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Review Article

Emerging treatment for post-inflammatory hyperpigmentation in dark-skinned individuals: a review of the current literatures

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ABSTRACT

Post-inflammatory hyperpigmentation (PIH) is a prevalent and psychologically distressing condition, particularly for individuals with dark skin (Fitzpatrick types III-VI). The heightened susceptibility and severity in this population are linked to unique molecular and structural skin characteristics, including a predisposition to inflammation, which can be exacerbated by conventional treatments like high-concentration chemical peels and aggressive laser therapies. This paper presents a narrative literature review that synthesizes current research on emerging and optimized treatment strategies for PIH in dark-skinned individuals. A focused search of peer-reviewed articles and clinical abstracts revealed that successful management relies on a multi-faceted approach. Key findings include the efficacy and favorable safety profiles of new topical agents such as azelaic acid, adapalene, and cysteamine cream, which possess dual anti-melanogenic and anti-inflammatory properties. Procedural advancements emphasize conservative, low-fluence laser techniques (e.g.,1064-nm Nd:YAG) combined with robust pre- and post-procedure regimens. Most importantly, a consistent, daily photoprotection regimen with broad-spectrum sunscreen is confirmed as the single most effective preventive measure. The review concludes that moving beyond conventional monotherapies to a nuanced, combination-based approach is essential for enhancing outcomes, minimizing adverse effects, and improving the quality of life for individuals with PIH in dark skin.

Keywords: Post-inflammatory hyperpigmentation, Emerging treatments, Anti-inflammatory, Photoprotection, Dark skin

INTRODUCTION

Post-inflammatory hyperpigmentation (PIH) is a common dermatological condition characterized by the formation of darkened macules or patches on the skin following an inflammatory event, such as acne, atopic dermatitis, injuries, or cosmetic procedures.[1,2] This process, known as hypermelanosis, results from the overproduction and irregular deposition of melanin in the skin in response to inflammatory triggers.[3] While PIH can affect individuals of all skin tones, it is particularly prevalent and often more severe in individuals with darkly pigmented skin, corresponding to Fitzpatrick skin types III-VI.[2-4] A recent international survey confirmed this, revealing that 15% of the global population self-reports suffering from PIH, with a disproportionately high representation of individuals with phototype IV or higher.[5] The impact of PIH extends beyond cosmetic concerns. The discoloration can be persistent and psychologically distressing, significantly affecting a patient's quality of life (QOL) and leading to social stigmatization. The large international survey on PIH demonstrated that 35% of

respondents with the condition reported a high impact on their QOL, and 26% faced discrimination at work, underscoring the serious social and emotional burden of this disorder.[5] This heightened susceptibility and impact in dark-skinned individuals is attributed to unique molecular and structural characteristics of the skin. Research into the molecular mechanisms of PIH in dark skin suggests a predisposition to systemic and localized inflammation, which triggers a more pronounced and prolonged melanogenic response. These factors, coupled with structural differences such as a potentially less robust epidermal barrier and weaker dermal-epidermal junctions, make darkly pigmented skin more vulnerable to both the development of PIH and complications from aggressive treatments.[2]

Historically, conventional treatments for hyperpigmentation have included topical agents like hydroquinone, retinoids, and azelaic acid, as well as procedures such as chemical peels and laser therapy.[3] However, many of these therapies present significant limitations for dark skin types. For example, higher-concentration chemical peels and certain laser types can trigger new or worsened inflammation, leading to paradoxical hyperpigmentation and, in some cases, excessive scarring like keloids.[2-6] The risk of adverse effects with these conventional treatments highlights a critical need for therapies that are not only effective in reducing melanin but also possess anti-inflammatory properties and are specifically tailored for the unique characteristics of dark skin.

This review aims to synthesize the current literature on emerging treatments for PIH in dark-skinned individuals. It will explore novel therapeutic approaches that are gaining traction in dermatological practice, including new topical agents with dual anti-melanogenic and anti-inflammatory mechanisms, innovative drug delivery systems that enhance efficacy while minimizing irritation, and procedural advancements optimized for skin of color. Specifically, this review will examine the roles of oral agents like tranexamic acid and ν-3 polyunsaturated fatty acids (ν-3 PUFAs) in preventing PIH after laser treatment, as well as the potential of novel formulations such as solid lipid nanocarriers and liposomes.[3-7] By reviewing these emerging therapies, this paper seeks to provide a comprehensive overview of the most promising, safe, and effective strategies for managing PIH in the dark-skinned population.

METHODS

This paper presents a narrative literature review that synthesizes and evaluates current research on the management of post-inflammatory hyperpigmentation (PIH) in dark-skinned individuals. The primary objective of this review is to provide a comprehensive overview of the molecular mechanisms underlying PIH and to critically analyze the efficacy, safety, and novelty of emerging treatment strategies specifically for Fitzpatrick skin types III-VI.

Search strategy and data sources

A focused search was conducted to identify relevant literature from dermatological and scientific sources. The search terms used included, but were not limited to, "post-inflammatory hyperpigmentation," "PIH," "dark skin," "Fitzpatrick skin types III-VI," "treatment," "emerging therapies," "nanocarriers," "nanoparticles," "laser therapy," "chemical peels," "oral supplementation," "omega-3," and "tranexamic acid." The materials for this review were drawn from peer-reviewed articles, abstracts from medical conferences, and other review papers that addressed the topic. The selected literature provided insights into the epidemiology, molecular pathology, and clinical outcomes of various treatment modalities.

Inclusion and exclusion criteria

The review included publications that met specific criteria. We selected articles directly addressing the pathogenesis or management of post-inflammatory PIH, with a particular focus on studies and reviews that included or focused on patient populations with Fitzpatrick skin types III-VI. The literature we considered detailed conventional, novel, and emerging therapies, such as topical agents, oral supplements, and procedural interventions. For publication types, we considered primary research studies, clinical trial abstracts, and comprehensive review articles. Publications were excluded if they focused on hyperpigmentation disorders other than PIH (e.g., vitiligo) or if their findings were not relevant to the management of PIH in dark-skinned individuals.

Data extraction and synthesis

We systematically extracted and categorized information from the selected literature based on key themes. The data we collected included prevalence and epidemiological information on PIH, as well as molecular and histopathological mechanisms with a specific focus on inflammatory pathways. We also gathered details on the clinical outcomes and efficacy of both conventional and novel treatment modalities, along with the safety profiles and reported adverse effects of treatments in darker skin tones. Finally, we documented innovations in drug delivery systems and procedural techniques. We then synthesized this extracted information into a thematic narrative. This approach allowed for a critical discussion of the evolving understanding of PIH in dark skin and an informed evaluation of the most promising emerging therapies. No original research was conducted, and no human or animal subjects were involved in the preparation of this review. The conclusions and recommendations presented are based solely on a careful analysis and interpretation of the provided literature.

EMERGING TREATMENTS FOR POST-INFLAMMATORY HYPERPIGMENTATION IN DARK-SKINNED INDIVIDUALS

Novel topical agents and formulations

While classic topical agents like hydroquinone and retinoids remain staples, recent literature highlights the increasing focus on alternatives that are both effective and well-tolerated in skin of color. New agents often work by inhibiting tyrosinase, scavenging reactive oxygen species, and possessing anti-inflammatory properties, which are crucial for PIH.

Azelaic acid and adapalene

These agents are well-established but continue to be a cornerstone of PIH treatment, particularly for cases stemming from acne. Azelaic acid, a dicarboxylic acid, works by competitively inhibiting tyrosinase and has anti-inflammatory properties that make it a gentle option.[8] Adapalene, a topical retinoid, accelerates cell turnover and reduces inflammation, helping to fade dark spots and treat the underlying acne.[9] Studies have shown that both are well-tolerated and effective in patients with skin of color, with adapalene demonstrating significant reductions in inflammatory lesions among African American patients compared to Caucasian patients.[8]

Tranexamic acid (TXA)

While more commonly studied for melasma, topical tranexamic acid has shown promise for PIH by inhibiting plasminogen activators, which are involved in melanogenesis. A systematic review and meta-analysis of microneedling with topical TXA for melasma found significant improvements, suggesting a potential role for this combination in PIH as well.[10]

Cysteamine cream

Cysteamine, a naturally occurring antioxidant, has emerged as a promising non-hydroquinone option for hyperpigmentation. It works by inhibiting tyrosinase and peroxidase enzymes, scavenging dopaquinone, and increasing intracellular glutathione.[11] A randomized, double-blind, placebo-controlled clinical trial confirmed the efficacy of a 5% cysteamine cream for epidermal melasma, a condition with similar underlying mechanisms to PIH, and it is suitable for all skin types with a favorable safety profile.[11]

Procedural advancements: lasers and chemical peels

Procedural interventions in dark skin require a meticulous approach to prevent new inflammation and subsequent PIH. The literature emphasizes conservative, low-fluence settings and combination therapy.

Refined laser techniques

Modern laser protocols for skin of color favor wavelengths with minimal absorption by epidermal melanin, such as the 1064-nm Nd:YAG and picosecond lasers.[12] A conservative, low-fluence approach with these lasers is crucial to gradually break down pigment without causing thermal injury that could trigger PIH.[13] A small case series showed that a combination of topical skin lighteners with low-density, low-fluence fractional nonablative lasers was both safe and effective for treating PIH in Fitzpatrick skin types V and VI.[14]

Pre- and post-procedure regimens

An essential component of a successful procedural outcome is a robust skincare regimen before and after the treatment. A study comparing laser with and without a topical triple combination cream (TCC) found that pre-treatment with the TCC was more effective as it decreased melanin production prior to the laser injury, thereby reducing the chances of PIH.[15] Similarly, a systematic review on PIH prevention found that applying topical corticosteroids after fractional CO2 laser treatments significantly decreased the intensity and size of PIH.[16]

The importance of photoprotection and adjuvant therapies

Sunscreen as a primary preventive

A systematic review on preventing trauma-induced PIH in skin of color confirmed that consistent use of a broad-spectrum sunscreen is the most effective single measure.[16] The review found that sunscreen alone prevented PIH in 98% of cases over a two-month follow-up period, and when combined with anti-inflammatory ingredients like lichocalcone A and L-carnitine, it achieved a 100% success rate.[16] This highlights the critical need for patient education on the importance of daily photoprotection for managing and preventing PIH, even in individuals who may not typically use sunscreen.

Oral and other agents

While the efficacy of oral tranexamic acid for preventing PIH after laser procedures has shown mixed results, it remains a topic of ongoing research, with some studies demonstrating its benefit in combination regimens.[17] Additionally, other agents like bakuchiol have been found to be effective for trichloroacetic acid-induced PIH, but not for acne-induced PIH.[16] indicating that the choice of therapy may need to be tailored to the specific cause of the pigmentation.

CONCLUSION

The management of PIH in dark-skinned individuals is a complex and evolving field. While conventional therapies

remain relevant, the literature points to a growing body of evidence supporting a more nuanced and combination-based approach. Emerging treatments focus on dual-action ingredients that are both anti-melanogenic and anti-inflammatory, novel procedural protocols that prioritize safety, and the essential role of pre- and post-procedure care. The most promising strategies include using well-tolerated topical agents like azelaic acid and adapalene, employing conservative laser settings with a focus on pre-treatment with depigmenting agents, and, most importantly, educating patients on the non-negotiable role of daily photoprotection. As research continues to fill the gaps in understanding the specific needs of skin of color, there is considerable optimism for enhancing intervention strategies and improving the quality of life for those affected by PIH.

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