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Advances in photoaging: causes, treatments, and diagnostic and therapeutic challenges

Saumya Subhra Samantaray
Department of Zoology, Utkal University, Odisha, India

ABSTRACT

Photoaging, or extrinsic ageing, results from prolonged exposure to ultraviolet (UV) rays in the sunlight. Unlike intrinsic ageing, which is driven by genetic and chronological factors, photoaging accelerates visible signs such as wrinkles, loss of skin elasticity, and pigmentation changes due to UV-induced oxidative stress, DNA damage, and inflammation. Photoaging is a prevalent dermatological challenge worldwide, and there is a need to understand the mechanisms behind it, evaluate existing treatments, and identify diagnostic challenges to improve skin health and prevent associated risks. Photoaging is primarily driven by UV radiation, which causes oxidative stress, inflammation, and DNA damage, leading to skin structural degradation. Effective management involves preventive strategies, e.g., sunscreen use, topical treatments, e.g., retinoids, and procedural interventions, e.g., laser therapy. Diagnostic challenges include distinguishing photoaging from intrinsic ageing, identifying subclinical damage, and standardising diagnostic metrics. Variability in skin types and ethnicities further complicates diagnosis and treatment. Photoaging significantly impacts skin health, with implications beyond cosmetic concerns, including increased cancer risk. Effective management requires a multifaceted approach combining prevention, accurate diagnosis, and personalised treatment. Advanced diagnostic technologies to detect early subclinical damage, standardised diagnostic metrics, and personalised treatments for diverse skin types are means to address photoaging efficiently in the future. Emphasising preventive measures and patient education is crucial for long-term skin health globally.

KEYWORDS

Photoaging; Therapeutics; Tgeing; UV radiation; Extrinsic; Sunscreen

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Introduction

Photoaging, also known as extrinsic ageing, is the premature ageing of the skin resulting from prolonged and repeated exposure to ultraviolet (UV) radiation, primarily from the sun [1]. Unlike intrinsic ageing, which is a natural process driven by genetic and chronological factors, photoaging accelerates the appearance of wrinkles, loss of skin elasticity, pigmentation changes, and other visible signs of ageing [2]. This phenomenon is primarily driven by the damaging effects of UV radiation, which penetrates the skin, inducing oxidative stress, DNA damage, and inflammation [3,4]. These mechanisms collectively contribute to the degradation of the skin's structural integrity and the appearance of ageing skin.

Photoaging, a distinct form of ageing, is often confused with intrinsic ageing [4]. However, it is crucial to understand that they are not the same. Intrinsic ageing is a natural, gradual process that affects everyone regardless of their lifestyle or environmental exposure. It is characterised by fine wrinkles, thinning of the skin, and a gradual loss of underlying fat. On the other hand, photoaging results from environmental factors, particularly UV radiation. It manifests as coarse wrinkles, mottled pigmentation, rough skin texture, and telangiectasia, diagnosed by examining visible blood vessels [5]. While intrinsic ageing primarily affects skin not regularly exposed to sunlight, such as the inner arms and thighs, photoaging is most pronounced on sun-exposed areas like the face, neck, and hands.

Photoaging is a widespread issue affecting individuals across different age groups, genders, and ethnicities, although its prevalence and severity can vary significantly [6]. People with fair skin (Fitzpatrick skin types I and II) are more susceptible to photoaging due to their lower levels of melanin, which provides some protection against UV radiation [7]. Additionally, individuals who spend significant time outdoors, whether for work or recreational activities, are at a higher risk. This includes outdoor workers, athletes, and sunbathers. While photoaging can begin [as early as one's twenties, the cumulative effects of UV exposure become more apparent with age, leading to more pronounced signs of photoaging in middle-aged and older adults [6]. The wide demographic range of those affected underscores the importance of understanding and addressing this issue.

Understanding and diagnosing photoaging involves recognising its signs and appreciating the potential for early intervention and prevention. Early diagnosis facilitates timely treatment, improving skin appearance and reducing the risk of skin cancers, which are more common in photoaged skin due to UV-induced DNA damage [7]. Recognising the signs of photoaging can also help differentiate it from other

***Correspondence:** Ms. Saumya Subhra Samantaray, Department of Zoology, Utkal University, Odisha, India, e-mail: biology.saumya@gmail.com

dermatological conditions, ensuring appropriate and effective treatment.

The adverse effects of photoaging extend beyond cosmetic concerns. While the visible signs of photoaging, such as wrinkles and pigmentation, can impact an individual's self-esteem and quality of life, there are significant health implications [8]. Chronic UV exposure not only accelerates skin aging but also increases the risk of developing various forms of skin cancer, including basal cell carcinoma, squamous cell carcinoma, and melanoma. Furthermore, photoaged skin is more prone to developing actinic keratoses, which are precancerous lesions that can progress to squamous cell carcinoma if left untreated [4,9]. These conditions underscore the importance of understanding, preventing, and managing photoaging to protect both skin health and overall well-being.

Effective management of photoaging requires a multifaceted approach combining preventive strategies, accurate diagnosis, and appropriate treatment modalities. Prevention is paramount and includes measures such as regular use of broad-spectrum sunscreens, wearing protective clothing, and avoiding peak sun exposure [10]. In terms of treatment, various options are available, ranging from topical agents like retinoids and antioxidants to procedural interventions such as chemical peels, laser therapy, and dermal fillers [11,12]. Advances in dermatological research continue to enhance our understanding of photoaging, leading to the development of more targeted and effective therapies.

Photoaging is a significant dermatological concern that impacts a wide range of individuals, particularly those with fair skin and high levels of sun exposure [11]. Recognising the importance of diagnosing and managing photoaging is essential not only for maintaining aesthetic appearance but also for preventing more serious skin conditions, including skin cancer. Hence, a clear understanding of the mechanisms and effects of photoaging is essential to plan and implement various strategies for preventing and treating this common yet preventable condition.

Clinical Manifestations of Photoaging

Photoaging, primarily caused by prolonged exposure to ultraviolet (UV) radiation, manifests in various ways on the skin, significantly affecting its appearance and structure [1]. Wrinkles and fine lines are hallmark signs of photoaging. UV radiation accelerates the breakdown of collagen and elastin, essential proteins that maintain the skin's firmness and elasticity. This degradation leads to the formation of fine lines and deeper wrinkles, particularly in sun-exposed areas like the face, neck, and hands [6].

Pigmentation changes, such as solar lentigines and melasma, are also common. Solar lentigines, or age spots, are flat brownish patches that appear due to the localised proliferation of melanocytes and increased melanin production hyperpigmentation [13]. Melasma presents as darker, irregular patches, often on the face, and is exacerbated by sun exposure [11]. These pigmentation alterations result from UV-induced changes in melanocyte activity and distribution.

Loss of skin elasticity and firmness is another significant manifestation [6]. The skin's connective tissue weakens due to cumulative UV damage, leading to sagging and loss of youthful firmness. This loss is more pronounced in areas frequently exposed to the sun and can contribute to a prematurely aged appearance. Telangiectasia, or the appearance of visible blood vessels, occurs as UV radiation damages the small blood vessels in the skin, causing them to dilate and become more noticeable. This condition typically appears on the face and can be exacerbated by chronic sun exposure [7].

Photoaged skin also features a rough texture and actinic keratosis [14]. The skin surface becomes uneven and coarse due to impaired cellular turnover and the accumulation of dead skin cells. Actinic keratosis manifests as rough, scaly patches or lesions caused by prolonged UV exposure and is considered a precancerous condition as it can potentially progress to squamous cell carcinoma if left untreated.

Photoaging significantly impacts the skin's appearance and health, presenting as wrinkles, pigmentation changes, loss of elasticity, visible blood vessels, and rough texture with potential precancerous lesions. Prevention and treatment strategies focus on minimising sun exposure and repairing UV-induced damage.

Cause and Mechanism of Photoaging

Photoaging is primarily driven by the effects of ultraviolet (UV) radiation, which encompasses both UVA and UVB rays [15]. These rays induce distinct yet overlapping damage mechanisms in the skin. The effects of UVA radiation are significant due to its deep penetration into the skin, reaching the dermis. UVA radiation primarily causes damage by generating reactive oxygen species (ROS), leading to oxidative stress. This oxidative stress results in the degradation of cellular components, including lipids, proteins, and DNA. The ROS also triggers cellular signalling pathways that increase the expression of matrix metalloproteinases (MMPs), enzymes that degrade collagen, and elastin in the extracellular matrix. The cumulative effect is the breakdown of structural proteins, contributing to wrinkles and loss of skin elasticity [16].

The effects of UVB radiation are more superficial but equally detrimental. UVB primarily affects the epidermis and directly damages DNA by inducing the formation of cyclobutane pyrimidine dimers (CPDs) [15]. These CPDs cause mutations that can lead to skin cancer if not properly repaired. Additionally, UVB radiation stimulates an inflammatory response, increasing the production of pro-inflammatory cytokines and mediators [17]. This inflammation not only accelerates skin ageing but also compromises the skin's immune function, reducing its ability to repair and protect itself.

The major factors causing photoaging are stated in Table 1. The combined effects of ROS, oxidative stress, and inflammation from both UVA and UVB radiation exacerbate the photoaging process. ROS generated by UV exposure leads to oxidative damage and activates signalling pathways that upregulate MMPs, further degrading collagen and elastin [16]. Inflammation-induced by UVB exposure amplifies oxidative stress and disrupts normal cellular functions [17]. Together, these processes accelerate the breakdown of structural components, impair skin repair mechanisms, and enhance the visible signs of ageing, such as wrinkles, pigmentation changes, and loss of firmness [7]. Various environmental and lifestyle factors also play a crucial role in the manifestation of photoaging along with the genetic predisposition of each individual [6,7,9,18].

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Table 1. The molecular pathways and the characteristic clinical manifestations of photoaging.

Cause	Type of UV Radiation	Mechanisms of Damage	Resulting Skin Effects	References
UVA Radiation	UVA (320-400 nm)	- Penetrates deep into the dermis - Generates reactive oxygen species (ROS) - Increases MMPs	- Breakdown of collagen and elastin - Wrinkles and sagging skin -Pigmentation changes	[15]
UVB Radiation	UVB (290-320 nm)	- Affects primarily the epidermis - Direct DNA damage (formation of CPDs) - Triggers inflammation	- Sunburn - DNA mutations leading to skin cancer - Actinic keratosis	[15]
ROS and Oxidative Stress	Both UVA and UVB	- ROS damage cellular components (DNA, proteins, lipids)	- Accelerated ageing - Cellular dysfunction - Loss of skin structure	[16]
Inflammation	Both UVA and UVB	- UV exposure triggers inflammatory response	- Chronic inflammation - Increased risk of skin disorders - Accelerated degradation of skin matrix	[17]
Environmental Factors	Both UVA and UVB	- Pollution and environmental toxins can enhance UV damage	- Exacerbated oxidative stress - Increased pigmentation and texture irregularities	[6]
Lifestyle Factors	Both UVA and UVB	- Smoking and poor nutrition can exacerbate UV damage	-Decreased collagen production -Reduced skin repair capacity -More pronounced wrinkles	[9]
Intrinsic Aging	N/A	- Genetic and physiological factors	-Thinning skin -Reduced elasticity -Fine lines and wrinkles	[18]
Photoaging and Lifestyle Synergy	Both UVA and UVB	- Combined effect of UV radiation and lifestyle choices	-Compounded skin damage -Accelerated appearance of ageing signs	[7]

Treatment of Photoaging

Early intervention is paramount in preventing further dermal damage and enhancing skin appearance and health [19]. Treatment efficacy varies across different stages of skin ageing [20]. Currently, there are various treatment options available to treat photoaging (Table 1). In the early stage, mild pigmentation and fine lines can be effectively managed with topical treatments such as retinoids, antioxidants, and sunscreen [21]. During the moderate stage, more pronounced wrinkles and uneven skin tone may benefit from non-invasive procedures, including chemical peels, microdermabrasion, and laser therapy [22]. Advanced stages, characterised by deep wrinkles and significant sagging, may necessitate more intensive treatments. Minimally invasive methods, such as Botox injections and dermal fillers, can reduce wrinkles and restore volume, while micro-needling stimulates collagen production to improve skin texture [23,24]. Invasive surgical interventions, including facelifts and blepharoplasty (eyelid surgery), provide more dramatic and long-lasting results but require extended recovery periods [25,26]. Timely and appropriate intervention significantly enhances skin health and appearance (Table 2).

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Table 2. Various treatments are available for photoageing.

Treatment	Mechanism	Efficacy	Side Effects	Additional Notes	References
Retinoids	Increase cell turnover, stimulate collagen production, reduce pigmentation	Improves wrinkles, fine lines, and skin texture	Irritation, dryness, photosensitivity	Gradual introduction recommended	[19]
Vitamin C	Antioxidant, neutralises ROS, promotes collagen synthesis, reduces melanin	Improves brightness, firmness, and reduces pigmentation	Minimal possible irritation in sensitive skin	The stability of formulation is crucial	[21]
Alpha Hydroxy Acids (AHAs)	Exfoliate skin, promote cell turnover, improve moisture content	Effective in reducing fine lines pigmentation, and enhancing skin texture	Irritation, photosensitivity	Gradual introduction recommended	[20]
Niacinamide	Reduces inflammation, improves skin barrier, decreases pigmentation	Improves elasticity, barrier function and reduces discolouration	Generally well-tolerated with minimal side effects	Suitable for most skin types	[22]
Chemical Peels	Controlled exfoliation of the skin, promoting regeneration	Effective in reducing fine lines, pigmentation, and improving skin texture	Varies by peel depth; deeper peels require longer recovery	Types: superficial, medium, and deep peels	[11]
Laser Therapy	Concentrated light energy targets damaged cells, stimulates collagen	Effective for wrinkles, pigmentation, and skin tightening	Varies by laser type; ablative lasers require more downtime	Types: ablative and non-ablative lasers	[22]
Microneedling	Creates micro-injuries to stimulate collagen production and enhance absorption	Improves wrinkles, scars, and skin texture	Redness, swelling for a few days	Minimal downtime required	[27]
Dermal Fillers	Injection of hyaluronic acid or other fillers to restore volume	Immediate improvement in skin plumpness and reduction of deep lines	Temporary results; last 6-12 months	Typically, last 6-12 months	[24]
Botulinum Toxin (Botox)	Temporarily relaxes facial muscles to reduce dynamic wrinkles	Noticeable reduction in wrinkles with effects lasting 3-6 months	Generally safe with minimal side effects	Administered by trained professionals	[23]
Stem Cell Therapy	Use of stem cells to regenerate and repair damaged skin	Potential for long-term improvements in skin health and appearance	Under research, long-term effects are not fully known	Promising future treatment	[26]

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Diagnostic Challenges

Photoaging, the premature ageing of the skin caused by prolonged and repeated exposure to ultraviolet (UV) radiation, presents several challenges in its diagnosis [30]. These challenges complicate the differentiation from chronological ageing, the identification of subclinical damage, the reliance on subjective visual assessments, the lack of standardised diagnostic metrics, and the variability across different skin types and ethnicities [31].

One of the primary challenges in diagnosing photoaging is distinguishing it from chronological ageing, which is the natural ageing process driven by genetic and environmental factors [32]. While chronological ageing manifests as fine lines, loss of elasticity, and thinning of the skin, photoaging specifically results in deep wrinkles, pigmentation changes, and a leathery texture [31]. However, both processes often occur simultaneously, making it difficult to attribute specific skin changes solely to photoaging. Accurate differentiation requires a detailed patient history and an understanding of the individual's sun exposure patterns [33].

Photoaging begins long before visible signs appear on the skin. Subclinical damage, such as DNA mutations and oxidative stress, occurs at the cellular level and may not be detectable through routine visual inspection [31]. Early detection is crucial for effective intervention, yet current diagnostic tools are limited in their ability to identify these early changes [7]. Advanced imaging technologies, such as reflectance confocal microscopy and optical coherence tomography, offer some promise but are not widely accessible in standard dermatological practice [34].

Visual assessment of photoaging is inherently subjective, relying heavily on the clinician's experience and expertise. This subjectivity can lead to inconsistencies in diagnosis, especially among less experienced practitioners [34]. Tools such as the Glogau classification system and the Fitzpatrick scale provide some structure but still depend on visual inspection, which can vary significantly between observers [7,31]. The absence of universally accepted diagnostic metrics further complicates the diagnosis of photoaging. While various scales and tools exist, no single standard exists for measuring and evaluating the extent of photoaged skin [34]. This lack of standardisation hinders the ability to compare clinical outcomes across different studies and practice settings, impacting the development of effective treatment protocols.

Photoaging manifests differently across skin types and ethnicities, adding another layer of complexity to diagnosis [33]. Lighter skin tones tend to show more pronounced wrinkling and pigmentation changes, while darker skin may exhibit uneven skin tone and hyperpigmentation [7]. This variability necessitates a tailored approach to diagnosis and treatment, considering the unique characteristics of each skin type and the individual's ethnic background.

The diagnosis of photoaging is fraught with challenges that require a multifaceted approach. Advancements in diagnostic technologies and a better understanding of skin ageing processes across diverse populations are essential for improving the accuracy and consistency of photoaging diagnoses.

Challenges in the Treatment of Photoaging

The challenges to the treatment of photoaging are as pronounced as the challenges in diagnostics. Treating photoaging effectively requires personalised treatment plans tailored to individual skin types, the severity of the damage, and patient expectations [7]. This personalised approach considers factors such as genetic predispositions, skin type, and the degree of photoaging [35]. While this customisation can enhance treatment efficacy, it also necessitates a thorough initial assessment and continuous monitoring, which can be resource-intensive. Clinicians must balance the need for bespoke treatments with the practicalities of time and cost, ensuring that each patient receives the most appropriate and effective care [36].

The long-term efficacy of treatments for photoaging is a significant challenge. While many treatments, such as topical retinoids, chemical peels, and laser therapies, can provide noticeable short-term improvements, maintaining these results over time can be difficult. Photoaging is an ongoing process, and continued exposure to UV radiation can reverse the benefits of treatment [15]. Additionally, the skin's response to treatment can vary, and some patients may experience a plateau in results despite ongoing therapy. Long-term maintenance often requires a combination of treatments and consistent follow-up, which can be burdensome for both patients and healthcare providers [32].

Treatments for photoaging can come with various side effects, ranging from mild irritation and redness to more severe reactions like blistering and pigmentation changes [11]. Managing these side effects is crucial to ensure patient compliance and satisfaction. For instance, topical retinoids, a common treatment for photoaging, can cause dryness and peeling, which some patients may find intolerable [19]. Laser treatments and chemical peels also carry risks of post-inflammatory hyperpigmentation and scarring, particularly in patients with darker skin types [22]. Balancing efficacy with tolerability is essential to minimise adverse effects and enhance patient adherence to treatment regimens.

The cost and accessibility of treatments for photoaging present significant barriers for many patients. Advanced treatments such as laser therapy, intense pulsed light (IPL), and professional-grade chemical peels can be expensive and are often not covered by insurance, making them inaccessible to individuals with limited financial resources [37]. Additionally, access to skilled dermatologists or aesthetic practitioners who can perform these treatments may be limited, particularly in rural or underserved areas [29]. These barriers can prevent many patients from receiving the optimal treatment for their photoaging concerns.

Preventive strategies are crucial in managing photoaging and should complement any treatment plan. Consistent use of broad-spectrum sunscreens, wearing protective clothing, and minimising sun exposure are foundational preventive measures [38]. Educating patients about the importance of these strategies can enhance the long-term success of treatment by preventing further UV-induced damage [39]. However, ensuring patient adherence to preventive measures can be challenging, requiring a sustained commitment and lifestyle

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changes. Integrating preventive education into treatment plans and reinforcing it during follow-up visits is essential for achieving the best outcomes. A comprehensive approach that combines effective treatment modalities with preventive education and patient-centred care is necessary to address these challenges successfully [35].

Future research in photoaging treatment must address current diagnostic and therapeutic challenges through technological advancements, improved understanding of skin biology, and enhanced patient-centred care [37]. Emerging technologies like artificial intelligence (AI) and machine learning can enhance diagnostic precision by analysing skin images to differentiate photoaging from chronological ageing and identify subclinical damage [40]. AI-driven tools could offer standardised diagnostic metrics, reducing subjectivity in visual assessments. Advances in genomics and proteomics can pave the way for personalised treatment plans tailored to an individual's genetic makeup and specific skin characteristics [18]. This personalized approach ensures better efficacy and tolerability of treatments. The development of novel treatments, such as topical DNA repair enzymes, antioxidants, and advanced laser technologies, could improve long-term outcomes [36-39]. These therapies should aim for minimal side effects and better patient compliance. Incorporating preventive education into routine dermatological care is crucial. Innovations in sunscreen formulations and wearable UV detectors can encourage consistent use and better protection against UV damage [38]. Efforts to make treatments more affordable and accessible, including teledermatology services, can bridge gaps in care, especially in underserved areas [41]. Policies that promote insurance coverage of photoaging treatments can also alleviate financial barriers. With the advancements in research and increasing awareness about photoaging, the diagnosis and treatment of photoaging can become more effective, accessible, and patient-centric.

Conclusions

Photoaging presents significant diagnostic and treatment challenges, including difficulty differentiating it from chronological ageing, detecting subclinical damage, the subjective nature of visual assessments, the lack of standardised diagnostic metrics, and variability across skin types and ethnicities. Effective treatment faces obstacles such as the need for personalised approaches, managing long-term efficacy and side effects, addressing cost and accessibility barriers, and emphasising preventive strategies.

Addressing these challenges requires interdisciplinary approaches integrating dermatology, technology, and patient education. Ongoing research is essential to develop advanced diagnostic tools and innovative treatments tailored to diverse patient needs. Strategies such as leveraging AI for precise diagnostics, embracing personalised medicine, fostering preventive education, and making treatments more accessible and affordable can significantly improve outcomes. Adopting these comprehensive approaches can enhance patient care and effectively manage photoaging.

Disclosure statement

No potential conflict of interest was reported by the author.

References

1. Wanitphakdeedecha R, Yan C, Ng JN, Fundarò S. Absorbable barbed threads for lower facial soft-tissue repositioning in Asians. Dermatol Ther. 2021:1395-1408. https://doi.org/10.1007/s13555-021-00569-x
2. Swift A, Liew S, Weinkle S, Garcia JK, Silberberg MB. The facial aging process from the "inside out". Aesthet Surg J. 2021;41(10):1107-1119. https://doi.org/10.1093/asj/sjaa339
3. Albert AM, Ricanek Jr K, Patterson E. A review of the literature on the aging adult skull and face: Implications for forensic science research and applications. Forensic Sci Int. 2007;172(1):1-9. https://doi.org/10.1016/j.forsciint.2007.03.015
4. Langton AK, Sherratt MJ, Griffiths CE, Watson RE. A new wrinkle on old skin: the role of elastic fibres in skin ageing. Int J Cosmet Sci. 2010;32(5):330-339. https://doi.org/10.1111/j.1468-2494.2010.00574.x
5. Li M, Vierkötter A, Schikowski T, Hüls A, Ding A, Matsui MS, et al. Epidemiological evidence that indoor air pollution from cooking with solid fuels accelerates skin aging in Chinese women. J Dermatol Sci. 2015;79(2):148-154. https://doi.org/10.1016/j.jdermsci.2015.04.001
6. Debacq-Chainiaux F, Leduc C, Verbeke A, Toussaint O. UV, stress and aging. Dermatoendocrinol. 2012;4(3):236-240. https://doi.org/10.4161/derm.23652
7. Oliveira R, Ferreira J, Azevedo LF, Almeida IF. An overview of methods to characterize skin type: focus on visual rating scales and self-report instruments. Cosmetics. 2023;10(1):14. https://doi.org/10.3390/cosmetics10010014
8. Nanzadsuren T, Myatav T, Dorjkhuu A, Ganbat M, Batbold C, Batsuuri B, et al. Skin aging risk factors: A nationwide population study in Mongolia risk factors of skin aging. Plos one. 2022;17(1): e0249506. https://doi.org/10.1371/journal.pone.0249506
9. Clatici VG, Racoceanu D, Dalle C, Voicu C, Tomas-Aragones L, Marron SE. Perceived age and life style. The specific contributions of seven factors involved in health and beauty. Maedica. 2017;12(3):191-201.
10. Kulka M. Mechanisms and treatment of photoaging and photodamage. Using Old Solutions to New Problems-Natural Drug Discovery in the 21st Century. 2013. https://dx.doi.org/10.5772756425
11. Lee CH, Lee KW, Chan LK, Lee KF. Review of chemical peeling in photoaging skin. J Cosmet Med. 2023;7(1):1-5. https://doi.org/10.25056/JCM.2023.7.1.1
12. Poon F, Kang S, Chien AL. Mechanisms and treatments of photoaging. Photodermatol Photoimmuno Photomed. 2015;31(2):65-74. https://doi.org/10.1111/phpp.12145
13. Fanning J, Jacob C, Diaz I, Ibrahim O. Treatment of mild-to-moderate facial cutaneous aging using a combination peel containing 6% trichloroacetic acid and 12% lactic acid. J Cosmet Dermatol. 2023;22(11):3033-3041. https://doi.org/10.1111/jocd.15814
14. Belmontesi M. Sequential Treatment of Actinic Keratosis and Photoaging by Daylight PDT and Injectable NASHA Gel as Skin Booster. J Drugs Dermatol. 2020;19(11):1065-1068. https://doi.org/10.36849/jdd.2020.2229
15. Gromkowska-Kępka KJ, Puścion-Jakubik A, Markiewicz-Żukowska R, Socha K. The impact of ultraviolet radiation on skin photoaging—review of in vitro studies. J Cosmet Dermatol. 2021;20(11):3427-3431. https://doi.org/10.1111/jocd.14033
16. Chen X, Yang C, Jiang G. Research progress on skin photoaging and oxidative stress. Adv Dermatol Allergol. 2021;38(6):931-936. https://doi.org/10.5114/ada.2021.112275
17. Salminen A, Kaarniranta K, Kauppinen A. Photoaging: UV radiation-induced inflammation and immunosuppression accelerate the aging process in the skin. Inflamm Res.

https://doi.org/10.61577/amsd.2024.1000010

2022;71(7):817-831. https://doi.org/10.1007/s00011-022-01598-8
18. Yılmaz ÖÖ, Polat T, Aslan BT, Ulucan K. Can Skin Aging be Reversible by Anti-Aging Treatments with Genetic Analysis?. Istanbul Gelisim University J Health Sci. 2023;(21):1242-1250. https://doi.org/10.38079/igusabder.987140
19. Shu P, Jiang L, Li M, Li Y, Yuan Z, Lin L, et al. Comparison of five retinoids for anti-photoaging therapy: Evaluation of anti-inflammatory and anti-oxidative activities in vitro and therapeutic efficacy in vivo. Photochem Photobiol. 2024;100(3):633-645. https://doi.org/10.1111/php.13872
20. Karwal K, Mukovozov I. Topical AHA in Dermatology: Formulations, Mechanisms of Action, Efficacy, and Future Perspectives. Cosmetics. 2023;10(5):131. https://doi.org/10.3390/cosmetics10050131
21. Correia G, Magina S. Efficacy of topical vitamin C in melasma and photoaging: A systematic review. J Cosmet Dermatol. 2023;22(7):1938-1945. https://doi.org/10.1111/jocd.15748
22. Griffiths TW, Watson RE, Langton AK. Skin ageing and topical rejuvenation strategies. Br J Dermatol. 2023;189(Supplement_1): i17-23. https://doi.org/10.1093/bjd/ljad282
23. Erdil D, Manav V, Türk CB, Kara Polat A, Koku Aksu AE. The clinical effect of botulinum toxin on pigmentation. Int J Dermatol. 2023;62(2):250-256. https://doi.org/10.1111/ijd.16522
24. Park KY, López Gehrke I. Combined multilevel anti-aging strategies and practical applications of dermocosmetics in aesthetic procedures. J Eur Acad Dermatol Venereol. 2024;38:23-35. https://doi.org/10.1111/jdv.19975
25. Fedok FG, Lighthall JG. Evaluation and treatment planning for the aging face patient. Facial Plast Surg. 2022;30(3):277-290. https://doi.org/10.1016/j.fsc.2022.03.002
26. Jiang Z, Cheng H, Qian X, Tu J, Fan C, Pan Y, et al. The role and mechanism of engineered nanovesicles derived from hair follicle mesenchymal stem cells in the treatment of UVB-induced skin photoaging. J Cosmet Dermatol. 2024. https://doi.org/10.1111/jocd.16336
27. Pour Mohammad A, GholizadehMesgarha M, Seirafianpour F, Karimi Y, Sodagar S, Afraie M, et al. A systematic review and meta-analysis of efficacy, safety, and satisfaction rates of laser combination treatments vs laser monotherapy in skin rejuvenation resurfacing. Lasers Med Sci. 2023;38(1):228. https://doi.org/10.1111/jocd.16336
28. Shin SH, Koh YG, Lee WG, Seok J, Park KY. The use of epidermal growth factor in dermatological practice. Int Wound J. 2023;20(6):2414-2423. https://doi.org/10.1111/iwj.14075
29. Veiga E, Ferreira L, Correia M, Pires PC, Hameed H, Araújo AR, et al. Anti-aging peptides for advanced skincare: focus on nanodelivery systems. J Drug Deliv Technol. 2023:105087. https://doi.org/10.1016/j.jddst.2023.105087
30. Shi J, Zeng Q, Wang P, Chang Q, Huang J, Wu M, et al. A novel chlorin e6 derivative-mediated photodynamic therapy STBF-PDT reverses photoaging via the TGF-β pathway. Photodiagnosis Photodyn Ther. 2023;41:103321. https://doi.org/10.1016/j.pdpdt.2023.103321
31. Glogau RG. Photoaging and aging skin. Clin Dermatol. 2004;28:65-72.
32. Goodman GJ, Bagatin E. Photoaging and cosmeceutical solutions in sun-overexposed countries: The experience of Australia and Brazil. J Eur Acad Dermatol Venereol. 2024;38:36-44. https://doi.org/10.1111/jdv.19867
33. Trivedi MK, Kroumpouzos G, Murase JE. A review of the safety of cosmetic procedures during pregnancy and lactation. Int J Dermatol. 2017;3(1):6-10. https://doi.org/10.1016/j.ijwd.2017.01.005
34. Jdid R, Latreille J, Soppelsa F, Tschachler E, Morizot F. Validation of digital photographic reference scales for evaluating facial aging signs. Skin res technol. 2018;24(2):196-202. https://doi.org/10.1111/srt.12413
35. Tierney EP, Hanke CW. Recent advances in combination treatments for photoaging: review of the literature. Dermatol Surg. 2010;36(6): 829-840. https://doi.org/10.1111/j.1524-4725.2010.01557.x
36. Utama RC, Yenny SW, Norawati L, Arimuko A. Combination Procedure for Acne Scars Revision, Is It Needed?. BioSci Med J Biomed Transl Res. 2024;8(4):4186-4191. https://doi.org/10.37275/bsm.v8i4.954
37. Ngoc LT, Moon JY, Lee YC. Antioxidants for improved skin appearance: Intracellular mechanism, challenges, and future strategies. Int J Cosmet Sci. 2023;45(3):299-314. https://doi.org/10.1111/ics.12848
38. Lin CH, Lin MH, Chung YK, Alalaiwe A, Hung CF, Fang JY. Exploring the potential of the nano-based sunscreens and antioxidants for preventing and treating skin photoaging. Chemosphere. 2023:140702. https://doi.org/10.1016/j.chemosphere.2023.140702
39. Goh CL, Kang HY, Morita A, Zhang C, Wu Y, Prakoeswa CR, et al. Awareness of sun exposure risks and photoprotection for preventing pigmentary disorders in Asian populations: Survey results from three Asian countries and expert panel recommendations. Photodermatol Photoimmunol Photomed. 2024;40(1):e12932. https://doi.org/10.1111/phpp.12932
40. Georgievskaya A, Danko D, Baxter RA, Corstjens H, Tlyachev T. Artificial Intelligence Approaches for Skin Anti-aging and Skin Resilience Research. In Artificial Intelligence for Healthy Longevity: Cham: Springer International Publishing. 2023;189-214.
41. Pacifico A, Ardigò M, Frascione P, Damiani G, Morrone A. Phototherapeutic approach to dermatology patients during the 2019 coronavirus pandemic: real-life data from the Italian red zone. Br J Dermatol. 2020;183(2):375-376. https://doi.org/10.1111/bjd.19145

https://doi.org/10.61577/amsd.2024.1000010