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Original Article

Role of Vitamin C in Skin Aging Mechanism-A Narrative Review

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ABSTRACT

Background: The cosmetics industry has seen significant growth due to the pursuit of beauty and the increasing demand for anti-aging agents. These agents, derived from active ingredients like polyphenols, retinol, and pro-xylane, are categorized into synthetic, plant, and fermentation components. Among these, synthetic components such as vitamins A, B, and C are widely used. Vitamin C has long been utilized in food and medicine for its beneficial effects, including its crucial role in collagen formation. The aging process, while slow and prolonged, is significantly influenced by vitamin C, making it an indispensable component for skin health.

Objective: This study aimed to determine how vitamin C helps reduce aging and controls the mechanisms associated with skin aging.

Methods: A comprehensive narrative review was conducted by synthesizing existing literature from electronic databases such as PubMed, Scopus, and Google Scholar. The search included keywords like "Vitamin C," "skin aging," "collagen synthesis," "oxidative stress," and "melanogenesis." Studies included were peer-reviewed, written in English, and published within the last 20 years. Both in vivo and in vitro studies were considered to assess the biochemical functions of vitamin C, its protective roles against UV radiation, and its therapeutic potential in various skin conditions. Data were critically analyzed, focusing on study designs, sample sizes, and statistical analyses.

Results: Vitamin C was found to enhance collagen synthesis, with studies showing a significant increase in collagen production (Makrantonaki & Zouboulis, 2007). Its antioxidant properties effectively neutralized reactive oxygen species, reducing oxidative stress and preventing DNA damage, with a reduction of ROS levels by 30-50% in UV-exposed skin cells (Rinnerthaler et al., 2015). Inhibitory effects on melanogenesis were observed, with vitamin C reducing melanin synthesis by 25% (Shimada et al., 2009). Additionally, therapeutic benefits were noted in treating acne, psoriasis, and hyperpigmentation, with a 40% improvement in acne scars (Chawla, 2014) and a 35% reduction in psoriasis symptoms (Soodgupta et al., 2014).

Conclusion: Vitamin C plays a crucial role in maintaining skin health and combating aging through various mechanisms, including enhancing collagen synthesis, providing antioxidant protection, inhibiting melanogenesis, and treating skin diseases. Its consistent findings across multiple studies support its continued use in clinical and cosmetic dermatology. Further research with standardized methodologies is recommended to optimize its application and fully understand its potential.

Keywords: Vitamin C, skin aging, collagen synthesis, oxidative stress, melanogenesis, anti-aging, dermatology, skin health, UV protection, acne treatment, psoriasis, hyperpigmentation.

INTRODUCTION

The skin plays a vital role in human aesthetics, significantly influencing social and reproductive lives by providing beauty and a youthful appearance. As individuals age, their skin exhibits noticeable signs of aging, such as dryness, thinning, and the formation of wrinkles, driven by both intrinsic and extrinsic factors (1, 2). Intrinsic factors include genetic predispositions and metabolic processes, while extrinsic factors encompass environmental influences such as smoking, poor diet, air pollution, and particularly ultraviolet (UV) radiation, which leads to photo-aging (2-4). UV exposure affects up to 80% of facial skin, altering the differentiation of epidermal keratinocytes and reducing the expression of critical proteins like β1-integrin and type VII collagen, thereby contributing to wrinkle formation (5-8). These changes underscore the complex interplay between genetic and environmental factors in skin aging, necessitating extensive research to develop effective anti-aging treatments (8-10).

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The pursuit of beauty and the desire to maintain a youthful appearance have fueled the growth of the cosmetics industry, with consumers increasingly seeking anti-aging agents derived from active ingredients like polyphenols, retinol, and pro-xylane. Among these, vitamin C (VITC) has garnered significant attention for its multifaceted role in delaying the aging process and enhancing skin health (10-13). VITC, also known as ascorbic acid, is a water-soluble vitamin integral to various biochemical functions, including collagen synthesis, antioxidant defense, proline hydroxylation, and the detoxification of histamine. It also activates several hormones and enhances the phagocytic activity of leukocytes (13-15). The human body cannot synthesize VITC; hence, it must be obtained through diet, with the recommended daily intake ranging from 40 to 60 mg. VITC levels vary across different organs, being highest in skeletal muscles, liver, and brain, and lower in the thyroid and testis (16-18). In the skin, VITC is present in higher concentrations in the epidermis compared to the dermis, facilitated by sodium-ascorbate cotransporters (SVCT1 in the epidermis and SVCT2 in the dermis), which underscores its critical role in skin physiology (19, 20).

VITC's role in skin health extends to its protective effects against UV-induced oxidative stress. UV radiation, particularly UVA, induces oxidative stress by generating reactive oxygen species (ROS), which can damage DNA, proteins, and lipids, ultimately leading to skin cancer (21-24). The skin's antioxidant system, comprising both enzymatic (superoxide dismutase, catalase) and non-enzymatic (VITC, glutathione, vitamin E) components, mitigates these harmful effects (19). VITC supplementation and topical application have been shown to reduce UV-induced oxidative damage by decreasing the production of matrix metalloproteinase-1 (MMP-1), an enzyme that degrades collagen, thereby preserving the skin's structural integrity (25-27).

Furthermore, VITC inhibits melanogenesis, the process by which melanin is produced in the skin. While the exact mechanism remains unclear, some studies suggest that VITC, particularly when used in combination with vitamin E, can reduce melanin production by inhibiting the tyrosinase enzyme, which catalyzes the oxidation of tyrosine to melanin (28-31). This property makes VITC a valuable component in treatments aimed at reducing hyperpigmentation and maintaining even skin tone. Additionally, VITC promotes the differentiation of keratinocytes, which is crucial for maintaining the skin barrier's integrity and preventing transepidermal water loss, thereby preserving skin hydration (19).

The therapeutic potential of VITC extends to various skin diseases. It has been shown to be effective in the treatment of conditions such as atopic dermatitis, porphyria cutanea tarda, malignant melanoma, herpes zoster, and postherpetic neuralgia. In acne treatment, VITC, in combination with clarithromycin and zinc, has demonstrated efficacy in reducing inflammation and improving skin health. VITC is also utilized in microneedling procedures to minimize acne scars and is frequently incorporated into treatments for allergic skin conditions (32-38). The diverse applications of VITC in dermatology highlight its significance as a potent anti-aging and therapeutic agent.

In conclusion, skin aging is a multifactorial process influenced by both genetic and environmental factors. VITC emerges as a crucial nutrient in mitigating skin aging, owing to its roles in collagen synthesis, antioxidant defense, and skin barrier maintenance. Regular dietary intake and topical application of VITC can significantly enhance skin health and delay the aging process, making it an indispensable component of anti-aging strategies. Continued research into the molecular mechanisms of VITC's effects on the skin will further elucidate its potential in dermatological applications (20, 21).

MATERIAL AND METHODS

The narrative review on the role of vitamin C in the skin aging mechanism was conducted by synthesizing existing literature from various sources, including scientific journals, books, and reputable online databases. The study adhered to the ethical principles outlined in the Declaration of Helsinki and did not involve any human or animal subjects, thereby not requiring formal ethical approval. However, all efforts were made to ensure the integrity and accuracy of the data presented.

The data collection process involved a comprehensive search of electronic databases such as PubMed, Scopus, and Google Scholar. Keywords such as "Vitamin C," "skin aging," "collagen synthesis," "oxidative stress," and "melanogenesis" were used to identify relevant studies. Inclusion criteria for the selected studies were that they must be peer-reviewed, written in English, and published within the last 20 years. Studies focusing on the biochemical mechanisms of vitamin C in skin health, its role in anti-aging, and its application in dermatological treatments were prioritized. Articles not meeting these criteria, including those not related to skin health or vitamin C, were excluded.

The assessment of the gathered literature was performed by critically analyzing the methodologies, results, and conclusions of the selected studies. This involved evaluating the experimental designs, sample sizes, statistical analyses, and the reproducibility of the findings. The quality of the studies was also assessed based on the impact factor of the journals in which they were published and the citations they had received.

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Data synthesis was carried out by categorizing the findings into different thematic areas such as collagen synthesis, antioxidant activity, inhibition of melanogenesis, and the treatment of skin diseases. This approach allowed for a structured presentation of the role of vitamin C in skin health and aging.

Throughout the review, efforts were made to ensure the unbiased representation of the data. Conflicts of interest, if any, were disclosed, and the potential limitations of the included studies were acknowledged. The review also adhered to the principles of transparency and reproducibility by providing detailed descriptions of the search strategy and selection criteria.

In the synthesis of findings, vitamin C's role in collagen synthesis was highlighted, emphasizing its necessity for the hydroxylation of proline and lysine, which are essential for stable collagen triple-helix formation (12). Its antioxidant properties were discussed in the context of neutralizing reactive oxygen species and protecting the skin from UV-induced oxidative damage (19). The review also covered the role of vitamin C in inhibiting melanogenesis by interacting with copper ions in the tyrosinase enzyme, thus reducing melanin production (28-31). Furthermore, the therapeutic applications of vitamin C in treating various skin conditions, such as acne, atopic dermatitis, and hyperpigmentation, were explored (32-38).

This review aimed to provide a comprehensive understanding of the multifaceted role of vitamin C in skin health and aging, drawing on the latest scientific evidence to inform future research and clinical practices. All references were cited appropriately to ensure the credibility and traceability of the information presented.

RESULTS

The narrative review synthesized findings from multiple studies examining the role of vitamin C in skin aging and its related mechanisms. The results are categorized into several key areas, including collagen synthesis, antioxidant activity, inhibition of melanogenesis, and treatment of skin diseases. The data is presented in both descriptive and tabulated formats for clarity.

Collagen Synthesis

Vitamin C is essential for the hydroxylation of proline and lysine, which are crucial for the formation of stable collagen triple helices. Studies consistently showed that vitamin C supplementation enhances collagen production, thereby improving skin elasticity and reducing wrinkles.

Table 1: Vitamin C and Collagen Synthesis: Insights from In Vivo, In Vitro, and Clinical Studies

Study	Method	Key Findings
Cao et al. (2020)	In vivo and in vitro studies	Vitamin C promotes collagen synthesis by stabilizing collagen mRNA (1).
Makrantonaki & Zouboulis (2007)	Clinical trials	Increased collagen production observed with topical application of vitamin C (8).

Antioxidant Activity

Vitamin C acts as a potent antioxidant, neutralizing reactive oxygen species (ROS) generated by UV radiation. This activity protects the skin from oxidative stress, preventing DNA damage and reducing the risk of skin cancer.

Table 2: Vitamin C's Role in Reducing Oxidative Stress and Inflammation in Skin Cells

Study	Method	Key Findings
Rinnerthaler et al. (2015)	Oxidative stress assays	Vitamin C significantly reduces ROS levels in UV-exposed skin cells (26).
Godic et al. (2014)	Clinical observations	Topical application of vitamin C decreases oxidative damage and inflammation (27).

Inhibition of Melanogenesis

Vitamin C inhibits melanogenesis by interacting with copper ions in the tyrosinase enzyme, thereby reducing melanin production and preventing hyperpigmentation.

Table 3: Vitamin C and Melanin Synthesis: Biochemical and In Vivo Evidence

Study	Method	Key Findings
Shimada et al. (2009)	Biochemical assays	Vitamin C reduces melanin synthesis by inhibiting tyrosinase activity (31).
Panich et al. (2011)	In vivo studies	Combination of vitamin C and vitamin E showed enhanced inhibition of melanogenesis (30).

Treatment of Skin Diseases

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Vitamin C has therapeutic potential in treating various skin conditions such as acne, atopic dermatitis, and hyperpigmentation. Its anti-inflammatory and antioxidant properties contribute to its efficacy in these treatments.

Table 4: Impact of Vitamin C on Skin Conditions

Study	Condition	Treatment	Key Findings
Chawla (2014)	Acne	Microneedling with vitamin C	Significant reduction in acne scars (33).
Soodgupta et al. (2014)	Psoriasis	Oral and topical vitamin C	Improvement in skin lesions and reduction in inflammation (36).

Summary of Key Findings

The review revealed that vitamin C plays a crucial role in maintaining skin health and combating aging through various mechanisms. Its ability to enhance collagen synthesis, protect against oxidative stress, inhibit melanin production, and treat skin diseases underscores its significance as a vital nutrient in dermatology.

In summary, the comprehensive analysis of existing literature confirmed that vitamin C is indispensable for skin health, with multiple studies supporting its beneficial effects in anti-aging and skin disease treatments. These findings provide a robust foundation for future research and clinical applications of vitamin C in dermatology.

DISCUSSION

The findings of this narrative review underscored the multifaceted role of vitamin C in skin health, particularly its impact on aging mechanisms. Vitamin C, or ascorbic acid, was found to be integral in collagen synthesis, functioning as a potent antioxidant, inhibiting melanogenesis, and providing therapeutic benefits for various skin conditions. These results were consistent with prior research, confirming the essential nature of vitamin C in dermatology.

Collagen synthesis, a critical process for maintaining skin elasticity and structure, was significantly enhanced by vitamin C. Previous studies demonstrated that vitamin C stabilizes collagen mRNA, thus promoting collagen production and reducing wrinkles (24). This review reinforced these findings, highlighting the importance of vitamin C in anti-aging treatments.

The antioxidant properties of vitamin C were also well-documented. The ability of vitamin C to neutralize reactive oxygen species (ROS) generated by UV radiation plays a crucial role in protecting the skin from oxidative stress. This protection not only prevents DNA damage but also reduces the risk of skin cancer. Studies consistently showed that vitamin C application decreased oxidative damage and inflammation, supporting its use as a preventative measure against photo-aging (7, 16).

In terms of inhibiting melanogenesis, vitamin C's interaction with copper ions in the tyrosinase enzyme reduced melanin production, thereby preventing hyperpigmentation. Although some studies suggested that vitamin C alone might not significantly inhibit melanogenesis, its combination with vitamin E showed a more potent effect, indicating a synergistic relationship between these antioxidants (21-23).

The therapeutic potential of vitamin C in treating various skin conditions, such as acne, atopic dermatitis, and hyperpigmentation, was another crucial finding. Its anti-inflammatory and antioxidant properties contributed to its efficacy in these treatments. For instance, the use of microneedling with vitamin C significantly reduced acne scars, while oral and topical vitamin C improved symptoms of psoriasis by reducing inflammation (26-34).

This review had several strengths, including a comprehensive synthesis of recent and relevant studies, which provided a robust understanding of vitamin C's role in skin health. The inclusion of both in vivo and in vitro studies ensured a well-rounded perspective on its biochemical and clinical effects. However, there were also limitations. The variability in study designs, sample sizes, and methods of vitamin C application posed challenges in drawing definitive conclusions. Additionally, the review primarily relied on published literature, which may be subject to publication bias (35-37).

Future research should focus on standardized methodologies to evaluate the efficacy of vitamin C in dermatological applications more consistently. Longitudinal studies with larger sample sizes could provide more definitive evidence of its long-term benefits and potential side effects. Exploring the synergistic effects of vitamin C with other antioxidants and its role in different skin types and conditions could further enhance our understanding and application of this vital nutrient (38).

CONCLUSION

In conclusion, this narrative review confirmed the significant role of vitamin C in maintaining skin health and combating the aging process. Its ability to enhance collagen synthesis, protect against oxidative stress, inhibit melanin production, and treat various skin diseases underscores its importance in dermatology. While there are limitations and variability in existing research, the consistent

findings support the continued use and exploration of vitamin C in clinical and cosmetic dermatology. Further research is warranted to optimize its application and fully understand its potential in improving skin health.

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