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Newer developments in the treatment of aesthetic lesions caused by excessive exposure of the skin to blue light

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Abstract
Blue light, with wavelengths from 400 nm to 500 nm, is an important part of the sun's electromagnetic radiation spectrum, which is present in human daily life, especially in the modern era due to the increased use of electronic devices through their screens. Low-energy and low time of expo-sure to blue light can enhance the prevention of certain skin conditions such as psoriasis, eczema, and atopic dermatitis, while studies have demonstrated that prolonged exposure to high-energy blue light can increase the amount of skin damage. DNA, cell death, skin barrier and fibroblast damage, hyperpigmentation, and photoaging. Therefore, in the fields of aesthetics and cosmetology, it is important to study the problems caused by exposure to the blue radiation spectrum. Improved protection filters, extracts of plant products, a variety of antioxidants, and natural ingredients from plants and algae are added to cosmetic products and compose innovative formulations as part of a comprehensive photoprotection strategy. In recent decades, antiaging strategies have been developed that include minimally invasive treatments with remarkable safety and efficacy and reduced recovery time. A combined approach of these treatments can provide optimal results in repairing the skin damage caused by ultraviolet (UV) and visible radiation and, consequently, in the overall improvement of the appearance of photoaged skin.

KEYWORDS
blue light, blue light protection, skin protection, antioxidants, photoprotection, anti-aging strategies, skin photoaging

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1. INTRODUCTION

The sun is the most important source of ultraviolet, visible, and infrared radiation [1]. Blue light is typically described as falling within the range of 380 nm to 495 nm and can be found in many artificial sources other than the sun, such as light-emitting diodes (LEDs) and electronic device displays [2-4]. In recent decades, skin exposure time to these sources has increased significantly as the population has gradually digitized and these devices are now integral to the functioning of society. Time spent in front of digital devices is constantly increasing, giving rise to the term "screentime" [5]. Therefore, in the field of aesthetics and cosmetology,

it is important to study the problems caused by exposure to the blue radiation spectrum.

Blue light, also known as High Energy Visible Light (HEV light), has been found to have the ability to penetrate deeper into the skin compared to UVA and UVB rays [6], while numerous studies have revealed that prolonged exposure to high-energy blue light increases the production of reactive oxygen species (ROS) [7], causes cellular DNA damage [8], photoaging [9], increases oxidative stress [10] and hyperpigmentation [11], has a negative effect on the epidermal barrier [12], reduces antioxidants [13], affects the circadian rhythm [14], and increasing the oxidative stress in endoplasmic reticulum, enhancing cellular autophagy [15].

Visible light (400–700 nm) and UVA1 radiation (340–400 nm) synergistically induce skin pigmentation and erythema, therefore photoprotection as well as repair of blue light-induced damage are increasingly advocated [16]. This article is a review of the latest developments in active ingredients and treatment protocols related to protecting and reversing the harmful effects of blue light.

2. MATERIALS AND METHODS

An internet search was completed using the PubMed and Scopus databases. The article was implemented using in-depth studies and bibliographic references to povide the latest developments regarding the design of proper innovative cosmetic products and the application of treatment protocols that protect and restore the harmful effects on the skin due to excessive exposure to blue light.

2.1. Photo protection

2.1.1. Protection Filters

A complete sun protection system that acts as a barrier and can neutralize oxidative stress is key to protecting the skin [7].

Zinc oxide (Parsol® ZX, DMS) [17], Titanium Dioxide (Parsol® TX) [18], and Iron Oxides [19] have been shown to be effective, safe, and environmentally friendly in terms of protection from high-energy visible blue light. Iron oxides are added to sunscreen formulations as they improve blue light protection efficacy, enhance the aesthetic appearance of the products [17], and prove effective in preventing pigmentation, showing higher VL-PF in Fitzpatrick IV-VI skin types. In addition, recently developed organic filters BDBP [20] and TriAsorB [21] and the sunscreen formulation TDF® Blu Voile [22] have been shown to provide protection against blue light.

2.1.2. Extracts

Given the current trend for natural products in cosmetics, plant extracts appear among the most promising ingredients for skin care product development [23]. Botanical extracts such as Hydroxytyrosol [24], Deschampsia antarctica Edafence (EDA) [23], Pomegranate extract [25], Rheum rhaponticum L. Rhizome [26], Withania Somnifera [27], and Polypodium leucotomos (Fernblock) [28] are particularly interesting as they are characterized by low toxicity and proved to be effective because, in addition to their photoprotective action against ultraviolet and blue radiation, they also exhibit antioxidant, antiaging, and whitening properties.

2.1.3. Antioxidants

Given the close relationship between blue light-induced oxidative stress and cellular damage, antioxidant protection is important in the photoprotection strategy [29]. Licochalcone A (LicA) [30], Resveratrol [10], Polyphenols [31], and the combination of diethylhexyl syringylidene malonate and vitamin E [32] have been shown to be effective in suppressing ROS formation. In Avadhani's study [33], the co-encapsulation of EGCG (epigallocatechin-3-gallate) and HA (hyaluronic acid) in a single nano-transferosomal carrier system increased the penetration and utilization of the benefits of both components. These nano-transporters help protect the skin from UV radiation. Also, in Elhabak's study [34], the entrapment of a high dose of vitamin C in highly permeable elastic nanovesicles provided the maximum stability and efficacy in antioxidant protection against photodamage and activation of collagen synthesis.

2.1.4. Natural Ingredients

Compared to synthetic and harmful compounds, natural products are biodegradable and gentle on the skin.

Chitosan Oligosaccharide (COS) [35], Waterdrop (Oenanthe javanica) [36], Niacinamide [17], GHK Peptide [37], Black Rice Ethanol Extract [Hernandes], Curcumin (Cur) [38], and numerous marine-derived natural compounds (MDNC-Marine-Derived Natural Compounds) [39] have the potential to develop formulations effective against photoaging and photodamage caused by UV and visible radiation.

2.1.5. Photoprotection: Antiaging Formulas

Alto Defense SerumTM [29], Night Cream (NC) with niacinamide, hyaluronic acid, carnosine, matricin peptides, and melatonin [40], sunscreen

formulation with vitamin E, vitamin C, diethylhexyl syringylidene malonate, licochalcone A, and glycyrrhetinic acid [41], as well as the cosmetic cream (o/w) containing EAE (ethyl ascorbyl ether) [42] proved to be effective formulations that protect against the harmful effects of UV radiation, blue light, and IR wavelengths, neutralizing free roots and providing anti-inflammatory action. The results of the studies showed that transdermal water loss is reduced, skin hydration and elasticity are restored, and the skin barrier is restored. At the same time, the production of new collagen is enhanced, increasing the elasticity of the skin; brightness increases; and the levels of redness and hyperpigmentation are reduced, demonstrating overall photoprotective effects.

2.2. Treatment Protocols

Anti-aging strategies with individual or combined treatment protocols aim to increase skin hydration, enhance its regenerative capacity, activate the creation of new collagen, and strengthen pre-existing collagen and elastin fibers, addressing the overall skin characteristics of photoaging and restoring the skin from the damage of solar and blue radiation.

2.2.1. Mesotherapy

Mesotherapy methods with either the electroporation technique or the microneedling technique are considered safe and effective protocols for the penetration of active ingredients and skin regeneration [43]. Also, the study by Kim [44] evaluated the ability of a topical liquid formulation of polydeoxyribonucleotide (PDRN), vitamin C, and niacinamide (PVN) delivered via a microneedling therapy system (MTS) to reduce photoaging and pigmentation in a radiation animal model (UV-B).

2.2.2. Radio Frequencies

Fractional RF devices and Fractional Microneedling RF energy systems are proving to be safe and effective protocols for improving skin laxity and wrinkles [45-50]. In addition, it is among the newly introduced technologies for skin regeneration with increased efficiency, faster recovery, shorter recovery time, and fewer side effects on the reticular dermis.

2.2.3. Lasers

Lasers resurface the skin, and the exfoliation they cause makes them capable of reducing fine lines, but they also potentially have the benefit of treating deeper lines by stimulating the creation of new collagen. In particular, the Low-Fluence Q-Switched Nd:YAG laser (LFQSNY) [51], the 1064-nm Nd:YAG picosecond laser [52], and the combination of the 595-nm pulsed laser (PDL) with the low-power fractional diode laser in 1927 nm (FDL) have been shown by studies to be safe and effective treatments in the treatment of melasma[53].

At the same time, photobiomodulation lasers (PBM) [54] and intense pulsed light (IPL) treatments have a significant effect on skin tone, activating collagen synthesis, which leads to an increase in skin tightening. In addition, the combination of IPL with non-ablative fractional laser (NAFL) in a single-session treatment protocol was shown to be safe and resulted in a synergistic and long-lasting effect on the various clinical manifestations of photoaged skin [55].

2.2.4. Ultrasonics

Numerous independent and company-sponsored clinical studies and publications have demonstrated the safety and effectiveness of micro-focused ultrasound with visualization (MFU-V) in skin rejuvenation. Findings show that HIFU treatment lifts and tightens the skin through the formation and rearrangement of skin collagen [56-57]

2.2.5. Stem cells

In a recent study showed that topical application of ADSC-CM (human adipocyte-derived mesenchymal stem cell) in combination with 2% niacinamide further reduced wrinkles and pigmentary skin lesions after fractional ablative laser treatment, providing significantly greater skin rejuvenation compared to the vehicle formulation. New stem cell-based therapies using growth factors can repair damaged skin tissue through a direct cellular effect [58].

2.2.6. Platelet-rich plasma

Platelet-rich plasma and the combination of PRP with laser treatments and microneedling work synergistically, enhancing the result. Also, the combination of fractional microneedling (RF) and PRP shows significant improvement in average skin thickness and has been shown to be a powerful, safe, and effective treatment method for mild to moderate laxity in the neck area. PRP shows promising uses in skin rejuvenation; however, more studies are needed to test its validity alone or in combination to improve results [59-60].

3. DISCUSSION

Numerous studies have demonstrated the undeni-

able negative effects of blue light, which is responsible for increased production of reactive oxygen species and increased pigmentation. Recent reports conclude that oxidation of pre-existing melanin appears to contribute to increased pigmentation. It causes damage to cellular DNA, affects the circadian rhythm of cells, inhibits the restoration of the skin barrier after injury, and exhibits strong toxicity to human skin fibroblasts, leading to premature photoaging. It can also damage the structure and elasticity of the skin, thus supporting the need to develop strategies to protect against visible light.

However, further studies considering more parameters besides wavelengths, such as total received doses, radiation, and chronic exposure times, are needed to assess the actual cumulative skin damage. Furthermore, comparison between studies is difficult because most research uses different light sources with different wavelengths, and the studies have been performed in different cells, such as reconstructed human skin, mice, or humans.

The development of new, safe broad-spectrum filters to effectively protect the skin from the effects of solar radiation is an emerging critical issue. In addition, the use of natural and synthetic antioxidants to reduce the harmful effects of reactive oxygen radicals is a new approach to preventing damage caused by blue light exposure. It is a promising strategy to reduce melanogenesis and prevent photoaging [29].

Also, the bioactive compounds obtained from algae show antioxidant, anti-wrinkle, antimicrobial, and photoprotective effects, with the result that the number of commercially produced products from algae is gradually increasing. However, more research is needed to identify the types of algae that are available, and safety issues should be considered when adding them to cosmetic formulations, as they may contain heavy metals, pesticide residues, dioxins, or marine biotoxins.

Age, previous procedures or surgeries, general health, skin type, lifestyle, and many other factors should be considered before choosing any invasive or non-invasive technique. The desired therapeutic effect of anti-aging skin is the continuous, step-by-step process, which combines various methods of biorejuvenation and rejuvenation of the skin with the aim of achieving healthy, smooth, pigment-free, and elastic skin. Fractional microneedling RF has been found to improve melasma through reduced inflammation, increased angiogenesis, and mast cell activity and is therefore part of a combination therapy strategy with concomitant use of treatments ranging from topical to oral medications along with sun protection. It is noteworthy that in clinical practice, melasma did not worsen with fractional radiofrequency needle treatments, as this is often a concern, but further studies are needed [62].

New types of laser devices are emerging, including devices that operate with picosecond pulse duration in combination with a microlens array, which are considered a new breakthrough for skin rejuvenation. Finally, mesenchymal stem cells (MSCs) alone and in combination with microneedling show significant improvements in skin brightness and texture and increased elasticity [55,58].

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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