PRAGER-ZIMNY, Marta, SIMACHI, Michalina, JANISZEWSKA, Michalina, IMBIRSKA, Beata, HŁADKI, Michał, CYRULIK, Michalina, RAMLAU, Natalia, KOLENDA, Dominika, FISCHER, Zuzanna and PODOLAK, Marcin. The Impact of LED Therapy on Skin: The Review. *Journal of Education, Health and Sport*. 2025;86:66942. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.86.66942
https://apcz.umk.pl/JEHS/article/view/66942

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 28.11.2025. Revised: 08.12.2025. Accepted: 08.12.2025. Published: 13.12.2025.

The Impact of LED Therapy on Skin: The Review

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ABSTRACT

Introduction

Skin health can significantly impact quality of life and mental health. Erythema, acne or aging-related changes are leading reasons for dermatological consultation. It has been proven, that one third of dermatological patients struggle with mental health issues (1). In recent years, light-emitting diode (LED) technology gained massive popularity for offering clinicians and patients a non-invasive, safe and effective method for treating a wide spectrum of skin conditions. LED phototherapy uses specific wavelengths of visible and near -infrared light to modulate cellular activity, resulting in the rejuvenation of skin, accelerating wound healing and modulation of the inflammatory response. The comprehensiveness and excellent safety profile of the LED devices have led to their wide use in both medical and cosmetic fields. Clinical studies have shown significant benefits of use LED technology in coping with *acne vulgaris*, melasma, skin fibrosis and aging signs, among many others. As research on this technology develops, it is becoming an integral part of protocol in many therapies (2–4).

Aim of the study
The aim of this clinical review is to evaluate the efficacy, safety, and underlying mechanisms of light-emitting diode (LED) therapy in dermatological applications, with a focus on its therapeutic potential in treating a broad spectrum of skin conditions including *acne vulgaris*, melasma, rosacea, photoaging, wound healing, scarring and hair loss. By synthesizing current clinical evidence and mechanistic insights, the study seeks to provide a comprehensive overview of LED therapy as a non-invasive, well-tolerated, and biologically targeted intervention in modern dermatology.
Materials and methods
The data used for this review were collected from PubMed, Google Scholar, and the Wiley Online Library. Literature search was carried out using the keywords “LED”, “phototherapy”, “skin therapy”, “skin rejuvenation”, “rosacea”, “skin wound healing”, “photobiomodulation”, “red led light”, “blue led light”, “infrared light therapy”, “yellow light therapy”, “phototherapy”, “led treatment”, “acne vulgaris”, “hair loss”, “melasma”, “skin fibrosis”.
Conclusion
Light-emitting diode (LED) gains popularity over last years as a safe, non-invasive therapy tool in dermatology for influence on broad spectrum of skin conditions. The evolution of LED technology - starting from phototherapy to NASA-driven improvement - has made possible precise photobiomodulation using specific wavelenghts; particularly red, blue, and near-infrared light. These wavelenghts penetrate the skin at varying depths, stimulating cellular activity, modulating inflammation and promoting tissue repair and hair growth. Reliable clinical evidence supports the efficacy of LED therapy in skin rejuvenation, *acne vulgaris* wound healing, melasma and rosacea. Red LED light intensifies collagen synthesis and reduces signs of aging, while bule LED light targets *Cutibacterium acnes*, reducing both non-inflammatory and inflammatory acne lesions. LED therapy seems promising in managing melasma and rosacea by modulating melanogenesis and inflammatory mediators. Studies prove, that LED light therapy is safe and the percentage of side effects - mainly skin redness - is low.

Keywords: LED; phototherapy; skin therapy; skin rejuvenation; rosacea; skin wound healing; photobiomodulation; red led light; blue led light; infrared light therapy; yellow light therapy; phototherapy; led treatment; acne vulgaris; hair loss; melasma; skin fibrosis.

The History behind LED Light Therapy in Dermatology

The pioneer in the field of using light in medicine was Niels Ryberg Finsen, winner of the Nobel prize in 1903, who was called the father of modern phototherapy (5). The first light-emitting diode (LED) was invented in 1962 by Nick Holonyak Jr. First LEDs were limited by low power and broad, inconsistent wavelengths. This technology was improved by NASA in 1990s into the LEDs that are capable of producing narrow-spectrum light at biologically relevant energies - at that time occurred their first clinical application in medicine. Initial medical research focused on wound healing and tissue regeneration, as NASA and other groups observed, that specific wavelengths of LED light could accelerate healing (6). This initiated research into the use of light-emitting diodes technology in various skin issues, including acne, psoriasis, aging processes. By the early 2000s, studies demonstrated the significant impact on collagen synthesis stimulation of red and infra-red LED light.

Moreover, was observed skin elasticity improvement and fine lines reduction. This established LED light therapy as a non-invasive anti-aging intervention (2).
The versatility of LED devices has caused them to quickly become widespread in medical practice and cosmetology, used in the treatment of acne, erythema, wound healing and anti-aging of the skin (2,3). Today, LED therapy is recognized as a revolutionary and minimally invasive tool in managing skin health, with ongoing research expanding its applications and optimizing therapy protocols. By applying different wavelengths, dermatologists can tailor treatments to target specific cellular processes, modulate inflammation, promote collagen synthesis, and accelerate tissue repair, among many others (7).

Mechanism

Photobiomodulation (PBM) is a non-invasive and safe phototherapy technology that uses specific wavelengths of visible light, particularly red light (620-700 nm), blue light (405-420 nm) and near infrared light (700-1440 nm) in modulating cellular processes. PBM is delivered using various light sources, including low-level lasers and light-emitting diodes (LEDs) (2–4).
Different LED wavelengths target divergent skin depths, inducing distinct biological effects:

- Red Light (620-700 nm) has a deep penetration, which causes stimulation of the fibroblasts to increase collagen and elastin production (8) (9),
- Blue Light acts superficially, aiming *Cutibacterium acnes* by exciting endogenous porphyrins, resulting in ROS-mediated bacterial cell death. Blue light also affects on sebaceous gland activity, causing them to lowering sebum production, which stands as key factor of acne pathogenesis (10),
- Near-Infrared Light reduces erythema and accelerates wounds healing (11) (4):
- Yellow Light (590nm) has been shown to speed healing and reduce erythema after fractionated laser therapy (6).

Cellular Mechanism of Photobiomodulation (PBM)

Photobiomodulation (PBM) operates through light-triggered biochemical cascades at the cellular level, primarily mediated by mitochondrial chromophores. The key mechanisms include:

1. Primary Photon Absorption:
   - Light (typically 600–1100 nm) penetrates tissue and is absorbed by **cytochrome c oxidase (CCO)** in the mitochondrial electron transport chain,
   - This absorption dissociates inhibitory **nitric oxide (NO)** from CCO, reversing respiratory suppression and enhancing **oxygen consumption** (7,12).
2. Mitochondrial Response:
   - Increased electron transport elevates **proton gradient** and **ATP synthesis (**up to 70%)**,**
   - Transient **reactive oxygen species (ROS)** generation activates redox-sensitive transcription factors (e.g., **NF-κB**, **AP-1**), triggering cytoprotective gene expression (12).

Summary of Key Cellular Effects

Process	Key Molecules/Pathways	Outcome
Energy Metabolism	↑ATP, ↑O_2 consumption	Enhanced cellular function
Oxidative Response	Moderate ROS → Nrf2 activation	Antioxidant defence
Inflammation	↓TNF-α, ↑IL-10	Reduced tissue damage
Proliferation	Akt/ERK activation	Tissue regeneration

3. Downstream Signaling:
   - **Ca^{2+} influx** modulates kinase pathways (e.g., **PI3K/Akt**, **MAPK**), promoting:
     - Cell proliferation and migration,
     - Anti-apoptotic effects,
     - Antioxidant enzyme upregulation (e.g., superoxide dismutase),
   - Stem cell activation occurs via Wnt/β-catenin pathway stimulation (12).
4. Anti-Inflammatory Effects:
   - PBM reduces **pro-inflammatory cytokines** (TNF-α, IL-1β, IL-6) and increases **anti-inflammatory mediators** (IL-10, TGF-β),
   - Neutrophil infiltration decreases while macrophage phagocytosis improves (4,12).
5. Tissue Repair Mechanisms:
   - Fibroblasts show **accelerated collagen synthesis** and **matrix metalloproteinase (MMP) inhibition**, enhancing extracellular matrix remodeling (7),
   - Endothelial cells exhibit **VEGF upregulation**, promoting angiogenesis (6).

LED Therapy & Anti-Aging Effect

The skin aging process involves a pigmentation changes and gradual decrease in the number of collagen and elastin fibers, which causes wrinkles and sagging of the tissue. Red LED light therapy promotes collagen synthesis by activating fibroblasts, which can result in reversing some of photo aging signs. It has emerged as scientifically validated, non-invasive approach to skin rejuvenation (2) (4). Light in wavelength of 630-700 nm penetrates into the dermis, where it is absorbed by mitochondrial chromophores such as cytochrome c oxidase. This causes increase in adenosine triphosphate (ATP) level. This results in enhancing cellular energy metabolism and activating fibroblasts responsible for the collagen and elastin synthesis (3,7), thereby studies report a measurable increase - 15-30% after 4-8 weeks of red LED treatment - which results in improved skin firmness, elasticity and reduced wrinkles (2,3). Beyond structural rejuvenation, red LED therapy exerts anti-inflammatory effects by down regulating key cytokines such as TNF-alpha and IL-6, which are implicated in chronic skin inflammation and the aging process (7).

Enhanced ATP production also supports keratinocyte turnover and tissue repair, further contributing to the reversal of photo aging manifestations such as rough texture and fine lines. Improvements in skin hydration - up to a 25% increase - and barrier function have also been documented, likely due to the reinforcement of the extracellular matrix and epidermal integrity (3). Clinical trials and systematic review confirm these benefits: they have demonstrated 30-50% improvement in wrinkle severity following 12 weeks of treatment, with additional evidence supporting accelerated wound healing and enhanced angiogenesis (3). At the top of that, red LED light therapy maintains an excellent safety profile, with no evidence of DNA damage and only rare, mild and transient adverse effects such as erythema (2,3).

Anti-Aging Treatment Schemes

1. Wavelength Selection:
   - Red Light (around 630–660 nm): Most commonly used for anti-aging due to its ability to penetrate the dermis, where it stimulates fibroblasts, increases collagen and elastin synthesis, and reduces matrix metalloproteinase (MMP) activity, thus improving skin texture and reducing wrinkles (4,7,13),
   - Near-Infrared Light (830 nm): Penetrates even deeper, supporting wound healing and further stimulating collagen production (2,11,13).
2. Session Frequency and Duration:
   - Standard Protocol: Sessions typically last 10–20 minutes per treatment area (13),
   - Treatment Course: Most protocols involve 8–10 sessions, performed 2–3 times per week over a period of 3–5 weeks (13,14),
   - Maintenance: After the initial course, ongoing maintenance with 2–3 sessions per month is sometimes recommended to sustain results (4).
3. Energy Dosage:
   - Fluence (Energy Density): Commonly used fluences range from 3.8 to 5.4 J/cm² per session for each wavelength (14).

Outcomes:

Studies report reductions in fine lines, wrinkles, and overall skin rejuvenation, with improvements in skin texture, firmness, and tone (4,7,13). Visible effects are typically observed after several weeks of consistent treatment, with cumulative benefits over time (7,13). Additionally, LED phototherapy is well-tolerated, with no significant adverse events reported in clinical trials (7,13). Reassuming, anti-aging LED protocols most often use red (630–660 nm) and near-infrared (830 nm) light, applied in 10–20-minute sessions, 2–3 times per week for several weeks, with energy densities around 3.8–5.4 J/cm². (4,7,13,14).

LED Therapy & Melasma

Melasma is a chronic disease that is characterized by the presence of symmetrical, dark brown spots on the skin. These changes are discolorations that result from excessive melanin production, most often affecting sun-exposed facial areas, such as the cheeks, forehead, nose and upper lip (15). Pathogenesis involves complex interactions between genetic predisposition, ultraviolet (UV) radiation, hormonal influences (notably estrogen), and skin inflammation (15,16). Clinically, melasma presents epidermal and dermal melanin deposition.

Histology examination revealed epidermal atrophy, thickened vessels, and elastic fiber fragmentation (15). It definitely more often affects women (especially Fitzpatrick skin types III–V) and significantly impairs quality of life due to cosmetic disfigurement (15,17). Research has proven that photobiomodulation (PBM) using specific wavelengths (red: 630 nm; amber/yellow: 585 and 590 nm; infrared: 830 and 850 nm) at radiant exposures between 1 and 20 J/cm² can significantly decrease melanin content by modulating tyrosinase activity and gene expression in melanogenesis pathways. PBM also improves dermal structure and reduces erythema and neovascularization (18). Another research also revealed that yellow LED light (585 nm) cause inhibition of melanocytes maturation and decreases the levels of melanin and tyrosinase activity. Moreover, the reduction in expression of TYR gene was observed. Researchers observed the activation of autophagy process, which was confirmed by LC3-I to LC3-II conversion (19). No serious side effects were reported. The researchers concluded that yellow and red LED photobiomodulation is a safe and effective method for diminishing hyperpigmentation (18).

LED phototherapy has emerged as a safe, non-invasive treatment for melasma, particularly effective for darker skin types (V-VI) where traditional therapies put patients in of risk post-inflammatory hyperpigmentation. Protocols base on specific wavelengths to target melanogenesis, vascularization, and dermal remodeling, with treatment schemes differentiated by wavelength, energy density, and session frequency (4,14).

LED Therapy & Acne Management

Acne vulgaris is one of the most common chronic skin diseases, primarily affecting adolescents and young adults, with consequences such as scarring, dyspigmentation, but also reduced self-esteem or depression (20,21). The pathogenesis of acne is multifactorial: increased sebum production, hyperkeratinization of the follicular epithelium, colonization by *Cutibacterium acnes* (formerly Probionibacterium acnes) and subsequent inflammation (20,22). *C. acnes* is a commensal bacterium residing in the sebaceous glands and hair follicles. Its exact role in the initiation of inflammatory acne lesions remains under investigation, however it is well established as a key factor in the development and inflaming of acne (23). It is suspected, that *C. acnes* produces biofilm and causes releasing pro-inflammatory mediators, which leads to follicular inflammation and lesion formation. Differences in *C. acnes* populations, as well as increasing antibiotic resistance, can provide both the severity of acne and the efficacy of antimicrobial therapies (23). Thereby, *C. acnes* is instrumental in acne pathogenesis, acting as both a therapeutic target and a challenge in the treatment of this widespread condition (22,23). The therapeutic application of blue LED light (typically 405–420 nm) has become a well-established, evidence-based modality in the management of *acne vulgaris*. Numerous randomized controlled trials and systematic reviews confirm, that blue LED light provides a safe, non-invasive, and effective approach for reducing both inflammatory and non-inflammatory acne lesions (2,4). The primary mechanism underlying blue LED therapy is the photoactivation of endogenous porphyrins produced by *Cutibacterium acnes* (formerly *Propionibacterium acnes*). Upon exposure to blue light, these porphyrins generate reactive oxygen species (ROS), which induce oxidative damage to bacterial cell membranes, proteins, and DNA, causing cell death. This mechanism is selective for bacteria-producing porphyrins, without harming surrounding healthy tissue (24).

Additionally, studies show that blue light therapy regulates sebaceous gland activity and decreases sebum production, which results in minimizing the risk of new lesion formation (25). Clinical studies consistently demonstrate that blue LED phototherapy leads to significant reductions in both inflammatory, and - in lower grade - non-inflammatory acne lesions. In clinical report the final mean percentage enhancements in non-inflammatory and inflammatory lesions were 34.28% and 77.93%, respectively. Instrumental measurements proved, that the melanin levels significantly decreased after treatment. Brightened skin tone and improved skin texture were spontaneously reported by 14 patients (21). An open label study evaluated the safety and efficacy of narrowband blue light on inflammatory and noninflammatory acne lesions in patients with mild-to-moderate facial acne. Subjects received eight 10- or 20-minute light treatments using LEDs with peak wavelengths of 409nm to 419nm (40mW/cm2) through four-week period. Lesion counts were repeated at Weeks 5, 8, and 12. An advantageous effect on inflammatory lesions was noticed at Week 5, became significant at Weeks 8 and 12. The mean percent reduction in lesion counts at each time point was 25 percent, 53 percent ($p<0.001$), and 60 percent ($p<0.001$), respectively. The effect on non-inflammatory lesions was little (26). Blue LED therapy is associated with a very beneficial safety profile. Reported adverse effects are mostly mild, transient, and limited to slight erythema, dryness, or pruritus. There were no reports of scarring, pigmentary changes, or systemic side effects. This makes blue LED treatment suitable for a broad range of patients, including those who cannot tolerate or do not respond to conventional topical or systemic therapies (2,21,25,26). The main methodological limitations of studies on blue light therapy for acne treatment include small sample sizes, short duration of treatment (none exceeding 12 weeks), high risk of bias due to lack of blinding and selective outcome reporting, diversities in treatment protocols (frequency, intensity, duration). There are no studies considering the long-term effects of blue light on the skin, thus long-term safety should be monitored. Additionally, many studies lack long-term follow-up data and do not sufficiently evaluate patient-centered outcomes such as quality of life. These limitations hinder the ability to draw definitive conclusions about the efficacy and safety of blue light therapy for acne (27).

LED Light Therapy Protocols for Acne Treatment

- Blue light (around 415 nm): Penetrates the epidermis, is absorbed by porphyrins produced by C. acnes, leading to the synthesis of reactive oxygen species that destroy the bacteria (2,10,28),
- Red light (around 633–640 nm): Penetrates deeper into the dermis, reduces inflammation, supports healing, helps regulate sebum production (2,10,28),
- Combination therapy: Blue and red light together provide synergistic antibacterial and anti-inflammatory effects, often resulting in greater clinical improvement than either wavelength singly (2,10,28).

Example Blue Light Protocol:

- Two 20-minute sessions per week for 4–8 weeks using 415 nm blue light at 48 J/cm² (2,29)
- Results: Mean improvement score of 3.14 (out of 4) at four weeks, with some patients achieving complete clearing at eight weeks (2).

Example Blue + Red Light Protocol:

- Two sessions per week, alternating between 415 nm blue light (20 min, 48 J/cm²) and 633 nm red light (20 min, 96 J/cm²), for four weeks (2),
- Mild microdermabrasion may be performed prior to each session to enhance penetration (2),
- Results: Up to 77% reduction in inflammatory lesions after eight weeks (6).

Outcomes

The most evidence-based LED protocols for acne use blue light (415 nm) or a combination of blue and red light (415 nm + 633 nm), delivered 2–3 times weekly for 4–8 weeks, with each session lasting 15–20 minutes. Combination protocols are typically more effective than monotherapy, particularly for inflammatory lesions. LED therapy is safe, well-tolerated, and suitable for all skin types (2) (10,28,29).

Rosacea & LED light Therapy

Rosacea is a chronic skin disease that predominantly affects central areas of the face, including cheeks, nose, chin and forehead. Its prevalence in adult population is estimated at approximately 5,5%. Rosacea can manifest in all of skin types, however, most often occurs in fair-skin phototypes, thus erythema is less apparent in darker skin types (30). Usually, onset is after the age of 30, with a higher incidence in women, although men may present more severe symptoms. The clinical diagnosis of rosacea is based on the presence of chronic midfacial erythema or phymatous changes; if above are not attending, the diagnosis can be predicated on at least two of the following features: flushing, papules, pustules, telangiectasia or ocular involvement (30–32). The pathophysiology of rosacea is multifactorial: involves congenital factor, immune system activation, neurogenic inflammation and excessive vascular activity. Furthermore, another contributing factor is Demodex mites and certain bacteria (30) (32). Rosacea has significant impact on patients' quality of life, which leads to psychological distress due to visible facial changes. Current therapy relies on a phenotype-based approach, focusing on specific clinical features including topical agents, oral medications and light-based treatments (30,33). LED light therapy, particularly using combined blue (480 nm) and red (650 nm) wavelengths, shows notable efficacy in managing rosacea symptoms. Clinical evidence from case reports points out, that this dual-wavelength approach reduces erythema, papules, burning, and itching after 10 treatment sessions. The mechanism bases on downregulation of inflammatory mediators (e.g., IL-1β, TNF-α) and modulation of vascular hyperactivity characteristic of rosacea. Systematic reviews confirm, that LED-based photodynamic therapy (PDT) is safe and effective form of therapy, emphasizing its role in decreasing inflammatory lesions and persistent facial redness (33,34). Another study demonstrated case of 17 patients with rosacea, treated with photodynamic therapy based on red LED light and methylaminolevulate as photosensitizer. Good results was seen in 10 of 17 patients, and fair results in another 4 patients (35). In another study, combining blue and red LED light obtained a good response after treatments with LEDs. Patients reported reduction of symptoms such as burning and itching, alongside with decrease of erythema and papules after five sessions of LED therapy (34). While these outcomes are promising, larger randomized controlled trials are needed to standardize protocols and confirm long-term benefits (33,34).

LED Light Therapy Protocols for Rosacea Treatment

Wavelengths and Mechanism:

- Blue Light (around 480 nm): Targets superficial skin layers, exhibits antibacterial and anti-inflammatory effects, and may help reduce papules and pustules,
- Red Light (around 650 nm): Penetrates deeper, modulates inflammation, promotes healing, and reduces erythema and discomfort.

Typical Protocols and Treatment Schemes

Case-Based Protocol (34):

- Wavelengths: Sequential use of blue (480 nm ± 15 nm) and red (650 nm ± 15 nm) LED light,
- Device: Dermodinamica® (ELISOR Srl, Milan, Italy),
- Session Duration: 15 minutes per session (each wavelength),
- Energy: 300 J/minute for each wavelength,
- Frequency: Twice weekly,
- Total Sessions: 10 sessions (over 5 weeks),
- Adjunctive Therapy: Topical 15% azelaic acid was used alongside LED therapy.

Reduction in erythema, papules, burning, and itching observed after 5 sessions, with further improvement after all 10 treatments. Therapy is well tolerated, with no adverse effects reported (34).

Outcomes

LED therapy using sequential blue and red light is a promising, well-tolerated protocol for rosacea, especially for reducing erythema, papules, and subjective symptoms. Protocols typically involve 10 sessions, twice weekly, with each session lasting about 15 minutes per wavelength. This approach is supported by clinical case reports and is safe as an adjunct to standard topical therapies (33–35).

LED Light Therapy & Hair Loss

Hair loss is not a dangerous condition, although it affects the patient's quality of life. The patterns of hair loss can be from subtle, like diffuse hair loss that arise in telogen efflovium, to obvious, such as the bald patches occurring in alopecia areata (36). In randomized controlled trials the authors report, that low-level laser therapy (LLLT), including red and near-infrared LED light, 600–950 nm promotes hair growth in both men and women with androgenetic alopecia. The elevation of hair density was observed. What is also important – patients reported satisfaction of the treatment. LLLT is suspected to work by stimulating hair follicles to re-enter and prolong the anagen (growth) phase, enhance blood flow, and reduce inflammation. The therapy is FDA-approved, and safe, non-invasive, and may be used alone or in combination with minoxidil or finasteride. The authors note that while results seem promising, further large, controlled studies are needed to determine optimal parameters and long-term efficacy (37,38). Researchers suggest, that LLLT biological mechanism responsible for stimulating hair growth acts on mitochondria and can modify metabolism by photodissociation of inhibitory nitric oxide (NO) from cytochrome c oxidase (CCO).

This results in increase of ATP production, transformation of ROS and activation of transcription factors, which in return cause synthesis of protein triggering further effects down-stream, resulting in intensified cell proliferation and migration, also the levels of inflammatory mediators, growth factors and cytokines are modified. Another consequence is increased tissue oxygenation and blood flow (38,39). Study show, that using combined 655 nm red light and 780 nm infrared light once a day for 10 minutes can increase hair density on both the vertex (145.1/cm2 vs. 137.3/cm2 pre-treatment, $P < 0.005$) and occiput (163.3/cm2 vs. 153.3/cm2, $P < 0.005$). The anogen/telogen ratio was also significantly increased (vertex: 84.7 vs. 79.7 pre-treatment and occiput: 91.9 vs. 89.6 pre-treatment). Additionally, 83% of the patients reported to be satisfied with the treatment (39).

Safety and Tolerability:
LED/LLLT protocols are considered safe and non-invasive, with no significant adverse effects reported in clinical trials. The therapy is suitable for both men and women with androgenetic alopecia or telogen effluvium (37–39).

LED Light Impact on Skin Healing, Wound Repair, and Scarring
A wound is an interruption of the integrity of body tissue. It can be caused by physical, chemical, mechanical trauma, or be a consequence of medical condition. Cutaneous wounds are relatively common in adults. Numerous studies show that LED light treatment on wounds using wavelengths ranging 456-880 nm causes reduction of inflammatory cells, increases fibroblast proliferation, collagen synthesis and stimulates angiogenesis. Moreover, the promotion of granulation tissue formation was observed (40). The recent review analyzed 27 in vitro and in vivo studies on LED utilization in wound healing. The authors found that LED therapy promotes various healing pathways, including enhanced cell proliferation and migration, angiogenesis, increased collagen deposition, and modulation of the inflammatory response. The effects were wavelength-dependent, with green and red LEDs most effective for cell migration and proliferation, and all wavelengths contributing to extracellular matrix regulation and angiogenesis (41). Scar tissue production results from natural wound healing process. Scars can range from faint scarring to aberrant scarring, like hyperthropic scars and keloids. An abnormal scar formation process may result in skin fibrosis, which is excessive accumulation of fibrous connective tissue (mainly collagen) in the skin, often as a response to chronic inflammation or injury. It leads to thickening and stiffening of the skin. Preventing skin fibrosis is one of the goals of postoperative wound management, as this type of scarring can cause both functional and aesthetic consequences for the patients (42,43). Effective anti-scarring therapeutics remain an unmet need, underscoring the importance of developing novel approaches to treat and prevent skin fibrosis (43). Red light (630-700 nm) has the deepest tissue penetration depth of all visible light colors. Thanks to that property, can reach the dermis where the ibrosis process occurs. Clinical research proves, that red light treatment along with other modalities, like photosensitizers for photodynamic therapy can reduce skin fibrosis (42). As stated by in vitro data, light emitting diode-red light at high fluencies can apply anti-fibrotic cutaneous effects as a consequence of reducing the proliferation, collagen production and migration on human skin fibroblasts (43). LED light therapy is generally characterized by favorable safety profile, though adverse effects depend on treatment parameters and skin phototype.

Adverse events were mild; involved treatment-site erythema, hyperpigmentation, and blistering (41,42). Researchers concluded that LED-RL is safe up to 480 J/cm2 and cutaneous effects can depend on race and ethnicity (43).

Summary

LED therapy has emerged as a scientifically supported, non-invasive, and safe modality with wide-ranging applications in dermatology. By employing specific light wavelengths, particularly red, blue, and near-infrared, LED phototherapy stimulates cellular mechanisms such as ATP production, collagen synthesis, and modulation of inflammatory mediators. These actions translate into clinically observed benefits including skin rejuvenation, acne improvement, melasma depigmentation, rosacea symptoms relief, and enhanced wound healing. Moreover, its effectiveness in promoting hair regrowth and preventing skin fibrosis highlights its therapeutic versatility. Most protocols show favorable safety profiles, with mild and transient adverse events such as erythema being rare. Although current clinical data are encouraging, the need for standardized treatment parameters and long-term studies remains. LED therapy represents a valuable addition to both medical and aesthetical dermatologic practice, offering targeted, painless, and effective treatment for various skin disorders.

Disclosure:

Patient consent:

Not applicable.

Data were obtained from

PubMed, Google Scholar, Wiley Online Library

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Funding:

This research received no external funding.

Ethical Assessment and Institutional Review Board Statement:
Not applicable. As this article involves a review and synthesis of existing literature, rather than original research involving human subjects, ethical assessment and institutional review board statements are not applicable.

Data availability statement:
Not applicable.

The authors declare no conflicts of interest.

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