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RED LIGHT PROTOBIOMODULATION – THE WAY TO STAY YOUNG AND CURE DISEASE – A REVIEW OF THE LITERATURE

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ABSTRACT

Red light and infrared light are key in application of Low level laser therapy and Photodynamic therapy. Their use ranges from wound healing and acne therapy to skin rejuvenation and treatment of androgenic alopecia. Many clinical studies have proven its effectiveness and compatibility with other treatment forms.

Background: Visible red light (RL, 620-700 nm) and the near-infrared (NIR, 700-1440 nm) are key in process called photobiomodulation (PBM) in which absorbed light causes physiological effects in the skin at cellular level. Light of this wavelength penetrates into the dermis and interacts with melanocytes, as well as fibroblasts, endothelial cells, and immune cells residing within the dermal layer. Changes in biological processes resulting from this include: increased RNA and protein synthesis, and increases in oxygen consumption, membrane potential, and NADH and ATP synthesis. Observed physiological effects range from enhancement in cell signaling and growth factor synthesis to reduction of oxidative stress and decrease in IL-1 β , IL-10, and TNF- α levels.

Aim: The aim of this article is to present different ways red light therapy has been utilized in medical fields and the results accomplished with it.

KEYWORDS

Low-Level Laser Therapy, Photodynamic Therapy, Androgenic Alopecia, Acne Vulgaris, Skin Rejuvenation, LED Masks, Wound Healing

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Introduction

The skin, the largest organ in the human body, serves as the first line of defense against bacteria, chemicals, temperature extremes, and other environmental factors. It also plays a crucial role in vitamin D synthesis—just a few of the many reasons why it is essential to overall health and well-being.

Over the years, numerous efforts have been made to preserve a youthful appearance of the skin. Most have been commercial in nature, and relatively few have achieved lasting success. In the medical field, many advances in wound healing have proven beneficial, yet there remains considerable room for improvement.

These endeavors, along with extensive research into dermatological diseases, have identified a common ally—light. Low-level laser therapy (LLLT) employs red light (RL, 620–700 nm) and near-infrared (NIR, 700–1440 nm) wavelengths to stimulate biological processes through absorption by melanin, heme, and opsins. Photodynamic therapy (PDT), another light-based treatment, combines red light with a photosensitizing drug to induce therapeutic effects.

In this review, we will examine the applications of these therapies in medicine.

Material and methods: An evaluation of clinical literature regarding the application of photobiomodulation in skin rejuvenation—including treatment of facial rhytids and dyschromias—as well as acne vulgaris, wound healing, body contouring, and androgenic alopecia, was conducted.

Low Level Laser Therapy

Research into the effects of low-energy red laser light began approximately 50 years ago. Early experiments on mice investigated the potential oncogenic effects of red laser exposure and produced surprising results: no neoplasia occurred, but hair growth was accelerated⁴. Subsequent studies revealed that red light exposure enhanced cell proliferation⁵. Decades of further research have shed light on the biological mechanisms triggered by red and infrared light. Cytochrome c oxidase activation appears to play a key role,

stimulating mitochondrial ATP production and increasing cellular metabolic activity. Additionally, red light reduces the production of reactive oxygen species (ROS), while activating genes involved in tissue regeneration and repair. Notably, substantial immunological modulation has also been observed.

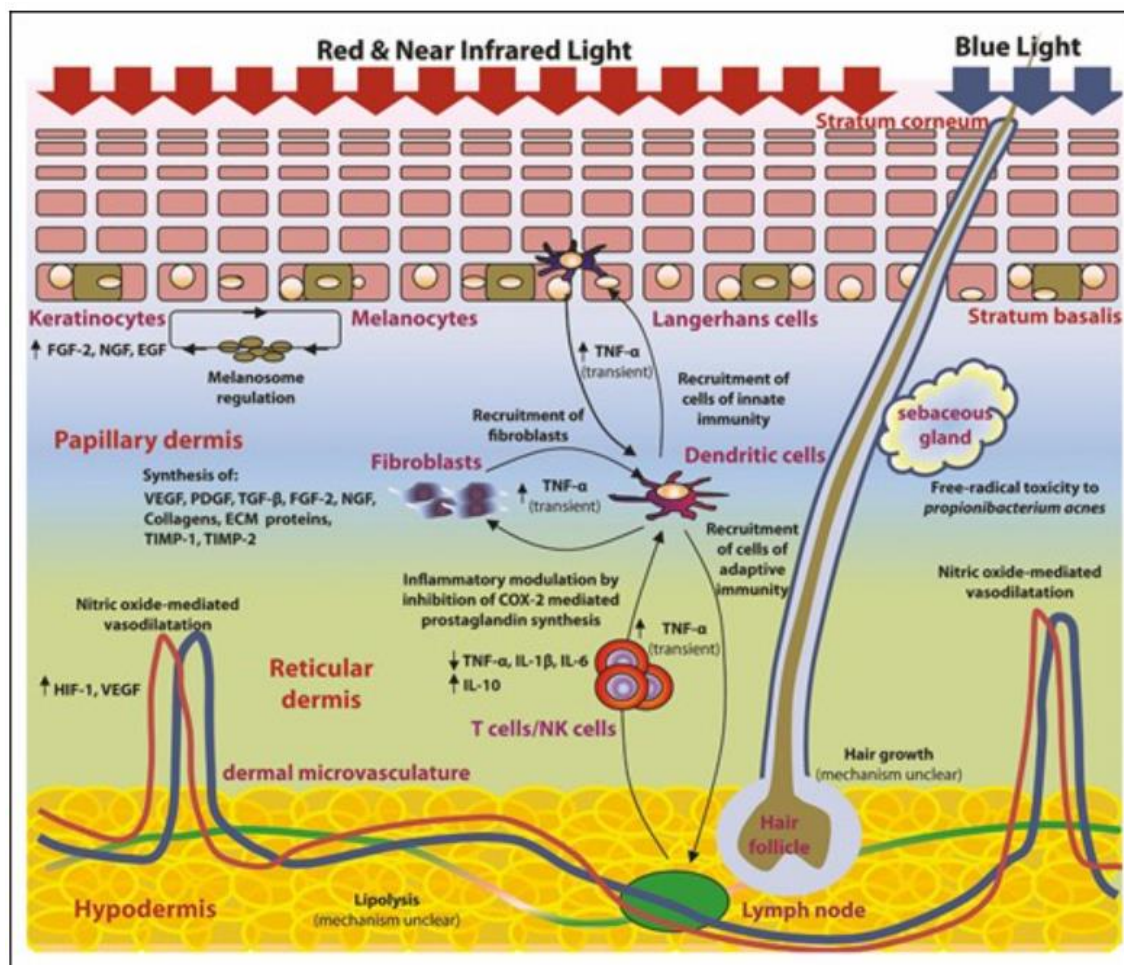


Fig. 1. Diagrammatic summary of the effects of red/near-infrared and blue light on epidermis, dermis, sebaceous glands, hair follicles, and subcutaneous fat. ECM, extracellular matrix; EGF, epidermal growth factor; FGF-2, fibroblast growth factor 2; HIF

Photodynamic therapy (PDT)

The concept of the photodynamic effect was first described in the early 20th century by Raab and von Tappeiner, who demonstrated that certain dyes could sensitize microorganisms to light, leading to cell death. In the 1970s, scientific interest in this phenomenon was renewed, resulting in numerous studies and experiments. Since then, photodynamic therapy (PDT) has been investigated and applied in the treatment of various diseases, with significant progress made in understanding its underlying mechanisms and in identifying optimal photosensitizing agents.

In dermatology and cosmetic medicine, PDT is widely used for both therapeutic and aesthetic purposes. The procedure requires three key components: a photosensitizer, a light source, and molecular oxygen in the target tissue. While both red and blue light are used, red light is often preferred due to its deeper tissue penetration—reaching the subcutaneous layer—and its lower incidence of adverse effects, making it more suitable for treating deeper lesions.

When the photosensitizer on or within the skin is activated by light of the appropriate wavelength, it generates reactive oxygen species (ROS). These ROS induce irreversible oxidative damage to essential cellular structures, triggering apoptosis, necrosis, and increased autophagy in the targeted cells.

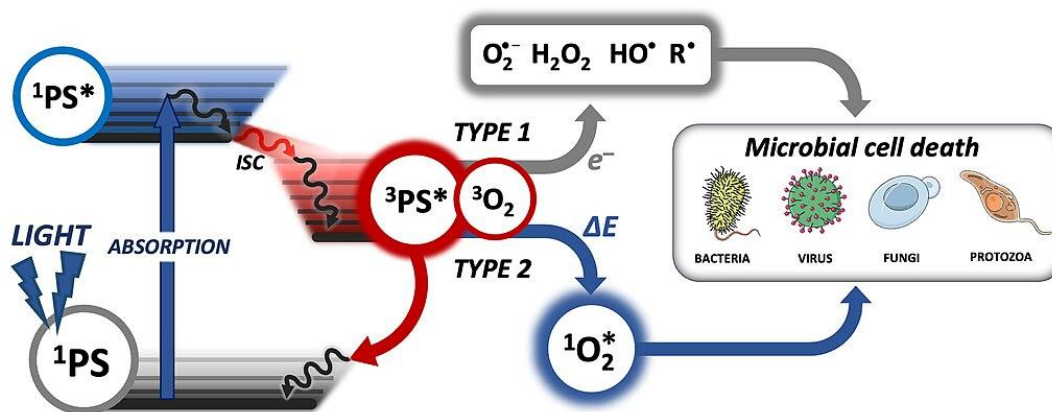


Fig. 2. Illustrative scheme of photodynamic reactions. The photosensitizer absorbs light and is promoted from its ground singlet state (1PS) to an excited singlet state (1PS*). Alternatively, the photosensitizer can convert to an excited triplet state (3PS*) by intersystem crossing. This is a longer-living state that allow sufficient time for chemical reactions to occur. A photosensitizer in 3PS* state can return to ground state (1PS) either by emitting phosphorescence, or by photochemical reactions that occur through transfer of charges or energy. These photochemical reactions can locally generate cytotoxic reactive oxygen species (ROS) via the Type I or II photodynamic reactions. In a cellular microenvironment, these ROS have a short lifespan ($<10\mu\text{s}$), and react with and destroy biomolecules, such as proteins, carbohydrates, nucleic acids, and lipids, very close ($<1\mu\text{m}$) to the production site. Type I: Charges, such as electrons, are transferred to surrounding substrates (R), forming radicals ($\text{R}\cdot$) due to the presence of the unpaired electron that was received. Molecular oxygen (O_2) participates directly or indirectly in this reaction pathway forming the radical anion known as superoxide ($\text{O}_2\cdot^-$). The superoxide radical can be further reduced to form hydrogen peroxide (H_2O_2), which can also be reduced to form highly reactive free hydroxyl radicals ($\text{HO}\cdot$) via Fenton-like reactions. Type II: Energy is transferred to ground state triplet molecular oxygen ($^3\text{O}_2$), creating singlet oxygen ($^1\text{O}_2^*$), an excited form of oxygen that is much more reactive than its ground state triplet counterpart. 1PS = Ground Singlet State of Photosensitizer; 1PS* = First Excited Singlet State of Photosensitizer; 3PS* = First Excited Triplet State of Photosensitizer; ISC = Intersystem Crossing; $^3\text{O}_2$ = Ground State Triplet Oxygen; $^1\text{O}_2$ = Excited State Singlet Oxygen.

LED masks

In recent years, one of the most commercialized methods of applying light therapy at home for skin rejuvenation has been the use of LED face masks. These devices are lined with light-emitting diodes that emit near-monochromatic light in the red (approximately 670–720 nm) and near-infrared (around 880 nm) ranges of the spectrum. They can be used daily at home with minimal to no reported adverse effects.

Their widespread popularity, however, is accompanied by controversy. Because these devices operate at energy levels below those considered a medical hazard, they are not regulated by the U.S. Food and Drug Administration (FDA). The large number of controllable parameters—such as wavelength, spatial coherence, polarization (the geometric orientation of the light wave relative to its direction of travel), pulse structure, fluence (total energy delivered), irradiance (power per unit area), and frequency of exposure—makes low-level light therapy (LLLT) difficult to standardize for clinical trials or systematic reviews.

This variability poses challenges in proving that the effects observed in patients are not simply due to placebo or marketing exaggeration. Additionally, optimal wavelengths, dosage schedules, and treatment conditions have yet to be firmly established.⁸

2. Research materials and methods

Methods

A list of therapeutic indications for LLLT and PDT was established by literature review. Independent searches were performed by the authors and discrepancies were handled. The search was conducted with PubMed (5year limit; United States National Library of Medicine [NLM], Bethesda, MD).

AI

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

3. Research results

Wound healing

In vitro and in vivo experimental studies performed on rats, along with clinical reviews conducted within the last five years, demonstrate that low-level laser therapy (LLLT) plays an important and significant role in wound healing.

In one experimental setup, LED light was applied daily to wounds in rats using the Oncollux device, which contains six diodes emitting at a wavelength of 660 ± 20 nm with a power output of 5 mW. Each exposure lasted 7 minutes, delivering an energy density of 2.7 J/cm^2 , equivalent to 2 J per point.

The wounds, 10 mm in diameter, were created on the animals' backs. LED exposure was administered immediately after wound induction, with the device placed in direct contact with the ulcer. LLLT treatment accelerated wound closure and was associated with a heightened inflammatory response compared to the control group—indicative of a more advanced healing process.

Additionally, an anti-oxidative effect was observed throughout the entire experimental period, with lower malondialdehyde (MDA) levels and higher glutathione (GSH) levels in the LED-treated group compared to controls.

Comparison of clinical studies in this topic is hard due to inconsistencies in applied treatment protocols. Many of the studies focused only on first days and weeks of healing time. Despite these limitations all of them have shown substantial impact of LLLT on wound healing.

Clinical trial performed in state university of New York tested the impact LLLT would have on post-operative scarring. One week post surgery patients started receiving LED Red Light to incision sites at fluences of 160 J/cm^2 , 320 J/cm^2 , or 480 J/cm^2 , triweekly for three weeks. At 1, 3 and 6-12 months assessments of injury site was performed. At 6 month mark groups receiving medium LED-RL dose presented greater improvements on scar flexibility. The high dose treated scars showed the best patient ratings from baseline to control group. Moreover medium and high dose-treated scars had less collagen than control group at 6 month point, which is associated with better healing.

Another research published in Indian Journal of Dental Research Looked into LLLT's influence on pain and periapical healing. Firstly notable but not statistically significant differences were reported by patients: those treated with red light felt less pain. Radiographical test results showed reduction in size of periapical lesions that was greater in patients in LLLT group.^{9,11}

Acne vulgaris

Acne vulgaris is often a chronic and treatment-resistant condition. In recent years, photodynamic therapy (PDT) has emerged as a highly effective therapeutic option. It is now recommended as a Grade A treatment, supported by Level I evidence in evidence-based medicine.

Clinical studies have demonstrated that PDT using aminolevulinic acid (ALA) solution in combination with red light significantly reduces both inflammatory and non-inflammatory lesions. In some patients, improvement in inflamed skin was observed after the first treatment session. The efficacy of PDT can be

further enhanced by adjunctive methods such as CO₂ fractional laser therapy or microneedling, although it is also highly effective as a standalone treatment.

When PDT was combined with intense pulsed light (IPL) therapy, notable additional benefits were observed, including reduced sebum secretion and decreased pore size, with effects lasting up to eight weeks. Another study reported that, in addition to ALA, a chlorin e6 derivative can serve as an effective photosensitizer for the treatment of acne vulgaris.¹²⁻¹⁵

Androgenic Alopecia

A non-scarring form of hair loss affects both men and women and is driven by genetic predisposition combined with androgen-mediated effects on hair follicle fiber production. Current standard treatments include 5 α -reductase inhibitors (finasteride, dutasteride) and topical minoxidil; however, these therapies fail to produce satisfactory results in many patients.

Recent studies have shown that low-level laser therapy (LLLT), when combined with these established treatments, can significantly increase hair density and thickness. Additional approaches—such as microneedling and autologous non-activated platelet-rich plasma (PRP)—have also demonstrated enhanced outcomes when used alongside LLLT.¹⁵⁻¹⁷

Skin rejuvenation

Aging is influenced by numerous factors. Some can be controlled—such as sun exposure, air pollution, malnutrition, and smoking—while others are largely beyond our control, such as hormone levels, DNA repair capacity, accumulation of DNA mutations, and reactive oxygen species (ROS).

Research into the medical applications of LLLT suggests that we can, to some extent, influence the latter group of factors. Exposure to red light has been shown to:

- Reduce the production of ROS
- Activate genes involved in tissue regeneration and repair
- Increase the number of dermal fibroblasts
- Boost the number of mitochondria and vimentin filaments



Fig. 3. Clinical example of skin rejuvenation (rhytids and dyschromia) with LLLT. A 73-year-old female treated with a homeuse dual-wavelength LLLT device at 470 and 808 nm for 20 minutes/day for 12 weeks. (A) Pretreatment and (B) 1 week after discontinuation of treatment. LLLT, low-level light therapy.

Enhanced fibroblast activity has been linked to greater collagen and elastin synthesis. Biochemically, LLLT has also been associated with elevated levels of cytokines—interleukin 1 β (IL-1 β), IL-6, tumor necrosis factor α (TNF- α)—and tissue inhibitors of matrix metalloproteinases (TIMP-1 and TIMP-2).

Clinically, numerous studies have reported significant reductions in wrinkle depth, improvements in skin elasticity, and high patient satisfaction. Furthermore, LLLT has been shown to promote repigmentation by stimulating melanoblast migration and melanogenesis in melanocytes.^{19,21}

Discussion

Red light has become an essential component in emerging treatment protocols and cosmetic applications. Whether used as LLLT or in photodynamic therapy (PDT)—alone or in combination with other modalities—it is increasingly important to integrate it into patient care and continue research into its potential.

Light, once viewed as the skin's enemy (through harmful UV radiation causing photoaging and cancer), is now emerging as a valuable ally in regeneration and rejuvenation. The growing body of evidence, coupled with public interest in health and wellness, suggests that innovations such as LED masks will continue to gain popularity.

Although LLLT has shown minimal adverse effects, ongoing research is essential to ensure safe, effective, and responsible use. The most pressing issue remains the lack of standardized treatment protocols, including the optimal number of sessions per week and total treatment duration, to achieve the best possible results.

Conclusions

Low-level laser therapy (LLLT) and photodynamic therapy (PDT) are valuable tools in medicine. They can be effectively incorporated into protocols for wound healing, acne treatment, androgenic alopecia, and skin rejuvenation.

Disclosures

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Declaration of the use of generative AI and AI-assisted technologies in the writing process

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

REFERENCES

1. Couturaud V, Le Fur M, Pelletier M, Granotier F. Reverse skin aging signs by red light photobiomodulation. *Skin Res Technol*. 2023 Jul;29(7):e13391. doi: 10.1111/srt.13391. PMID: 37522497; PMCID: PMC10311288.
2. Maghfour J, Ozog DM, Mineroff J, Jagdeo J, Kohli I, Lim HW. Photobiomodulation CME part I: Overview and mechanism of action. *J Am Acad Dermatol*. 2024 Nov;91(5):793-802. doi: 10.1016/j.jaad.2023.10.073. Epub 2024 Feb 1. PMID: 38309304.
3. Huang YY, Chen AC, Carroll JD, Hamblin MR. Biphasic dose response in low level light therapy. *Dose Response*. 2009 Sep 1;7(4):358-83. doi: 10.2203/dose-response.09-027.Hamblin. PMID: 20011653; PMCID: PMC2790317.
4. Mester E, Szende B, Gartner P. The effect of laser beams on the growth of hair in mice. *Radiobiol Radiother*. 1968;9(5):621-626.
5. Schmidt TR, Mármora BC, Brochado FT, Gonçalves L, Campos PS, Lamers ML, Araújo AA, Medeiros CACX, Ribeiro SB, Martins MAT, Pilar EFS, Martins MD, Wagner VP. Red light-emitting diode on skin healing: an in vitro and in vivo experimental study. *An Bras Dermatol*. 2025 Jan-Feb;100(1):54-62. doi: 10.1016/j.abd.2024.02.008. Epub 2024 Nov 8. PMID: 39521711; PMCID: PMC11745292.
6. Fan H, Tuo H, Xie Y, Ju M, Sun Y, Yang Y, Han X, Ren Z, Zheng Y, He D. Comparison of blue laser and red light-emitting diode-mediated aminolevulinic acid-based photodynamic therapy for moderate and severe acne vulgaris: A prospective, split-face, nonrandomized controlled study. *Photodiagnosis Photodyn Ther*. 2024 Oct;49:104325. doi: 10.1016/j.pdpdt.2024.104325. Epub 2024 Sep 6. PMID: 39245305.
7. Kessel D. Photodynamic Therapy: A Brief History. *J Clin Med*. 2019 Oct 2;8(10):1581. doi: 10.3390/jcm8101581. PMID: 31581613; PMCID: PMC6832404.
8. Basford JR. Low-energy laser treatment of pain and wounds: hype, hope, or hokum? *Mayo Clin Proc*. 1986 Aug;61(8):671-5. doi: 10.1016/s0025-6196(12)62034-5. PMID: 3523062.
9. Kurti A, Nguyen JK, Weedon J, Mamalis A, Lai Y, Masub N, Geisler A, Siegel DM, Jagdeo JR. Light emitting diode-red light for reduction of post-surgical scarring: Results from a dose-ranging, split-face, randomized controlled trial. *J Biophotonics*. 2021 Jul;14(7):e202100073. doi: 10.1002/jbio.202100073. Epub 2021 May 4. PMID: 33788987; PMCID: PMC8919713.
10. Schmidt TR, Mármora BC, Brochado FT, Gonçalves L, Campos PS, Lamers ML, Araújo AA, Medeiros CACX, Ribeiro SB, Martins MAT, Pilar EFS, Martins MD, Wagner VP. Red light-emitting diode on skin healing: an in vitro and in vivo experimental study. *An Bras Dermatol*. 2025 Jan-Feb;100(1):54-62. doi: 10.1016/j.abd.2024.02.008. Epub 2024 Nov 8. PMID: 39521711; PMCID: PMC11745292.
11. Shah D, Ponappa MC, Ponnappa KC. Evaluation of effect of low level laser therapy with intracanal medicament on periapical healing: A randomised control trial. *Indian J Dent Res*. 2021 Jul-Sep;32(3):299-304. doi: 10.4103/ijdr.IJDR_896_20. PMID: 35229767.
12. Huang C, Mao M, Peng Y, Wang B, Deng Y, Xie H, Jian D. Efficacy and safety of single microneedle radiofrequency vs . photodynamic therapy on moderate-to-severe acne vulgaris: A prospective, randomized, controlled study. *Chin Med J (Engl)*. 2024 Apr 20;137(8):1006-1008. doi: 10.1097/CM9.0000000000002911. Epub 2024 Jan 9. PMID: 38192026; PMCID: PMC11046016.
13. Liu Y, Sun DD, Chang SY, Ma LL, Jiang G. Study of different pre-treatments in the comparison of the efficacy of photodynamic therapy for moderate to severe acne vulgaris. *Photodiagnosis Photodyn Ther*. 2024 Oct;49:104298. doi: 10.1016/j.pdpdt.2024.104298. Epub 2024 Jul 30. PMID: 39089477.
14. Wang D, Yan Y, Wang P, Zhang H, Cao Y, Wang B, Zhang L, Wang X. A prospective, split-face, randomized controlled trial of intense pulsed light-photodynamic therapy for seborrhea. *Photodiagnosis Photodyn Ther*. 2024 Feb;45:103973. doi: 10.1016/j.pdpdt.2024.103973. Epub 2024 Feb 3. PMID: 38316341.
15. Zhang H, Zhao Y, Tao H, Feng C, Wang P, Zhang L, Liu X, Chen Y, Wang X. A chlorin e6 derivative-mediated photodynamic therapy for mild to moderate acne: A prospective, single-blind, randomized, split-face controlled study. *Photodiagnosis Photodyn Ther*. 2024 Oct;49:104304. doi: 10.1016/j.pdpdt.2024.104304. Epub 2024 Sep 2. PMID: 39226754.
16. Yang X, Qiao R, Cheng W, Lan X, Li Y, Jiang Y. Comparative efficacy of 2% minoxidil alone against combination of 2% minoxidil and low-level laser therapy in female pattern hair loss-A randomized controlled trial in Chinese females. *Photodiagnosis Photodyn Ther*. 2024 Feb;45:103966. doi: 10.1016/j.pdpdt.2024.103966. Epub 2024 Jan 10. PMID: 38211777.
17. Egger A, Resnik SR, Aickara D, Maranda E, Kaiser M, Wikramanayake TC, Jimenez JJ. Examining the Safety and Efficacy of Low-Level Laser Therapy for Male and Female Pattern Hair Loss: A Review of the Literature. *Skin Appendage Disord*. 2020 Sep;6(5):259-267. doi: 10.1159/000509001. Epub 2020 Jul 7. PMID: 33088809; PMCID: PMC7548873.
18. Gentile P, Dionisi L, Pizzicannella J, de Angelis B, de Fazio D, Garcovich S. A randomized blinded retrospective study: the combined use of micro-needling technique, low-level laser therapy and autologous non-activated platelet-rich plasma improves hair re-growth in patients with androgenic alopecia. *Expert Opin Biol Ther*. 2020 Sep;20(9):1099-1109. doi: 10.1080/14712598.2020.1797676. Epub 2020 Jul 27. PMID: 32678725.

19. Zargaran D, Zoller F, Zargaran A, Weyrich T, Mosahebi A. Facial skin ageing: Key concepts and overview of processes. *Int J Cosmet Sci.* 2022 Aug;44(4):414-420. doi: 10.1111/ics.12779. Epub 2022 Jul 8. PMID: 35426152; PMCID: PMC9543134.
20. Glass GE. Photobiomodulation: The Clinical Applications of Low-Level Light Therapy. *Aesthet Surg J.* 2021 May 18;41(6):723-738. doi: 10.1093/asj/sjab025. Erratum in: *Aesthet Surg J.* 2022 Apr 12;42(5):566. doi: 10.1093/asj/sjab396. PMID: 33471046.
21. Austin E, Geisler AN, Nguyen J, Kohli I, Hamzavi I, Lim HW, Jagdeo J. Visible light. Part I: Properties and cutaneous effects of visible light. *J Am Acad Dermatol.* 2021 May;84(5):1219-1231. doi: 10.1016/j.jaad.2021.02.048. Epub 2021 Feb 25. PMID: 33640508; PMCID: PMC8887026.