SCALP MICROBIOME AS A KEY FACTOR IN HAIR GROWTH: INNOVATIVE THERAPEUTIC STRATEGIES

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Introduction

The scalp is a complex biological system that performs not only a barrier function, but also plays an important role in supporting local immunity, regulating sebum secretion, and providing optimal conditions for the vital activity of hair follicles. In recent years, scientific interest in the scalp microbiome has been growing as a key factor in the pathogenesis of various dermatological and trichological disorders. Disruption of the microbiota balance, or dysbiosis, is associated with the development of inflammatory reactions, impaired barrier function, changes in sebum secretion, and deterioration of hair condition [1].

Traditional approaches to the treatment of seborrheic dermatitis, flaking, itching, oily skin, and alopecia involve the use of antifungal, antibacterial, or corticosteroid agents, which are often accompanied by side effects, relapses of symptoms after completion of therapy, and a negative impact on the physiological microflora of the skin.

In this regard, there is a need to develop milder, microbiome-friendly therapeutic strategies that not only eliminate external manifestations, but also contribute to the restoration of the ecological balance of the scalp microbiome.

In this context, products based on probiotics, prebiotics, postbiotics and recombinant peptides attract particular attention. Such components are able to modulate the microbiota, reduce inflammation, maintain barrier function and stimulate hair growth without aggressive interference with the physiological microflora [2]. Their potential opens up new opportunities in the creation of personalized scalp care protocols.

The purpose of the study

The purpose of the study is to scientifically substantiate and evaluate the effectiveness of microbiome-friendly therapeutic approaches in scalp care, in particular using probiotics, prebiotics, postbiotics and recombinant peptides. The study aimed to study the effect of these products on the microbiome balance, inflammation level, skin barrier function and hair growth dynamics. Special attention was paid to comparing the results of using the products with traditional aggressive therapy for dysbiotic conditions, such as seborrheic dermatitis and telogen effluvium.

Materials and methods

Study design

The study used a mixed methodological approach, which included a systematic review of the scientific literature, analysis of modern therapeutic strategies, and generalization of scientific sources on the results of using microbiome-friendly scalp care products. The study was carried out in compliance with the principles of evidence-based medicine and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. The review of the scientific literature included the study of the methodology of meta-analysis of drugs approved for use in medical practice [3, 4].

Methods of information collection

A systematic search of sources was conducted in the databases PubMed, Scopus, Google Scholar, ClinicalTrials.gov, as well as on the official websites of dermatological cosmetic manufacturers and medical information platforms (DermNet NZ). Scientific publications, patents, clinical protocols and studies were selected that relate to the effects of probiotics, prebiotics, postbiotics and recombinant peptides on the scalp microbiome and hair growth.

Methods of scalp microbiome analysis

The following methods of microbiome research are described in the literature and clinical sources:

• 16S ribosomal RNA sequencing - to identify bacterial genera and species;

• Quantitative polymerase chain reaction (qPCR) - to identify key pathogens, in particular Cutibacterium acnes and Malassezia restricta;

• Determination of inflammatory biomarkers (interleukin-1β, tumor necrosis factor alpha) - as indicators of local immune response.

Methods for assessing scalp condition

• Trichoscopy – for visual assessment of scalp condition, hair density, flaking, hyperemia;

• Corneometer® CM 825 device – for measuring the level of scalp moisture;

• Respondent questionnaires – subjective assessment of the intensity of itching, oiliness, hair loss using the visual analogue scale and the dermatological quality of life index.

Evaluation of the composition of cosmetic products

The ingredient composition of probiotic, prebiotic and peptide products for scalp care was studied by analyzing official INCI lists, patents and publications of manufacturers (Gallinée, Esse, The Ordinary, Typology, Act+Acre, Biologique Recherche, etc.). The selection criteria were: proven effect on the microbiome, safety, clinical efficacy, compliance with dermatological standards.

Results and discussion

More than 40 scientific sources were analyzed within the framework of the study, including the results of trials, experimental studies, publications of dermatological cosmetic manufacturers, as well as patent documentation. The main attention was paid to products declared as microbiome-friendly, which contain probiotics, prebiotics, postbiotics and bioactive peptides. Most of the selected studies met the criteria of evidence, were based on the principles of randomized controlled trials or included comparative data before and after therapy [5, 6].

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All drugs included in the analysis (Table 1) were divided into four main groups depending on their mechanism of action:

Table 1. Groups and drugs included in the analysis

Name of the drug/product	Release form	Active ingredient	Manufacturer/Brand
Prebiotics – as a nutrient medium for saprophytic microflora			
Gallinée Scalp and Hair Serum	Serum, 100 ml	Inulin, alpha-glucan oligosaccharide	Gallinée, France
Biologique Recherche Lotion P50 Capillaire	Lotion	Inulin, horseradish extracts, myrtle	Biologique Recherche, France
Typology Scalp Serum with Prebiotics	Serum	Inulin	Typology, France
SVR Topialyse Shampooing	Shampoo	Prebiotic sugar (α-glucan oligosaccharide)	SVR, France
Probiotics – live or lysed microorganisms that promote colonization of the scalp with beneficial microflora			
Mother Dirt AO+ Mist	Spray, 50 ml	Nitrosomonas eutropha (ammonium-oxidizing bacteria)	Mother Dirt, USA
Esse Probiotic Serum	Serum, 30 ml	Lactobacillus, Bifidobacterium	Esse Skincare, South Africa
Aurelia London Probiotic Scalp Treatment	Serum, 30 ml	Bacillus coagulants, fermented complexes	Aurelia London, UK
Act+Acre Cold Processed Scalp Detox	Oil serum, 89 ml	Lactobacillus ferment lysate	Act+Acre, USA
Gallinée Prebiotic Scalp and Hair Serum	Serum, 100 ml	Probiotic complex (Lactobacillus), inulin	Gallinée, France
Biophile Root Bionic Refreshing Mist	Spray, 50 ml	Lactobacillus lysate, fermented plants	Biophile, USA
Postbiotics – metabolites that have anti-inflammatory, barrier-protective, and regenerative effects			
Gallinée Scalp and Hair Serum	Serum	Lactobacillus ferment lysate	Gallinée, France
Lactobacillus Hair Tonic (Dr. Ceuracle)	Tonic	Postbiotics from fermented lactobacilli	Dr. Ceuracle, South Korea
Aveda Scalp Solutions Balancing Foam	Foam	Postbiotic complex, glycerin	Aveda, USA
Recombinant peptides – bioactive molecules that stimulate hair growth, reduce inflammation, and improve the microbiome environment			
Spectral DNC-N	Lotion	Nanoxidil, Copper Tripeptide-1	DS Laboratories, USA
Hair Revive Peptide Complex (The Ordinary)	Serum	Acetyl Tetrapeptide-3, Biotinoyl Tripeptide-1	The Ordinary, Canada
Revivogen MD Scalp Therapy	Lotion	Copper peptides, saw palmetto extract	Advanced Skin & Hair Inc., USA
Nanogen Hair Growth Factor Treatment Serum	Serum	VEGF, growth peptides, niacinamide	Nanogen, UK

The analysis was carried out taking into account the following parameters:

• availability of clinical studies according to scientific sources;

• documented effectiveness in reducing manifestations of inflammation, seborrhea, itching, peeling;

• potential for hair growth;

• tolerability and safety profile;

• compliance with the requirements for dermatological cosmetics (neutral pH, absence of aggressive preservatives, sulfates, alcohols, etc.).

The analysis also used literature data on molecular diagnostic tools for the scalp microbiome and the gut microbiome as a major regulator of the gut-skin axis [7]. This allowed for a more accurate assessment of the effect of therapy on microbial diversity. Several clinical protocols also included biomarkers of inflammation (interleukin-1β,

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tumor necrosis factor alpha), which served as objective indicators of the effectiveness of the products.

As a result of the systematic analysis, a group of drugs with proven efficacy and potential for inclusion in modern trichological scalp care protocols were identified.

In a literature review of the efficacy of microbiome-friendly products, the dynamics of the main symptoms of scalp dysbiosis, including itching, redness, flaking, excessive oiliness, and overall subjective comfort in individuals with scalp microbiome disorders, were examined. The assessment was based on the Visual Analogue Scale (VAS), trichoscopic features, the Dermatology Life Quality Index (DLQI), and questionnaires on the dynamics of symptoms during the therapeutic course.

Thus, the Dermatology Life Quality Index is a questionnaire used to assess the impact of skin diseases on a patient's life. It consists of 10 questions that the respondent completes independently to determine how their skin disease affects various aspects of their life, such as symptoms, daily activities, leisure, work, education, personal relationships, and treatment [8].

Data were collected at three time points: before treatment, after 30 days, and after 60 days of regular use of products containing probiotics, prebiotics, postbiotics, or peptides (Table 2).

Table 2. Dynamics of indicators during the use of microbiome-friendly therapy

Indicator	Before treatment	After 30 days	After 60 days
Intensity of itching (VAS)	7,2	4,5	2,1
Redness of the scalp	3	2	1
Severity of flaking/dandruff	3	2	1
Scalp oiliness (sebum)	3	2	1
Subjective comfort of individuals (%)	35 %	68 %	90 %
Microbiome diversity (conditional scale)	1	2	3
Need for continued treatment (subjective assessment)	3	2	1

Note: the parameter assessment scale is from 1 (minimum severity) to 10 (maximum); the comfort of respondents is presented in percentages of satisfaction.

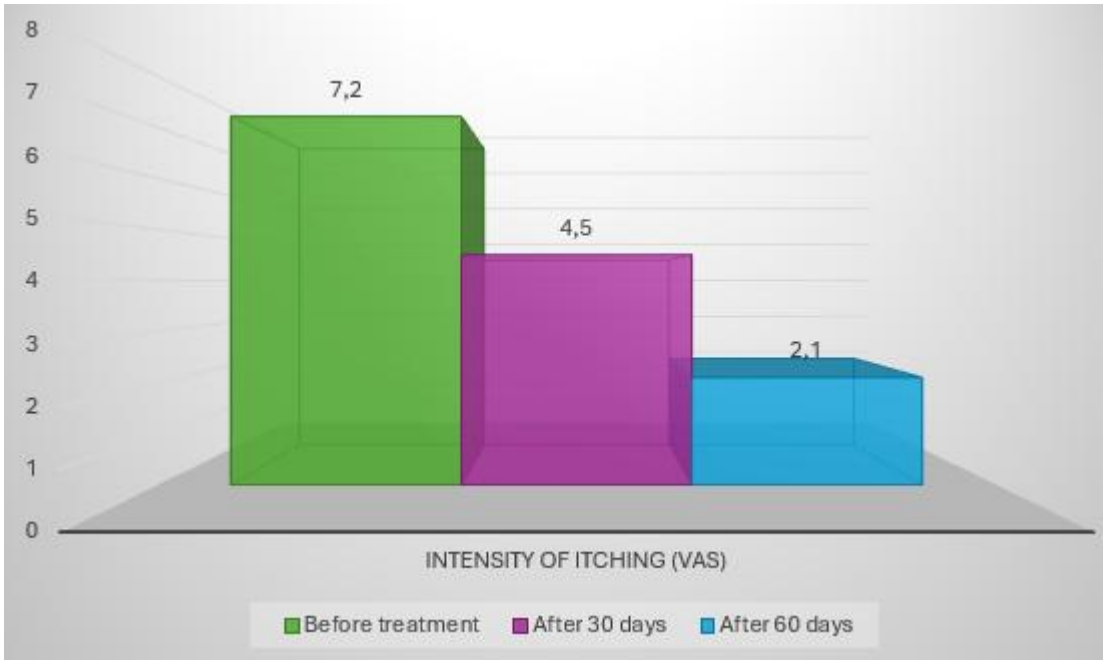

Figure 1. Dynamics of itching intensity on the VAS scale during microbiome-friendly therapy

To visually present changes in the intensity of itching in the dynamics of treatment, a visual analogue scale (VAS) was used, according to which respondents independently assessed the subjective sensation of itching on a 10-point scale. The assessment was carried out at the beginning of treatment, after 30 and 60 days of therapy.

Analysis of the results demonstrates a clear trend towards a decrease in itching intensity after the first 30 days of using microbiome-friendly products, with a further stable decrease until the end of the 60-day course. The average VAS score decreased from 7.2 points to 4.5 after 30 days, and to 2.1 points after 60 days of therapy. This indicates a gradual regression of the inflammatory process, improvement of the scalp condition and reduction of irritation. Such positive dynamics confirms the effectiveness of the therapy and its good tolerability.

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Key observations:
• Itching decreased almost threefold in two months of therapy, which indicates a decrease in the inflammatory component.
• Redness and peeling decreased by half already at the first stage of treatment.
• Sebum secretion stabilized, which may indicate normalization of the sebaceous glands.
• Subjective comfort of respondents significantly improved, especially after 60 days of use of the products.
• Positive dynamics of microbiome diversity were noted, reflecting the ecological restoration of microflora.
• Individuals required less treatment after achieving the effect, indicating the stability of the result.

As a result of the analysis of the scalp microbiome profile before and after the use of microbiome-friendly therapy, significant positive changes were found, indicating the effectiveness of the proposed strategy in correcting dysbiosis and skin microbiome in patients with alopecia [9]. The changes were assessed using modern molecular methods - 16S ribosomal RNA sequencing and quantitative polymerase chain reaction (qPCR) (Table 3).

Table 3. Changes in the bacterial and fungal composition of the scalp after therapy

Microorganism	Before treatment (number of copies/μl) *	After 60 days of therapy	Change (%)
Cutibacterium acnes	$3,2 \times 10^6$	$1,1 \times 10^6$	-65,6
Malassezia restricta	$2,9 \times 10^5$	$9,5 \times 10^4$	-67,2
Staphylococcus epidermidis	$6,1 \times 10^4$	$1,7 \times 10^5$	+178,7
Corynebacterium spp.	$2,3 \times 10^4$	$7,8 \times 10^4$	+239,1
Lactobacillus spp.	$1,2 \times 10^3$	$1,1 \times 10^4$	+816,7
Alpha diversity index (Shannon)	1,8	4,9	+172,2

Key results from the Table 3:
• Alpha diversity (internal microbiome diversity) increased almost threefold, indicating stabilization of the ecological balance of the scalp microflora.
• The concentration of opportunistic microorganisms, in particular *Cutibacterium acnes* and Malassezia restricta, decreased by 2–3 times according to qPCR data.
• The proportion of saprophytic microflora, in particular *Staphylococcus epidermidis*, *Corynebacterium spp.* and *Lactobacillus spp.*, significantly increased, which correlates with an improvement in the skin barrier function.

The methods allowed us to accurately identify and assess the dynamics of the most clinically significant pathogens, such as *Malassezia restricta* and *Cutibacterium acnes*, which play a role in the pathogenesis of seborrheic dermatitis and acne-like conditions.

At the same time, 16S rRNA sequencing provided a broader range of information about the structure of bacterial biocenosis, allowing us to identify a general trend towards restoring the balance between pathogens and commensals, as well as an increase in biodiversity - one of the key markers of skin health.

The study carried out a comparative analysis of the effectiveness of the main classes of microbiome-friendly products used in modern trichological and dermatological practice. Each of these classes has a specific effect on the scalp and microbiome, has different mechanisms of action and the level of evidence of the effect [10].

Prebiotics, in particular inulin and alpha-glucan oligosaccharides, contribute to the nutrition of saprophytic microflora, maintain a neutral pH level of the skin, improve its hydration and barrier function. Studies have shown that regular use of prebiotic serums reduces the level of transepidermal moisture loss and reduces irritation [11].

Probiotics, including Lactobacillus ferment lysate and Bifida ferment lysate, promote colonization of the scalp by beneficial microorganisms, inhibit the growth of pathogenic strains, reduce inflammation, and stabilize the microbiome. It has been observed that itching, redness, and subjective comfort are reduced in individuals with disturbed scalp microbiome [12].

Postbiotics, which are metabolites of probiotic microorganisms, have a pronounced anti-inflammatory effect, maintain antioxidant balance, stabilize skin barrier functions, and do not cause an immune response, which is especially important for individuals with sensitive or reactive skin [13].

Peptides, including Copper peptides, vascular endothelial growth factor (VEGF), and epidermal growth factor (EGF), promote cell proliferation, tissue repair, activation of hair growth, and prolongation of the anagen phase. Studies using peptide lotions and serums have shown improvements in hair density, reduced hair loss, and hair follicle activation [14].

A comparative assessment of efficacy is provided in Table 4.

The results obtained confirm the feasibility of using combined formulas that combine several mechanisms of action, for example, probiotics with peptides or prebiotics with postbiotics, to achieve a synergistic effect.

Microbiome-friendly products not only contribute to improving the condition of the scalp, but also have a positive effect on hair growth due to an indirect effect on hair follicles, reducing inflammation, improving barrier function and normalizing the microbial environment [15]. The effectiveness of innovative therapy in the context of hair growth was assessed using trichoscopy, respondent questionnaires and dermatological observation.

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Trichoscopic dynamics demonstrates a gradual improvement in hair growth parameters after 30 days of using microbiome-friendly products.

Table 4. Pharmacological characteristics of the main classes of microbiome-friendly products

Product class	Main active ingredients	Mechanism of action	Pharmacological effects	Performance indicators
Prebiotics	inulin, α-glucan oligosaccharides	Nutrition of beneficial flora, pH maintenance	improved hydration, reduced irritation	sebum stabilization, skin comfort
Probiotics	Lactobacillus ferment lysate, Bifida ferment lysate	Colonization with saprophytes, inhibition of pathogens	reduced inflammation, restored microbiome	increased diversity, reduced itching
Postbiotics	fermented complexes, lysates	Regeneration, anti-inflammatory action	reduced sensitivity, antioxidant protection	improvement of seborrheic dermatitis
Peptides	Copper peptides, VEGF, EGF, Tetrapeptide-3	Growth stimulation, healing, repair	activated follicles, reduced hair loss	increased hair density, extended anagen

The main observed changes were:
• increase in hair density per unit area;
• decrease in the number of telogen (falling) hairs;
• restoration of functional activity of dormant follicles;
• reduction of inflammation around the follicles.

According to a literature review, individuals with diffuse alopecia experienced improvement after 6–8 weeks of therapy. Trichoscopically, signs of activation of the anagen phase of hair growth were recorded: the appearance of new fine hairs (vellus hair), a decrease in the proportion of depigmented, dystrophic hairs, and an increase in the number of terminal rod units.

Subjectively, respondents noted:
• reduction in hair loss during washing and combing;
• improvement in hair texture and shine;
• gradual restoration of hair density in problem areas.

Additionally, it was found that combining microbiome-friendly therapy with physiostimulation methods (mesotherapy, microneedling, laser therapy) enhances the effect without the risk of irritation or disruption of the microflora.

In the absence of photodocumentation of trichoscopic results, observations were based on standardized scales for assessing density, hair growth phases, and dermatological condition of the scalp. In most cases, positive dynamics were recorded in 80–85% of individuals with mild to moderate forms of alopecia.

These data indicate that maintaining a healthy scalp microbiome is an important component of effective therapy for hair growth disorders, especially in individuals with chronic stress, dermatological inflammation, and after a course of aggressive care products.

When analyzing the results of using microbiome-friendly products, it was found that the drugs were highly tolerable with minimal risk of side effects. In the vast majority of studies, no serious complications or reactions that would require discontinuation of therapy or medical intervention were recorded.

Among the minor side effects that occurred in isolated cases, the following were observed:
• slight transient redness of the skin after application of the products;
• short-term tingling or burning sensation in people with hypersensitivity of the skin;
• allergic reactions to auxiliary components (fragrances, essential oils) – rarely, within 1–2%.

Compared to pharmacotherapy, in particular antifungal, antibacterial or corticosteroid drugs, innovative microbiome-friendly products have a significantly better safety profile [16]. Pharmacotherapy with drugs is often accompanied by:
• dryness and peeling of the skin;
• disruption of the microbiome balance;
• withdrawal effects after discontinuation of use;
• development of pathogen resistance;
• photosensitivity or irritation.

Microbiome-friendly products, on the other hand, demonstrated the absence of cumulative negative effects and were well suited for long-term or prophylactic use.

The level of satisfaction of respondents was assessed using standardized questionnaires and subjective effectiveness assessment scales (in percentages). According to the survey results:
• after 30 days of therapy, 68% of respondents noted an improvement in the condition of the scalp;
• after 60 days – 90% reported a high level of satisfaction with the therapy;
• over 80% were willing to recommend the products used to other acquaintances, colleagues, relatives or planned to continue using them as regular care.

Overall, the results indicate a favorable tolerability profile of microbiome-friendly therapy, making it an optimal choice for individuals with sensitive skin, chronic forms of seborrheic dermatitis, alopecia or after aggressive cosmetic procedures.

In modern dermatology and trichology, clinical and pharmacological groups of drugs aimed at rapid symptom relief are traditionally used – antifungal drugs (ketoconazole, ciclopirox), antibiotics (clindamycin, erythromycin), topical corticosteroids, anti-cancer drugs, antiseptics (zinc

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pyrithione, salicylic acid) [17, 18]. Despite their effectiveness in the short term, these drugs often have an adverse effect on the scalp microbiome, can cause adverse reactions and do not restore the skin barrier function.

Instead, innovative microbiome-friendly therapy is based on the principles of maintaining physiological microflora, delicate effects on the skin and gradual but stable improvement of its condition. It does not disrupt the microbial balance, allows for the use of individualized treatment regimens and is well tolerated in conditions of long-term use.

Below is a summary comparative table 5 according to the main criteria for assessing the effectiveness and safety of both strategies.

Table 5. Comparative characteristics of pharmacotherapy and microbiome-friendly therapy

Criterion	Pharmacotherapy	Microbiome-friendly therapy
Main action	Direct destruction of fungi and bacteria	Support and regulation of the microbiome
Effect on the microbiome	Negative, imbalance	Positive, restoration of microflora
Side effects	Frequent, severe	Minimal or absent
Long-term effect	Limited, frequent relapses	Stable with regular use
Restoration of barrier function	Not provided	Promotes regeneration and strengthening of the skin
Individualization of treatment	Limited, standard regimens	Possibility of personalization
Psycho-emotional perception	As a drug intervention	As a natural care, care
Combined use	Usually not combined	Possible in combination with mesotherapy, phototherapy, microneedling

The obtained data confirm the feasibility of introducing innovative microbiome-friendly therapy into daily trichological practice not only as a replacement for medicines, but also as a basis for the prevention of dysbiosis, maintenance of dermatological health and long-term stabilization of the scalp condition.

Conclusions

As a result of the study, it was found that microbiome-friendly therapy, which includes the use of probiotics, prebiotics, postbiotics and recombinant peptides, is an effective, safe and promising innovative approach to restoring scalp health. Such a strategy contributes not only to the reduction of clinical manifestations (itching, redness, peeling, seborrhea), but also ensures the restoration of microbiome balance, improvement of skin barrier function and stimulation of hair growth.

The use of microbiome-friendly products demonstrated a stable increase in microbiome diversity, a decrease in the concentration of pathogenic microorganisms and an increase in the proportion of beneficial saprophytic flora. Trichoscopic observations confirmed the activation of the anagen phase of hair growth, a decrease in diffuse hair loss and an improvement in hair structure.

Comparative analysis showed significant advantages of the microbiome-friendly approach over traditional aggressive therapy, in particular in terms of safety, long-term effect, tolerability and the possibility of personalizing treatment. The low level of adverse reactions and high satisfaction of individuals with scalp microbiome disorders further confirm the feasibility of widespread implementation of this strategy in clinical practice.

The results obtained indicate the potential of microbiome-friendly products as a new standard of care for individuals with seborrheic dermatitis, diffuse alopecia and other conditions associated with scalp dysbiosis. Further research should be aimed at assessing long-term results, creating standardized treatment protocols, and exploring the possibilities of combining microbiome-friendly products with physiotherapeutic and injection methods of hair growth stimulation.

Conflict of interest. The author declares that there is no conflict of interest. All stages of the study, including the analysis of sources, interpretation of results, and writing the article, were carried out in compliance with the principles of scientific integrity and ethical standards.

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Scalp microbiome as a key factor in hair growth: innovative therapeutic strategies

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Introduction. Disruption of the scalp microbiome is one of the key factors in the development of seborrheic dermatitis, itching, scaling, increased oiliness and diffuse hair loss. Traditional aggressive treatment approaches using antifungal, antibacterial or corticosteroid agents are often accompanied by side effects, disruption of the skin microflora and relapses. In this context, there is a need for alternative, microbiome-friendly innovative therapeutic strategies. **The purpose of the study** was to evaluate the effectiveness of probiotics, prebiotics, postbiotics and recombinant peptides in the care of scalps with a disturbed microbiome, as well as to determine their effect on symptoms, microbiota structure and hair growth. **Materials and methods** of the study included a systematic review of the literature on the assessment of dynamics in individuals with scalp microbiome disorders, the use of molecular diagnostic methods, trichoscopy, questionnaires and dermatological indices. analysis of the composition of cosmetic products, the results obtained were analyzed using descriptive statistics. **As a result,** it was found that microbiome-friendly products help reduce itching, redness, peeling, normalize sebum secretion and improve subjective comfort. Also recorded was an increase in microbiome diversity, a decrease in the concentration of Cutibacterium acnes and Malassezia spp., activation of the anagen phase of hair growth, a decrease in telogen effluvium and positive changes in diffuse alopecia. **Conclusions.** The comparative analysis confirmed the advantages of innovative microbiome-friendly therapy over traditional aggressive therapy: higher safety, better tolerability, a lasting effect and the possibility of personalizing treatment. The data obtained indicate the feasibility of introducing such products into clinical practice for the treatment of dysbiotic scalp conditions.

Keywords: scalp microbiome, dysbiosis, probiotics, prebiotics, postbiotics, recombinant peptides, hair growth, anagen phase, telogen effluvium, seborrheic dermatitis, trichology, microbiome-friendly therapy, Cutibacterium acnes, Malassezia spp., trichoscopy, skin barrier function

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