

Insights on the Impact of Scalp Barrier Condition on Hair Health

Maria Hordinsky MD FAAD,^a Anneke Andriessen PhD,^b
Natasha Mesinkovska MD FAAD,^c Heather Woolery-Lloyd MD FAAD^d

^aClinical Research Division, Department of Dermatology, University of Minnesota, Minneapolis, MN

^bUMC Radboud, Nijmegen, Andriessen Consultants, Malden, The Netherlands

^cUniversity of California Irvine, Irvine, CA

^dSkin of Color Division Dr Phillip Frost Department of Dermatology
and Cutaneous Surgery University of Miami Miller School of Medicine, Miami, FL

ABSTRACT

Scalp health is essential for healthy hair growth and may be affected by intrinsic or extrinsic factors. Reactive oxygen species are key contributors to aging and can have a detrimental impact on scalp health. Oxidative stress on the scalp is thought to be a factor in developing dandruff. We present consensus statements on scalp barrier health and its effects on hair through a systematic literature search and expert panel discussion. Three dermatologists with extensive experience in hair were selected to form a panel that formulated consensus statements that would best capture the current understanding of scalp health. The consensus statements developed and presented in this manuscript highlight the current literature and broader discussion surrounding scalp health and its impact on hair and dandruff. It also highlights the often-overlooked effects of scalp conditions on hair health and growth. Through our research, we found that there has been minimal emphasis on scalp health in the setting of dandruff, with most studies focusing on other inflammatory diseases such as psoriasis and atopic dermatitis. Here, we review the clinical importance of focusing on the impact of the scalp barrier condition on hair health.

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INTRODUCTION

Research has shown that scalp and hair health are connected, but the link is not yet fully understood or characterized. Hair growth begins within the hair follicle, about 4 mm deep in the skin.¹ The cells proliferate in the bulb of the follicle and produce a nascent hair fiber that continues to grow to the scalp surface.¹ As the hair extends to the skin surface, the hair fiber undergoes keratinization.¹ At the same time, the skin microenvironment surrounding each follicle propagates signals to the hair fiber, thereby impacting the quality and character of the resultant hair.¹ The hair follicle undergoes cycles of growth (anagen), apoptosis-mediated regression (catagen), and relative quiescence (telogen).^{1,2} During its life cycle, the hair follicle is highly sensitive to surrounding growth factors, cytokines, neuropeptides, and hormones, often produced by the hair follicle itself.² Thus, scalp and hair follicle health is critical to hair care. Factors affecting scalp health may go into four categories: hair follicle health, inflammatory conditions,

environmental/exogenous factors, and scalp microbiome.² While overall scalp health has yet to be understood, inflammatory scalp conditions such as psoriasis, dandruff/seborrheic dermatitis (D/SD), atopic dermatitis (AD), as well as fungal scalp conditions such as pityriasis versicolor (PV), and tinea capitis have been extensively studied.¹ It has long been known that inflammatory scalp conditions negatively impact hair growth; however, the characterization of overall scalp health and its impact on hair growth has been less evident in the literature. There is little information about scalp care in scalp-related inflammatory conditions. Furthermore, exogenous agents such as chemotherapy, smoking, ultraviolet radiation, and chemical insults from hair products and pollutants, amongst others, can negatively impact hair growth.³ Contact dermatitis from fragrances, hair colorants, or treatments containing formaldehyde and formaldehyde releasers may also result in an irritated scalp and inflammation, leading to hair shedding.³ Exogenous factors such as psychological and physical stressors have also been reported to impact the hair growth cycle, likely through modu-

lation of the body's hormones and inflammatory balance.³ The scalp environment, rich in sebaceous glands, supports a diverse microbiome. These microbes likely play a significant role in scalp health and hair growth. In conditions such as psoriasis and D/SD, *Malassezia* is present in abnormally high amounts.³ Studies have shown that *Malassezia* metabolism produces reactive oxygen species (ROS), which contribute to scalp skin and hair oxidative damage.^{4,6}

Healthy hair growth is rooted in scalp health and maintaining a healthy scalp barrier. Evidence supports a cause-and-effect linkage between scalp condition and resultant hair condition. Thus, hair health is inherently linked to the health of the scalp environment. Here, we present five consensus statements summarizing the current understanding of the scalp barrier and hair health through the lens of expert dermatologists.

METHODS

A panel of 3 expert dermatologists met on July 20th, 2022, in Vancouver, Canada, to discuss the outcomes of a systematic literature review that aimed to identify the challenges in scalp barrier health and provide insights and recommendations to promote healthy hair and scalp. The systematic literature review included guideline articles, consensus papers, clinical trials, comparative trials, open-label studies, and clinical or other research publications from 2010 to 2022. The scope of the literature search was scalp health, skincare, and the role of ceramides. Two reviewers (AA and HA) evaluated and assembled the results to yield 84 scalp-related papers (59 clinical studies and 25 reviews). Using the literature review, five statements were formed by the panel to summarize challenges in promoting scalp barrier and hair health and highlight the importance of ceramide-containing products in scalp care. The statements guided the expert panel's discussion of current scalp health literature to raise awareness about this important issue.

RESULTS

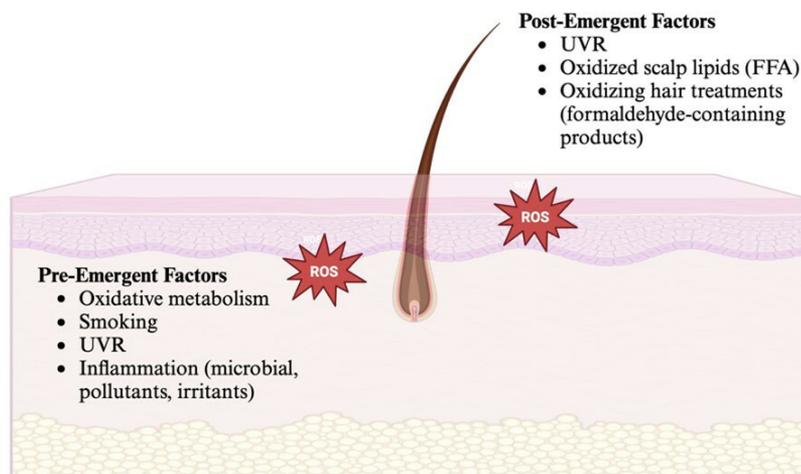
Statement 1: *There is evidence for a cause-and-effect link between the condition of the scalp and hair health. Scalp conditions such as psoriasis, D/SD, AD, contact/irritant dermatitis, and tinea capitis, among others, may lead to unhealthy hair.*

Like the skin, the scalp provides an essential barrier between the body and its environment, acting as a physical barrier that restricts water loss, prevents entry of external irritants, and regulates tissue homeostasis by balancing the immune response to endogenous and exogenous factors.⁷ Psoriasis results from an inflammatory imbalance in the skin and typically presents on the scalp as erythematous, white, and flaking plaques. Hair that grows on the psoriasis-affected scalp has been shown to be thinner and smaller in diameter with a rougher surface.⁴ Clinically, patients with psoriasis often report significant hair loss, which correlates with studies that show increased telogen and decreased anagen hair phases in those patients.⁸ Similarly, hair from patients with AD and D/SD has also been shown to have increased roughness with thicker cuticular edges.⁴ The rough hair texture contributes to a reduction in hair shine in these conditions. Inflammation caused by fungal infections in tinea capitis leads to alterations in hair morphology (corkscrew, comma, or zigzag hairs).⁴ Inflammation may be due to contact dermatitis from shampoos, hair dyes, keratin treatments, or hair accessories, and it may lead to hair loss, likely secondary to the chronic inflammation of the scalp.³ Hair products containing formaldehyde and formaldehyde releasers have been suggested to trigger the development of psoriasiform dermatitis.⁹ Thus, scalp inflammation is intrinsically tied to hair health, underscoring the importance of addressing the scalp's condition to promote hair health.

Statement 2: *Oxidative stress plays a role in the etiology of scalp conditions such as D/SD, contact dermatitis, psoriasis, and normal aging. Oxidative stress in the scalp may alter the normal hair keratinization process, contribute to brittle hair, and impede normal fiber anchorage.*

Oxidative stress has been thought to affect overall aging and health significantly. ROS, the primary driver of oxidative stress, damages the scalp's structural proteins and DNA, ultimately harming the hair.⁴ The body has built-in endogenous defense mechanisms in the form of antioxidant enzymes such as superoxide dismutase, glutathione peroxidase, and catalase, as well as anti-oxidative molecules such as vitamin E, vitamin C, glutathione, and ubiquinone that can neutralize ROS and protect the body and its structures.⁴ The condition of a hair fiber depends on a combination of pre- and post-emergent factors.⁴ Pre-emergent factors include oxidative factors such as smoking, ultraviolet (UV) radiation, microbe-induced inflammation, disease-induced inflammation, or oxidized scalp lipids. Post-emergent fiber stressors include chemical insults from oxidizing hair colorants, pollutants, and UV radiation (Figure 1).⁴ Free radical-mediated lipid peroxidation is used as a biomarker of oxidative stress and is commonly detected in conditions such as D/SD, psoriasis,

FIGURE 1. Oxidative stress factors on pre-emergent and post-emergent hairs.⁴ Oxidative stress can affect the hair pre-emergently, on the scalp, or post-emergently, on the surface of the head. Factors affecting the scalp microenvironment hair include oxidative metabolism, smoking, local or systemic inflammation, and UVR. Post-emergently, UVR, oxidized scalp lipids, and oxidizing hair treatments such as formaldehyde-containing products may also damage the hair.



Ultraviolet radiation (UVR)

and AD. Interestingly, in D/SD, the *Malassezia* species, a pathogenic driver of the condition, has also been shown to cause oxidative stress in a dose-dependent way.⁴ In a 24-week randomized, double-blind, placebo-controlled clinical trial using scalp application of functional antioxidants and barrier-enhancing cosmetic ingredients, there was a significant reduction in hair shedding and increased perceived hair fullness.¹⁰ Antioxidant ingredients used in this study included caffeine and niacinamide.¹⁰ Thus, further research is warranted to develop barrier-enhancing products that promote scalp and hair health.

Statement 3: *Dandruff is associated with an impaired epidermal barrier, leaving the scalp more prone to further fungal colonization, environmental pollutants, and inflammation. Individuals with dandruff have significantly reduced ceramides (EOS, NP), fatty acids, and cholesterol. The depleted and disorganized structural lipids may impact the barrier, as evidenced by elevated transepidermal water loss, subclinical inflammation, and higher susceptibility to topical irritants.*

Dandruff is characterized by flaking and pruritus without any visible signs of inflammation, such as erythema.¹¹ The pathogenesis of dandruff is multifactorial, involving microbial colonization and intrinsic host factors such as sebum production.¹¹ There is evidence of changes in epidermal morphology in the scalp skin of dandruff sufferers, with reports of an increase in mean thickness and more

nucleated cell layers.¹¹ The increased epidermal thickness is not conducive to proper hair growth as the hair must pass through a thicker epidermis to reach the surface.

Dandruff may present with a deficient scalp barrier. Collins et al. demonstrated that in D/SD scalps, the scalp barrier was characterized by higher transepidermal water loss, diminished levels of total ceramides, global inflammation, and a greater susceptibility to topical irritants.¹² Analysis of scalp lipids showed a marked decrease in ceramides, notably ceramide 1, in dandruff-affected scalps and a total decrease in stratum corneum lipid species such as fatty acids and cholesterol.^{13,14} Interestingly, males have also been shown to have 0.76 times lower ceramide levels and 1.4 times greater protein loss than females.¹² This impaired barrier makes dandruff sufferers increasingly susceptible to irritants, microbes, fungal colonization, inflammation, and pollutants that inevitably perpetuate and exacerbate the broken barrier.

Statement 4: *A healthy stratum corneum forms a protective barrier to prevent water loss and maintain scalp hydration, protecting against external insults such as microorganisms and environmental triggers.*

The stratum corneum has a multilayered structure that is frequently compared to a brick wall.¹⁵ It consists of corneocytes embedded into a continuous lipid matrix formed by specialized barrier lipids.¹⁵ Ceramides, cholesterol,

and fatty acids represent the main elements of the barrier lipids.¹⁵ A healthy stratum corneum can protect the skin and body from water loss, external insults, and inflammation. Protecting the scalp skin from these aggressors is key to preserving homeostasis and preventing oxidative stress that would damage resultant hair. Disease, hormones, temperature, humidity, and surfactants affect the stratum corneum barrier function.¹⁵ If the barrier is compromised, it can result in scalp dryness, itch, and dandruff.¹⁵ In dandruff-affected scalps, studies have shown a dramatic depletion of barrier lipids and a poorly organized lipid layer, which provides little permeability barrier and allows the introduction of *Malassezia* and other microbes and toxins.¹⁵ Thus, maintaining a healthy scalp barrier is key to protecting against exogenous insult.

Statement 5: *Improvement in scalp health has been shown to be able to reverse detrimental impacts on the hair by reducing oxidative stress and promoting a healthy scalp.*

Premature hair loss is primarily affected by the scalp environment in which it grows. Disturbed scalp conditions can perturb normal hair fiber maturation and firm fiber anchorage.¹⁰ Oxidative stress produced by *Malassezia* species, ROS from exogenous sources, or a natural decline in antioxidant response due to chronological age or a disease state has been predominately accepted as the major disrupters of scalp health. Neutralizing this oxidative stress has been shown to reverse the detrimental impacts of ROS on the hair.¹⁰ Multiple studies have demonstrated that reversing *Malassezia*-associated oxidative stress using zinc pyrithione shampoos results in healthier hair and reduced dandruff symptoms.^{13,16} Antioxidants such as zinc, niacinamide, and caffeine have also demonstrated antioxidant properties that lead to barrier improvement and improved hair health.¹⁰ Lastly, stratum corneum lipids in the scalp increase in dandruff patients treated with zinc pyrithione shampoo.¹³ Decreasing oxidative stress in these patients improves barrier function, reduces symptoms, and leads to healthier scalps and improved hair appearance.¹³

CONCLUSION

A healthy scalp and scalp barrier are required to protect from external insults and promote hair growth and retention. Oxidative stress is a significant driver of scalp barrier damage. ROS can lead to an impaired scalp barrier, resulting in dysfunctional hair growth and poor hair health. Scalp lipids, such as ceramides, are decreased in dandruff-affected scalps. Thus, reducing ROS and inflammation and maintaining a healthy scalp barrier may protect the scalp from further oxidative stress, promoting healthy hair.

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AUTHOR CORRESPONDENCE**Anneke Andriessen PhD**

E-mail:..... anneke.a@tiscali.nl