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Beyond Circadian Rhythm: Melatonin as a Bio-Regulatory Molecule in Skin and Hair Aesthetics

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Abstract: ***Melatonin has long been known for its function in circadian rhythm regulation, but new dermatological studies emphasize its significance as a multifunctional molecule in skin protection and hair biology. Melatonin protects the skin from UV radiation, oxidative stress, and inflammation by acting as a potent antioxidant, radioprotective agent, and mitochondrial stabilizer, according to scientific research. As a component of a "melatoninergic antioxidant system", topical melatonin improves DNA repair, lowers oxidative damage, and regulates inflammatory reactions. Melatonin also affects the cycling of hair follicles and may encourage the prolonging of the anagen phase, which supports hair renewal. In addition to highlighting melatonin's potential therapeutic uses in dermatology and cosmetology, this research examines the biological roles of melatonin in skin defense and hair repair.***

Keywords: Melatonin, antioxidants, photoprotection, skin defense, hair restoration, hair follicle biology, and dermatology

1. Introduction

The pineal gland is the primary source of melatonin (N-acetyl-5-methoxytryptamine), a hormone that is essential for controlling sleep cycles and circadian rhythms (Reiter et al., 2014).

Melatonin is produced both systemically and in peripheral organs such as the skin, gastrointestinal tract, and retina (Slominski et al., 2018).

Enzymes needed for melatonin production and receptors mediating its biological effects make up the skin's entire melatoninergic system (Slominski et al., 2014).

As a powerful antioxidant, melatonin can scavenge reactive oxygen species (ROS) and shield cellular constituents from oxidative damage (Tan et al., 2015).

Melatonin has been demonstrated in dermatology to have photoprotective properties against UV radiation and to lessen inflammation brought on by environmental stresses (Hardeland et al., 2012).

Furthermore, research indicates that melatonin may affect the physiology of hair follicles by encouraging the anagen stage of hair development and decreasing hair loss (Fischer et al., 2004).

These results suggest that melatonin may be an important component in treatments for hair regeneration and skin protection.

Aim

To examine and evaluate melatonin's function in hair repair and skin defense systems.

Objectives

1) To comprehend melatonin's physiological roles and biological characteristics.
2) To assess melatonin's function in shielding skin from environmental and oxidative harm.
3) To investigate how melatonin controls the formation of hair follicles and the hair cycle.
4) To investigate melatonin's possible therapeutic and cosmetic uses in dermatology and aesthetic medicine

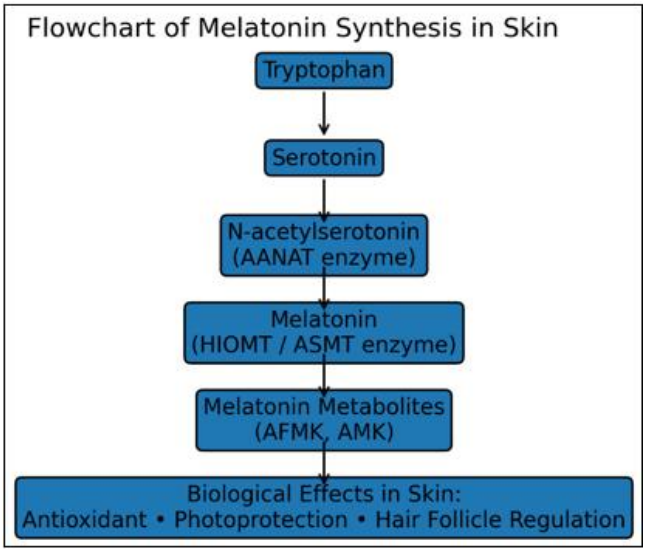
2. Biochemistry and Physiology of Melatonin

Melatonin is produced from the amino acid tryptophan via a sequence of enzymatic processes that use serotonin as an intermediary (Reiter et al., 2014).

Melatonin synthesis in the pineal gland is timed according to a circadian rhythm controlled by the hypothalamic suprachiasmatic nucleus.

Melatonin is synthesized outside of the pineal gland in a variety of tissues, including the skin, where it functions in both a paracrine and autocrine manner (Slominski et al. 2018).

Melatonin receptors MT1 and MT2 are expressed in many skin cells, including keratinocytes, fibroblasts, and melanocytes (Slominski et al., 2014).



Melatonin & Skin Defense
The skin is continually exposed to UV radiation and environmental contaminants, which cause oxidative stress (Tan et al., 2015).

Melatonin is a strong antioxidant that directly scavenges free radicals and stimulates antioxidant enzymes (Reiter et al., 2014).

In human biology, melatonin is regarded as one of the most potent endogenous antioxidants. It uses a multilayered antioxidant defense mechanism to shield the skin.

It Directly Scaveng the Free Radicals

Reactive oxygen species produced by UV radiation are immediately neutralized by melatonin, including: Hydroxyl radicals, Anions of superoxide, Hydrogen peroxide

In some oxidative stress scenarios, melatonin may be more beneficial than conventional antioxidants like vitamin C and vitamin E, according to experimental research.

It increases the activity of enzymes that protect skin cells from oxidative damage, including superoxide dismutase, catalase, and glutathione peroxidase (Hardeland et al., 2012).

Additionally, it triggers the NRF2 antioxidant signaling pathway, which controls the body's defense against oxidative damage.

Melatonin and its metabolites also protect DNA from UV-induced damage and mitochondrial dysfunction (Slominski et al., 2018).

Melatonin's characteristics make it a key chemical for anti-aging and photoprotection techniques.

Anti-Inflammatory and Immunomodulatory Effects
Melatonin has anti-inflammatory capabilities via regulating cytokine production and inhibiting inflammatory signaling pathways (Tan et al., 2015).

It acts as a Photoprotector. One of the main causes of early skin aging and carcinogenesis is ultraviolet light. Melatonin offers substantial protection in a number of ways.

DNA Repair and Protection
Melatonin improves the nucleotide excision repair processes that eliminate UV-induced DNA damage, including Dimers of cyclobutane pyrimidines, Markers of oxidative DNA damage (8-OHdG)

Additionally, it enhances DNA repair and inhibits malignant transformation by stimulating the tumor suppressor protein p53.

Stabilization of Mitochondria
Melatonin preserves the integrity of the mitochondria by Preserving the potential of the mitochondrial membrane by Preventing the release of cytochrome-c, Encouraging the synthesis of ATP

Both wound healing and skin regeneration depend on these processes.

Reduction of Inflammation
Melatonin lowers inflammatory reactions by preventing TNF-α, IL-1β, IL-6, IL-8

Inflammasome activation of NLRP3.

It inhibits pro-inflammatory mediators like TNF-α and interleukins, which cause skin inflammation and aging (Hardeland et al., 2012).

Melatonin also helps to maintain the skin barrier by regulating immunological responses in the epidermis (Slominski et al., 2014).

Role of Melatonin in Hair Growth and Hair Follicle Biology and it's Clinical and Cosmetic Applications
Melatonin receptors are present in hair follicles, and they can metabolize melatonin (Fischer et al., 2004).

Melatonin has been demonstrated to alter the hair development cycle by extending the anagen phase and delaying the transition to the catagen phase (Fischer et al., 2004).

Clinical trials have shown that topical melatonin helps prevent hair loss in people with androgenetic alopecia (Fischer et al., 2004).

Melatonin's antioxidant activity also protects hair follicle cells from oxidative stress, which can contribute to hair loss problems (Reiter et al., 2014).

As a result, melatonin is increasingly being investigated as a medicinal agent for hair restoration.

Melatonin has acquired popularity in dermatology and cosmetology due to its multifunctional qualities (Slominski et al., 2018).

Melatonin-based topical preparations are being explored for anti-aging, photoprotection, and hair growth promotion (Hardeland et al., 2012).

The Role of Melatonin in Skin Aging

Skin aging is caused by both internal and extrinsic mechanisms, with oxidative stress and mitochondrial dysfunction playing a primary role.

Melatonin delays aging by Prevents collagen breakdown, enhancing fibroblast function, increasing hydration and elasticity, Protecting mitochondrial DNA, Reducing oxidative stress.

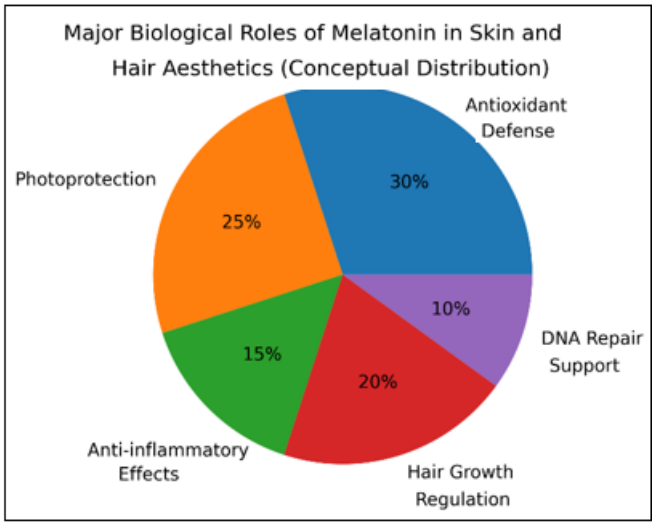
Clinical research indicates that topical melatonin dramatically improves Skin tonicity, Hydration, Wrinkle depth.

Melatonin and Hair Follicle Biology
Human hair follicles have a functioning melatoninergic signaling system that controls the hair growth cycle.

Melatonin stimulates hair regrowth by Activates MT1 and MT2 receptors in hair follicles leading to Prolonging the anagen phase, Protecting follicles against oxidative stress. And Provides anti-androgenic actions.

Its capacity to neutralize free radicals and heal cellular damage makes it an appealing element for skincare and trichology products (Tan et al., 2015).

Furthermore, melatonin-based therapy may be a safer alternative to traditional treatments for certain dermatological diseases.



Clinical applications of melatonine in aesthetic medicine

Melatonin is becoming increasingly used in dermatology and cosmetic practice.

Treatment Modalities includesTopical formulations, Mesotherapy, Combined with microneedling, Hair Growth Serums, and in protocols for healing after the surgery

Melatonin works best when applied before UV exposure for photoprotection and in the evening for hair growth treatments.

3. Conclusion

Melatonin is a versatile chemical that plays important roles in skin protection and hair follicle development. Its strong antioxidant, anti-inflammatory, and photoprotective characteristics make it a vital skin protectant. Furthermore, melatonin regulates hair growth cycles and has potential use in hair restoration therapies. According to emerging studies, melatonin could be a helpful medicinal and cosmetic element for skin protection and hair regeneration. More clinical research is needed to better understand its mechanisms and optimize its use in dermatological practice.

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Author Profile

Dr. Preeti Chopade is the Head of Department at IICAN Institute and a BHMS graduate with over five years of experience in cosmetology, aesthetic medicine, and medical education. She has worked with several cosmetology institutes as a Department Head, contributing to academic training, mentoring, and hands-on clinical practice in aesthetic procedures. Her professional interests include cosmetic dermatology and evidence-based aesthetic practice.