealed that alopecia areata is one of the main reasons for hair loss among children, whereas androgenetic alopecia is increasingly common among late adolescents and young adults[9].

Strengths

- Includes all epidemiological data from different populations.
- Includes age- and gender-wise prevalence rates of early hair fall.
- Includes several risk factors that are either modifiable or non-modifiable.
- Includes early screening and preventive healthcare approaches.

Weaknesses

- Significant differences in criteria among studies.
- Lack of longitudinal research using pediatric subjects.
- Sample not representative of low-and middle-income countries.
- Design differences lead to incompatibility among studies.

2.2 Classification of Early-Onset Alopecia

Clinical investigations in humans distinguish early-onset alopecia into different classes depending on the presentation, pathogenesis, and follicle involvement. Almost all of them have employed physical examination, dermoscopy, trichoscopy, scalp biopsy, and histopathological analysis for distinguishing different types of alopecia[10]. The data obtained suggest that androgenetic alopecia is the most common type of genetically determined hair loss in adolescents, while alopecia areata is the main autoimmune alopecia in children and young adults. Telogen effluvium is often related to stress of any kind, whereas traction alopecia occurs in case of mechanical stress exerted on hair follicles. Nutritional alopecia is often caused by the deficiency of iron, zinc, vitamin D, and proteins; moreover, scarring alopecia is rather rare but results in permanent damage of follicles. It was also found recently that artificial intelligence-assisted trichoscopy allows improving diagnostic precision of differentially diagnosing clinically similar types of alopecia.

Figure 2: Early-Onset Androgenetic Alopecia[11]

Strengths

- Simplified clinical classification improves diagnostic uniformity.
- Multimodal imaging methods aid differential diagnosis.
- Allows for personalized treatment planning based on sub-type of disease.
- Enables integration of AI diagnostic technologies.

Weaknesses

- There is clinical overlap between multiple subtypes of alopecia.
- Histopathological diagnosis is not done for all patients.
- Lack of pediatric literature on rare cases of scarring alopecia.
- Classification using AI needs to be clinically validated.

2.3 Etiological Insights

According to recent research using human subjects, early onset alopecia is a multifactorial condition that arises as a consequence of the interaction between genetic susceptibility, endocrine dysfunction, nutritional imbalance, psychological factors, environment, lifestyle, gut microbiome and sleep problems[12]. The majority of the studies used cohort studies, case control study design, hormonal assessment, nutritional assessment, psychological assessment, and prospective observational studies among adolescents and young adults. All the results consistently show that a family history of androgenetic alopecia along with androgen sensitivity increase genetic susceptibility to this condition while high levels of dihydrotestosterone are responsible for hair follicle miniaturization. Nutritional deficiencies such as ferritin, vitamin D, zinc, and protein deficiency have been shown to be linked with diffuse hair loss while chronic stress, anxiety, depression, and academic pressures raise the levels of cortisol hormone causing increased hair loss. Environmental pollution, poor diet, gut dysbiosis and poor sleep quality might affect hair follicles[13].

Strengths

- Understands alopecia as a multifaceted and complicated disorder.
- Takes into consideration biological, psychological, nutritional, and environmental aspects.
- Contributes to multidisciplinary medical treatment approach.
- Identifies new mechanisms that involve gut-skin interaction and lifestyle.

Weaknesses

- Many of the studies identify correlation but not causation.
- Very different levels of exposure to environmental factors across studies.
- Human data on gut microbiota mechanisms is limited.
- Little long-term prospective research exists.

2.4 Biomarkers of Early-Onset Alopecia

With the advancement in medical sciences, biomarkers have played a vital role in making the diagnosis, prognosis, and treatment of early onset alopecia easy and effective. Various clinical studies on humans have been done focusing on the serum ferritin, vitamin D, zinc, dihydrotestosterone (DHT), testosterone, cortisol, C-reactive protein (CRP), interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), microRNAs, and various other genetic biomarkers related to the hair follicles[14]. All these studies were based on case-control studies, clinical study, biochemical analysis laboratory experiments, hormonal assay, cytokine profile, and genetic sequence using adolescents and young people suffering from different types of alopecia. It has always been observed that low serum ferritin level, vitamin D deficiency, and zinc deficiency are commonly found in people suffering from diffuse alopecia, while increased DHT levels are strongly related to androgenetic alopecia. Increase in the inflammatory cytokine and stress-related biomarkers is associated with alopecia areata and telogen effluvium. MicroRNAs and genetic polymorphisms have been suggested by recent molecular studies as possible biomarkers[15].

Strengths

- Provides objective laboratory indicators for disease diagnosis.
- Supports individualized treatment through biomarker-guided management.
- Facilitates monitoring of therapeutic response.
- Emerging molecular biomarkers offer potential for precision dermatology.

Weaknesses

- Lack of standardized biomarker reference values.
- Laboratory methodologies differ among studies.
- Limited validation of novel genetic and microRNA biomarkers.
- High costs restrict routine molecular testing in clinical practice.

2.5 Human-Based Clinical Evidence of Early-Onset Alopecia

The present literature on early onset of alopecia mainly consists of clinical trials conducted on humans, cohort studies, case-control studies, cross-sectional studies, prospective observational studies, systematic reviews, and meta-analyses[16]. The studies undertaken have assessed the disease's epidemiology, clinical features, biomarkers, diagnostics, drug treatments, hair restoration methods, and psychosocial aspects in children, adolescents, and young adults. It has been observed that early detection and treatment result in hair growth, delay in disease progression, and improve their quality of life. The existing literature proves the efficacy of topical minoxidil, platelet-rich plasma (PRP), low level laser treatment, dietary supplements, and selected hair transplantation in appropriate patients. Studies have shown encouraging results in recent times on the use of artificial intelligence-based diagnoses, digital trichoscopy, and machine learning-based algorithms for better diagnoses and treatment of the condition. However, the researchers recommend conducting large multicenter studies including younger individuals to create standard diagnostic and treatment protocols[17].

Strengths

- Sound evidence based on studies conducted solely on humans.
- Contains various types of studies that are relevant clinically.
- Evidence-based diagnostic and treatment methods.
- Artificial intelligence used increasingly in dermatology.

Weaknesses

- Few randomized controlled trials conducted on children.
- Short duration of follow up in many studies.
- Different approaches used for treatment and outcomes.
- Need for more multinational and multicenter human studies.

2. AI-ENHANCED HAIR RESTORATION

The application of artificial intelligence (AI) technology in hair restoration has transformed the way in which the early-onset alopecia is diagnosed, planned for treatment, operated on surgically, and managed long-term[18]. Recent human-based clinical research suggests that there has been an advancement in the AI technology, from the basic AI technology for image processing to an intelligent clinical decision-making system using trichoscopy, machine learning, digital biomarker and personalized treatments. Human-based research conducted by dermatologists, hair transplantation surgeons, trichologists, biomedical engineers, and patients has shown that AI-assisted technology improves diagnostics, treatment choice, surgical procedures, and patient satisfaction. The following thematic sections highlight the major AI-based hair restoration technologies discussed in recent human clinical literature[19].

3.1 Artificial Intelligence in Diagnosis

Artificial intelligence has become a useful method for the early diagnosis of alopecia due to its ability to enhance the precision, reliability, and speed of the process. In recent times, artificial intelligence technology including CNN, deep learning technology, imaging analysis, AI-supported trichoscopy, and computer vision has been utilized in human clinical research to study scalp photos and dermoscopic images in order to diagnose various types of alopecia[20]. The majority of research has made use of retrospective clinical image data sets, prospective observational study, and diagnostic validation studies on patients suffering from androgenic alopecia, alopecia areata, telogen effluvium, and traction alopecia.

3.2 AI-based Hair Density Prediction

AI technologies have contributed to the prediction of hair density, follicular viability, and therapy outcomes by the means of quantification of images and clinical features of patients' scalps[21]. Clinical research involving humans has employed machine learning, digital trichoscopy, phototrichogram analysis, and three-dimensional images of scalps for the purposes of hair density, donor site capacity, disease prognosis, and therapy outcome prediction. The results show that AI-enabled predictive models help physicians make decisions in terms of medical or surgical treatment.

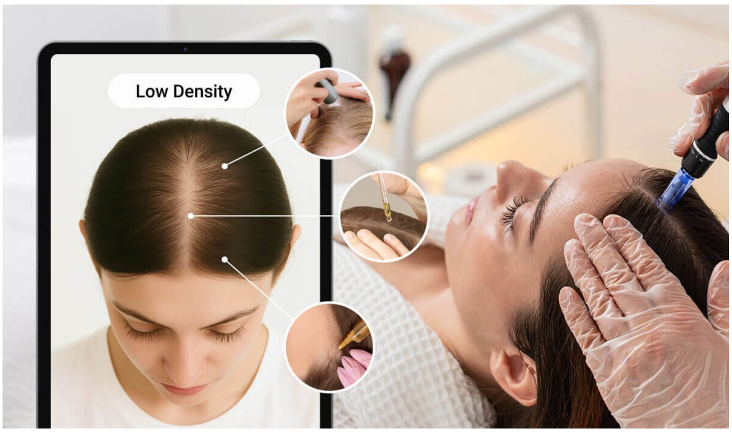

Figure 3: Hair Density Test Analysis[22]

3.3 FUE

Follicular Unit Extraction (FUE) is one of the most frequently conducted minimally invasive surgical interventions for hair restoration in patients who have early-onset androgenetic alopecia. Clinical human studies, which include prospective, comparative research, and patient satisfaction surveys, reveal that FUE gives natural cosmetic results by means of transplanting single follicular units from donor to recipient areas[23]. The latest advancements in technology involve the use of AI-assisted donor mapping, digital graft selection, and computer-aided surgery planning. The majority of patients who undergo FUE show improvements in hair density, cosmetic appearance, self-esteem, and overall quality of life.

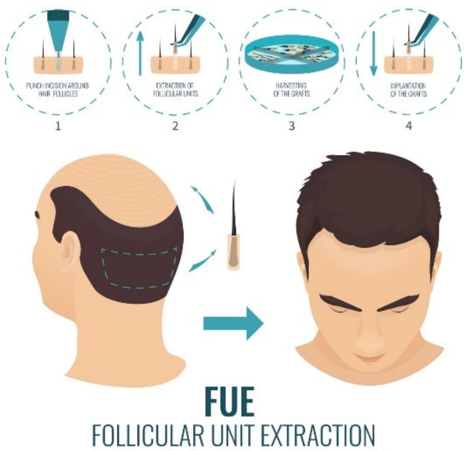

Figure 4: Follicular Unit Extraction (FUE)[24]

3.4 FUT

Follicular Unit Transplantation (FUT) is still an efficacious surgical method for individuals who need transplanting a large number of follicular grafts. Studies in human clinics on the comparison between FUT and FUE have revealed that FUT offers more graft yield and long-term hair density, although it comes with a linear donor scar and prolonged recovery period. Recent technological innovations in digital image processing and AI-based surgical planning have enhanced the designs of donor strip and recipient site planning.

Figure 5: Follicular Unit Transplantation (FUT)[25]

3.5 Hair Patch Technology

The use of hair patches offers a way out to those suffering from severe hair loss through non-invasive means. This is for those patients not considered fit for hair transplant surgeries. Human observations and patient satisfaction reports show that customized hair pieces greatly increase one's self-confidence and physical appearance. There have been breakthroughs in customizing scalp prosthesis using modern biomaterials.

3.6 PRP

Platelet Rich Plasma Therapy (PRP therapy) has emerged as one of the most studied regenerative therapies in early onset alopecia. Evidence from randomized controlled trials in humans, cohort studies and systematic reviews proves that PRP triggers hair follicle regeneration by virtue of growth factor production which promotes angiogenesis, cellular proliferation and follicular activity. There is consistent evidence regarding improvement in hair density, hair thickness, follicular count and patient satisfaction[26].

3.7 Low-Level Laser Therapy

The Low-Level Laser Therapy (LLLT) technique is among the promising non-invasive methods used to activate hair follicles by using photo biomodulation. The human trials have shown that there is improved hair density, hair thickness, and scalp coverage after treatment. The literature reviews suggest using LLLT in conjunction with medications or PRP for best results.

3.8 Exosome Therapy

Exosomes are a form of treatment that holds promise for regenerative purposes by utilizing extracellular vesicles isolated from stem cells to facilitate hair regeneration and tissue repair. Some promising results have been obtained in early clinical trials on humans; however, research is not as extensive as in other regenerative treatments.

3.9 Combination Therapy

The concept of combination treatment has emerged as a critical tool for achieving the best possible results in alopecia of early onset. Clinical studies on humans indicate that combination treatments like PRP+FUE, Microneedling + Minoxidil, and artificial intelligence (AI)-assisted treatment planning result in significantly better outcomes in terms of hair density, follicular survival, cosmetic effect, and patient satisfaction compared to individual therapies[27]. The use of AI is crucial in offering an individualized choice of therapy based on clinical data and previous experience.

3. RECENT DEVELOPMENTS

Current advancements made in the field of early alopecia management are a result of incorporating artificial intelligence (AI), deep learning, and precision dermatology, contributing to improved diagnosis, prognosis, and treatment. The studies conducted by humans revealed that the use of AI-based algorithms and deep learning models could successfully analyze the images of scalps, trichoscopy results, and data pertaining to patients for identifying the early signs of alopecia, disease sub-types, and predicting the treatment results[28]. The field of precision dermatology has contributed further to personalizing the treatment of patients by incorporating genetics, hormone levels, and lifestyle of patients in treatment decisions.

Other notable advancements include the use of nanotechnology and the multi-omics approach in investigating the molecular processes involved in early onset alopecia and improving efficacy of treatment. Studies involving human subjects have revealed that nanoparticle drug delivery system increases the bioavailability and effectiveness of drugs like minoxidil and other regenerative molecules by delivering them to the target sites without any harmful effect on the body as a whole. At the same time, other omics tools like genomics, transcriptomics, proteomics, metabolomics, and microbiomics have helped in unraveling the molecular processes behind hair follicle physiology[29].

Table 1: Summary of Selected Human-Based Studies on Early-Onset Alopecia and Associated Risk Factors[30]

Author(s) & Year	Study Focus	Methodology/Model	Key Findings
Zheng et al. (2016)[31]	Immunological mechanisms underlying	Narrative review of autoimmune skin diseases and	Autoimmune dysregulation and T-cell-mediated immune

	autoimmune dermatoses, including alopecia areata	immunodermatological mechanisms	responses were identified as major contributors to hair follicle destruction in alopecia areata. The study emphasized that understanding immunopathogenesis improved diagnostic accuracy and supported the development of targeted immunotherapeutic approaches for autoimmune-related hair loss.
Ibáñez et al. (2017)[32]	Pathophysiology, diagnosis, and management of polycystic ovarian syndrome (PCOS) in adolescents	International expert consortium review based on clinical and endocrine evidence	Hyperandrogenism was found to be strongly associated with androgenetic alopecia and other dermatological manifestations. Early diagnosis and multidisciplinary management of PCOS were considered essential for preventing long-term endocrine and dermatological complications in adolescents.
Zhang, Li, & Yao (2017)[33]	Genetic basis of reticulate pigmentary disorders and hereditary dermatological conditions	Comprehensive review of molecular genetics and hereditary dermatological disorders	Genetic susceptibility and mutations affecting skin and hair biology played a crucial role in inherited dermatological disorders. Advances in genomic research improved

			understanding of disease mechanisms and supported the identification of potential genetic biomarkers for precision dermatology.
Demir et al. (2016)[34]	Hyperandrogenism-related skin diseases among obese and overweight patients	Clinical observational study examining obesity, endocrine dysfunction, and dermatological disorders	Elevated androgen levels associated with obesity contributed significantly to androgenetic alopecia and other skin disorders. The study highlighted the importance of endocrine evaluation and weight management in preventing and managing hyperandrogenism-related hair loss.
Rajendrasingh (2017)[35]	Nutritional correction for hair loss, hair thinning, and hair regrowth	Evidence-based clinical review on nutritional management of hair disorders	Deficiencies in proteins, iron, zinc, vitamins, and amino acids adversely affected hair follicle function and hair growth. Individualized nutritional supplementation and dietary modification were reported to improve hair quality, reduce hair shedding, and promote follicular regeneration.

Moreover, recent developments in robotics and intelligent approaches in hair transplantation have revolutionized the field of hair restoration treatments through improvements in graft harvesting, implantation accuracy, follicular survival rates, and aesthetic effects. Robotic systems that incorporate AI allow for very accurate donor area evaluation, automated follicular unit extraction, optimized graft implantation, and surgical navigation, hence decreasing the effect of human factor and increasing effectiveness of the procedure[36]. Wearable devices and other digital health solutions can also be used for remote monitoring of patients and compliance assessment through the continuous acquisition of physiological and behavioral data. Taken together, these technological developments constitute a paradigm change in the management of early-onset alopecia through precision and minimally invasive interventions.

4. DISCUSSION

The analysis will discuss and critically interpret the results that have been identified in the literature review and will analyze their significance in the light of early onset alopecia in Generation Z and Generation Alpha. The analysis will also address the implications of such research, gaps in existing literature, present challenges, and future directions[37].

5.1 Interpretation and Analysis of Findings

In general, based on the findings of this review, it is possible to assume that early-onset alopecia is one of the most significant dermatological conditions among Generation Z and Generation Alpha patients because of its multicausal nature and increased psychosocial importance. According to the literature sources, the research conducted by humans proves that the predisposition to this disease is caused by several aspects such as genetics, hormonal imbalance, lack of nutrition, autoimmune disease, constant stress, environment, and unhealthy behavior of people[38]. In addition, it can be assumed that thanks to the new methods and technologies, including biomarkers, artificial intelligence (AI), machine learning, precision dermatology, and regenerative medicine, early-onset alopecia can be detected, classified, diagnosed, treated, and managed more effectively.

5.2 Practical Significance and Current Challenges

The current literature has revealed the rising clinical significance of AI-enabled diagnosis, biomarker-supported evaluation, regenerative treatment, and innovative methods of hair restoration that contribute to the effectiveness of the treatment of early onset alopecia. FUE, FUT, PRP therapy, LLLT, and AI-enabled treatment plan have shown promising results regarding improvement of hair density and its cosmetic appearance[39]. Machine learning has been useful in the early identification of depression, anxiety, and low quality of life in patients with the disease. Nevertheless, there are still some issues which should be discussed, such as high cost of the treatment, lack of accessibility to advanced technologies, variability of the treatment approaches, absence of biomarkers' standardization, the question of ethics in artificial intelligence use, and lack of multicenter human clinical trials.

5.3 Research Gaps and Future Directions

However, despite the achieved advances, there is still much room left for improvement in the currently available human-based literature in the field of early-onset alopecia. Most of the research in question is characterized by small sample sizes, limited follow-ups, and heterogeneity of methodology. The use of new techniques including exosome therapy, digital biomarkers, wearable devices, explainable artificial intelligence, multi-omics, and robotic hair transplantation warrants validation via multicenter clinical trials[40]. Future investigations need to concentrate on the development of uniform diagnostic criteria, combination of artificial intelligence and precision dermatology, assessment of the long-term psychosocial consequences, and cooperation between specialists in dermatology, psychology, genetics, and big data analysis.

5. CONCLUSION

This review shows that early-onset alopecia has become one of the most prominent dermatological and psychosocial health issues faced by Generation Z and Generation Alpha due to the interaction of various genetic, hormonal, nutritional, autoimmune, environmental, and lifestyle factors. It is evident from the human-based clinical literature that recent discoveries in biomarkers, artificial intelligence, machine learning, precision dermatology, and regenerative medicine have allowed to make a great leap forward in early diagnosis, classification, personalization of treatment and hair restoration. AI-assisted treatment modalities such as Follicular Unit Extraction (FUE), Follicular Unit Transplantation (FUT), hair patching, Platelet-Rich Plasma (PRP), Low-Level Laser Therapy (LLLT), exosomes, and combinations of different types of therapy have been successfully implemented to improve hair growth and cosmetic effects as well as increase patient satisfaction. Additionally, the use of machine learning has helped to implement the psychosocial management of alopecia allowing early recognition of depression, anxiety, decreased self-esteem, and reduced quality of life. However, it is necessary to conduct further large-scale human-based clinical trials to validate biomarkers and AI technologies and develop guidelines for the treatment of alopecia.

REFERENCES

1. Sharara, M. A., Elfeki, E. M., & Khafagy, N. H. (2025). Assessment of androgenic hormones and other risk factors in Egyptian males with early onset androgenetic alopecia: a case control study. *Archives of Dermatological Research*, *317*(1), 552.
2. Liu, L. P., Wariboko, M. A., Hu, X., Wang, Z. H., Wu, Q., & Li, Y. M. (2024). Factors associated with early-onset androgenetic alopecia: A scoping review. *PLoS One*, *19*(3), e0299212.
3. Oiwoh, S. O., Enitan, A. O., Adegbosin, O. T., Akinboro, A. O., & Onayemi, E. O. (2024). Androgenetic alopecia: a review. *Nigerian Postgraduate Medical Journal*, *31*(2), 85-92.
4. Elhabak, D. M., & Halim, W. A. A. (2020). YKL-40 a sensitive biomarker for early androgenetic alopecia and early hidden metabolic syndrome. *International journal of trichology*, *12*(2), 49-55.

5. Liu, Y., Tosti, A., Wang, E. C., Heilmann-Heimbach, S., Aguh, C., Jimenez, F., ... & Plikus, M. V. (2025). Androgenetic alopecia. *Nature Reviews Disease Primers*, *11*(1), 73.
6. Anastassakis, K. (2022). Hormonal and genetic etiology of male androgenetic alopecia. In *Androgenetic Alopecia From A to Z: Vol. 1 Basic Science, Diagnosis, Etiology, and Related Disorders* (pp. 135-180). Cham: Springer International Publishing.
7. Krysiak, R., Basiak, M., & Okopień, B. (2021). Impact of lisinopril on cardiometabolic risk factors in men with hypertension and early-onset androgenetic alopecia: a pilot study. *Journal of cardiovascular pharmacology*, *78*(5), e738-e742.
8. Zhang, T. (2026). The solar window hypothesis: androgenetic alopecia as an evolutionary adaptation to maintain bone mineral density in vitamin D receptor low-efficiency variants. *Medical Hypotheses*, 112005.
9. Minokawa, Y., Sawada, Y., & Nakamura, M. (2022). Lifestyle factors involved in the pathogenesis of alopecia areata. *International Journal of Molecular Sciences*, *23*(3), 1038.
10. Iska, N., Nwozo, E., Hassan, H., Peddireddy, N., Sataray-Rodriguez, A., & Frasier, K. (2026). Pathophysiology of Androgenetic Alopecia and Implications for Treatment: An Overview of Current Literature. *Journal of Biosciences and Medicines*, *14*(3), 566-584.
11. Mohan, S. (2019). *An Observational Study to Establish an Association Between Early Onset Androgenetic Alopecia and Prostatic Abnormalities* (Doctoral dissertation, Rajiv Gandhi University of Health Sciences (India)).
12. Chih-Yi, H., Chen, J. Y. F., Wen-Li, H., Yu, S., Wei-Chiao, C., Chiu, S. H., ... & Ching-Ying, W. (2023). Female pattern hair loss: an overview with focus on the genetics. *Genes*, *14*(7), 1326.
13. Kerure, A. S., Deshmukh, N., Agrawal, S., & Patwardhan, N. G. (2021). Follicular unit extraction [FUE]–one procedure, many uses. *Indian dermatology online journal*, *12*(3), 381-388.
14. Sharma, R., & Ranjan, A. (2019). Follicular unit extraction (FUE) hair transplant: curves ahead. *Journal of maxillofacial and oral surgery*, *18*(4), 509-517.
15. Azar, R. P. (2018). *FUE hair transplantation: a minimally invasive approach*. Springer.
16. Bhatti, A., & Bhatti, T. (2025). Hair Transplant Surgery: Going Forward. In *Manual of Cosmetic Medicine and Surgery: Volume 3-Non-invasive Procedures* (pp. 677-694). Singapore: Springer Nature Singapore.
17. Konstantinos, A. (2024). Hair Transplantation—From the "Ancient" 4 mm Plugs to the Latest Follicular Unit Excision Technique: 8 Decades of Painful Progress. In *Hair Loss: Advances and Treatments* (pp. 25-52). Cham: Springer Nature Switzerland.
18. Chen, A. H., Heil, B. V., & O'Brien, M. (2026). Automated Follicular Unit Extraction. In *Aesthetic Surgery for Men: A Comprehensive Clinical Guide* (pp. 453-468). Cham: Springer Nature Switzerland.

19. Park, J. H. (2024). Evolution of Hair Transplantation. In *Landmark Papers in Plastic Surgery: Commented Guide by Authors and Experts* (pp. 387-395). Cham: Springer International Publishing.
20. Barrera, A. (2026). Follicular Unit Transplantation (FUT): Hair Restoration. In *Aesthetic Surgery for Men: A Comprehensive Clinical Guide* (pp. 417-430). Cham: Springer Nature Switzerland.
21. Xu, L., Liu, K. X., & Senna, M. M. (2017). A practical approach to the diagnosis and management of hair loss in children and adolescents. *Frontiers in medicine*, *4*, 112.
22. Heilmann-Heimbach, S., Herold, C., Hochfeld, L. M., Hillmer, A. M., Nyholt, D. R., Hecker, J., ... & Nöthen, M. M. (2017). Meta-analysis identifies novel risk loci and yields systematic insights into the biology of male-pattern baldness. *Nature communications*, *8*(1), 14694.
23. Patel, B., Velasco, M. A., Gutierrez, F. T., & Khesin, D. (2017). Addressing androgenetic Alopecia-A complex disorder-with a multilateral treatment strategy. *MOJ Bioequiv Availab*, *3*(1), 00025.
24. Desai, P. B. (2017). *One Year Cross Sectional Study of Association Between Androgenetic Alopecia and Benign Prostatic Hyperplasia in Male Patients visiting KLES Dr. Prabhakar Kore Hospital and MRC, Belgaum* (Doctoral dissertation, KLE Academy of Higher Education & Research, Belagavi).
25. Rota, I. A., & Dhalla, F. (2017). FOXN1 deficient nude severe combined immunodeficiency. *Orphanet journal of rare diseases*, *12*(1), 6.
26. Tseng, M. H., Huang, S. M., Lo, F. S., Huang, J. L., Cheng, C. J., Lee, H. J., & Lin, S. H. (2017). Functional analysis of VDR gene mutation R343H in a child with vitamin D-resistant rickets with alopecia. *Scientific reports*, *7*(1), 15337.
27. Hema, S. (2017). *Comparative Study of Mesotherapy with Platelet Rich Plasma Versus Mesotherapy with 5% Minoxidil in Treatment of Androgenetic Alopecia in Males* (Doctoral dissertation, Rajiv Gandhi University of Health Sciences (India)).
28. Chaiyana, W., Punyoyai, C., Somwongin, S., Leelapornpisid, P., Ingkaninan, K., Waranuch, N., ... & Mueller, M. (2017). Inhibition of 5α-reductase, IL-6 secretion, and oxidation process of Equisetum debile Roxb. ex vaucher extract as functional food and nutraceuticals ingredients. *Nutrients*, *9*(10), 1105.
29. Volpi, S., Picco, P., Caorsi, R., Candotti, F., & Gattorno, M. (2016). Type I interferonopathies in pediatric rheumatology. *Pediatric Rheumatology*, *14*(1), 35.
30. Majersik, J. J. (2017). Inherited and uncommon causes of stroke. *CONTINUUM: Lifelong Learning in Neurology*, *23*(1, Cerebrovascular Disease), 211-237.
31. Zheng, J., Pan, M., Gianfaldoni, S., D'Erme, A. M., Lotti, T., Zhang, X., ... & Lewis, F. (2016). Autoimmune Dermatoses. In *Practical Immunodermatology* (pp. 297-340). Dordrecht: Springer Netherlands.
32. Ibáñez, L., Oberfield, S. E., Witchel, S., Auchus, R. J., Chang, R. J., Codner, E., ... & Lee, P. A. (2017). An international consortium update: pathophysiology, diagnosis, and

treatment of polycystic ovarian syndrome in adolescence. *Hormone research in paediatrics*, *88*(6), 371-395.

33. Zhang, J., Li, M., & Yao, Z. (2017). Updated review of genetic reticulate pigmentary disorders. *British journal of dermatology*, *177*(4), 945-959.
34. DEMİR, B., ÇİÇEK, D., NAZİK, H., & ÖNAL, O. (2016). Obez ve Aşırı Kilolu Hastalarda Hiperandrojenizmle İlişkili Deri Hastalıkları. *Türkiye Klinikleri Kozmetik Dermatoloji Özel Dergisi*, *9*(2).\
35. Rajendrasingh, R. R. (2017). Nutritional correction for hair loss, thinning of hair, and achieving new hair regrowth. In *Practical Aspects of Hair Transplantation in Asians* (pp. 667-685). Tokyo: Springer Japan.
36. Velez, A. M. A., & Howard, M. S. (2015). Tumor-suppressor genes, cell cycle regulatory checkpoints, and the skin. *North American Journal of Medical Sciences*, *7*(5), 176.
37. Wojtyna, E., Łakuta, P., Marcinkiewicz, K., Bergler-Czop, B., & Brzezińska-Wcisło, L. (2017). Gender, body image and social support: Biopsychosocial determinants of depression among patients with psoriasis. *Acta dermato-venereologica*, *97*(1), 91-97.
38. Bhattacharyya, A., Jain, N., Prasad, S., Jain, S., Yadav, V., Ghosh, S., & Sengupta, S. (2017). Evaluation of therapeutic potential of VB-001, a leave-on formulation, for the treatment of moderate adherent dandruff. *BMC dermatology*, *17*(1), 5.
39. Krapf, J. M., & Goldstein, A. T. (2017). Vulvar lichen sclerosus. In *The Vulva* (pp. 169-178). CRC Press.
40. Scherrer, M. A. R., Rocha, V. B., & Garcia, L. C. (2017). Behcet's disease: review with emphasis on dermatological aspects. *Anais brasileiros de dermatologia*, *92*(4), 452-464.