

Advances in Scalp Microbiome Research: Implications for Hair Health and Disease

Brandon Austin*

Department of Practical Cosmetology and Skin Diseases Prophylaxis, Poznan University of Medicinal Sciences, Poznan, Poland

Abstract

The human scalp, like other regions of the body, harbors a unique and dynamic microbial ecosystem that plays a crucial role in maintaining skin and hair health. Recent advances in microbiome research have illuminated the complex interactions between the scalp's microbial communities and various hair-related disorders, such as dandruff, seborrheic dermatitis, alopecia, and scalp infections. Understanding these microbial populations and their functions opens new avenues for targeted treatments, preventative strategies, and personalized hair care regimens. This article explores the latest findings in scalp microbiome research, focusing on the microbial diversity of the scalp, its potential impact on hair health, and the clinical implications for treating scalp-related conditions.

Keywords: Human scalp • Hair health • Microbial diversity • Clinical implications • Dysbiosis

Introduction

The human scalp is home to a rich and diverse community of microorganisms, including bacteria, fungi, viruses, and archaea, which collectively make up the scalp microbiome. Over the past decade, the advent of high-throughput sequencing technologies has allowed for the exploration of these microbial communities in greater detail, shifting our understanding of scalp health from a focus solely on genetic and environmental factors to include microbial influences. These microbes, particularly bacteria and fungi, interact with the host in ways that can influence hair growth, inflammation, and the development of scalp disorders.

The composition and balance of the scalp microbiome are influenced by various factors such as age, gender, diet, environmental conditions, and the use of hair care products. Disruptions in this microbial equilibrium, also known as dysbiosis, have been implicated in a range of scalp conditions, highlighting the need for a deeper understanding of the microbiome's role in scalp and hair health. This review aims to summarize recent advances in scalp microbiome research and explore its implications for hair health and disease.

Description

Composition of the scalp microbiome

Bacterial communities: The scalp microbiome is predominantly composed of bacteria, with key genera such as *Propionibacterium*, *Corynebacterium*, *Staphylococcus*, and *Dermabacter* playing pivotal roles in scalp health. These bacteria are involved in the breakdown of sebum, the oily substance produced by sebaceous glands, and help maintain a balance in the scalp environment. *Propionibacterium* acnes, for instance, is commonly found on the scalp and is known to be involved in the breakdown of sebum, potentially influencing the development of conditions like acne or seborrheic dermatitis when its growth is dysregulated.

In a healthy scalp, a balance of these bacteria helps prevent the overgrowth of harmful microbes. However, in conditions like dandruff or seborrheic dermatitis, this balance is often disrupted, with an overgrowth of *Malassezia*, a genus of fungi, and changes in the relative abundance of bacterial species, including a decrease in beneficial bacteria such as *Propionibacterium* and *Corynebacterium*.

*Address for Correspondence: Brandon Austin, Department of Practical Cosmetology and Skin Diseases Prophylaxis, Poznan University of Medicinal Sciences, Poznan, Poland; E-mail: austinb45@gmail.com

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Fungal communities: Fungi, particularly the *Malassezia* genus, are abundant in the scalp microbiome and have been closely linked to various scalp disorders. *Malassezia* species, which are lipophilic and thrive in oily environments, are often implicated in the development of dandruff, seborrheic dermatitis, and other inflammatory scalp conditions. These fungi feed on sebum and contribute to the inflammatory processes that characterize these disorders. Recent studies have shown that the relative abundance of *Malassezia* species varies between healthy individuals and those suffering from scalp conditions, suggesting that fungal dysbiosis may play a central role in the pathogenesis of these diseases.

Viral and archaea communities: While less is known about the role of viruses and archaea in the scalp microbiome, emerging research has started to identify viral species, particularly bacteriophages, that may play a role in modulating bacterial populations. These viruses could potentially contribute to the regulation of the scalp microbiome by infecting and killing specific bacterial strains. The presence and diversity of archaea in the scalp microbiome remain an area of active investigation, though they are generally less abundant than bacteria and fungi.

Scalp microbiome and hair health

Hair growth and follicular health: The scalp microbiome is intimately connected to the health of hair follicles. Studies suggest that certain bacterial populations may influence hair growth and hair follicle cycling through the modulation of inflammation, sebaceous gland activity, and local immune responses. Dysbiosis of the scalp microbiome has been associated with several hair loss conditions, including alopecia areata, a condition in which hair follicles are attacked by the immune system. The role of microbial communities in these autoimmune processes remains under investigation, with some studies suggesting that specific bacterial or fungal species may trigger or exacerbate inflammatory responses that damage hair follicles.

Seborrheic dermatitis and dandruff: Seborrheic dermatitis and dandruff are common scalp conditions that are closely linked to an imbalance in the microbiome. These disorders are characterized by excessive scaling, redness, and inflammation of the scalp, often associated with an overgrowth of *Malassezia* species. The lipophilic nature of *Malassezia* allows it to thrive in the sebum-rich environment of the scalp, where it may induce an inflammatory response through the release of pro-inflammatory molecules. Furthermore, the reduction of beneficial bacteria such as *Propionibacterium* and *Corynebacterium* has been observed in individuals with dandruff, suggesting that bacterial-fungal interactions on the scalp may contribute to the pathogenesis of these conditions.

Alopecia areata and autoimmunity: Recent studies have suggested that the scalp microbiome may influence autoimmune diseases, such as Alopecia Areata (AA), a condition characterized by patchy hair loss due to immune-mediated destruction of hair follicles. Dysbiosis of the microbiome, particularly an imbalance in bacterial populations, has been hypothesized to play a role in the onset of AA. The exact mechanisms by which the microbiome might influence immune responses and the development of AA are still unclear, but there is growing evidence that the microbiome may contribute to the modulation of inflammatory pathways and immune tolerance in the scalp.

Therapeutic implications of scalp microbiome research: The growing understanding of the scalp microbiome offers new opportunities for the prevention and treatment of hair and scalp disorders. Traditional treatments for conditions like dandruff and seborrheic dermatitis often rely on antifungal agents, corticosteroids, and anti-inflammatory medications. However, these treatments may not always address the underlying microbial imbalances that contribute to these conditions.

Probiotics and prebiotics: One promising area of research is the use of probiotics and prebiotics to restore balance to the scalp microbiome. Probiotics, which are live microorganisms that provide health benefits when administered in adequate amounts, have shown potential in promoting a healthy microbiome by encouraging the growth of beneficial bacteria. Studies have explored the use of topical probiotic applications to modulate the scalp microbiome and reduce symptoms of dandruff and seborrheic dermatitis. Similarly, prebiotics, which are compounds that stimulate the growth of beneficial microbes, may be used to nourish the healthy bacterial populations on the scalp.

Targeted microbial therapies: Another potential therapeutic avenue is the development of targeted microbial therapies. These therapies could involve the selective modulation of microbial communities on the scalp through the use of topical antimicrobials, bacteriophages, or fungal inhibitors. By restoring a balanced microbiome, these therapies could address the root cause of conditions like dandruff, seborrheic dermatitis, and alopecia, offering a more precise and personalized approach to treatment.

Personalized hair care products: With advances in microbiome research, the possibility of personalized hair care products that cater to an individual's unique scalp microbiome is becoming increasingly feasible. Such products could include formulations that specifically target microbial imbalances, provide nourishment to beneficial bacteria, and promote overall scalp health. These products could be tailored to an individual's age, gender, hair type, and specific scalp conditions, leading to more effective and customized treatment options.

Conclusion

The scalp microbiome is a complex and dynamic ecosystem that plays a crucial role in maintaining scalp health and preventing hair-related diseases. Advances in microbiome research have highlighted the importance of microbial diversity in promoting healthy hair follicles, preventing inflammatory scalp disorders, and potentially influencing hair growth. Dysbiosis of the scalp microbiome has been implicated in a variety of conditions, including dandruff, seborrheic dermatitis, and alopecia areata, suggesting that microbial imbalances may be central to the pathogenesis of these diseases.

As our understanding of the scalp microbiome continues to grow, new therapeutic strategies, including probiotics, prebiotics, and targeted microbial therapies, hold promise for improving the treatment and prevention of scalp-related conditions. Furthermore, the

rise of personalized hair care products tailored to the individual microbiome could revolutionize the way we approach hair health. Ultimately, continued research into the scalp microbiome will deepen our understanding of its role in scalp and hair health and pave the way for more effective, microbiome-based interventions in the future.

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