

Review

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Review

Premium Doctors' Advances in Light-Based Aesthetic Technologies: Efficacy Across Skin Types

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Abstract:

Background: Light-based aesthetic technologies, including lasers (picosecond, Nd:YAG, diode, alexandrite), Intense Pulsed Light (IPL), Photodynamic Therapy (PDT), and Light-Emitting Diodes (LED)/Photobiomodulation (PBM), are pivotal in addressing dermatological conditions such as hair reduction, pigmented and vascular lesions, acne, skin rejuvenation, and scar improvement. These modalities face challenges in darker Fitzpatrick Skin Types (FST IV–VI) due to melanin competition, increasing risks of post-inflammatory hyperpigmentation (PIH), burns, and scarring. Advances in device design, wavelength selection, pulse duration, and cooling systems, along with tools like the Excessive Setting Index of Clinical Fluence (EICF), have enhanced safety and efficacy across all skin types. This review synthesizes their mechanisms, applications, and challenges, emphasizing tailored protocols and practitioner expertise. **Methods:** A systematic search of PubMed, Scopus, Web of Science, and Google Scholar identified peer-reviewed articles (2014–2025) using terms like "light-based aesthetic technologies," "lasers," "IPL," "PDT," "LED," and "Fitzpatrick skin types." Inclusion criteria encompassed randomized controlled trials, systematic reviews, meta-analyses, and studies addressing efficacy and safety across FST I–VI. Non-peer-reviewed sources, non-English articles, and studies lacking methodological rigor were excluded. Data were extracted on mechanisms, applications, outcomes, and limitations, then synthesized thematically. Methodological quality was assessed using AMSTAR 2 guidelines. **Results:** Picosecond lasers excel in pigmentation and rejuvenation, with EICF optimizing safety in FST IV–VI. Nd:YAG (1064 nm) and diode lasers are effective for hair reduction in darker skin, requiring longer pulses (16–22 ms) and cooling. IPL treats multiple chromophores but risks PIH in FST IV–VI (up to 60% incidence). PDT reduces acne lesions (85.7% improvement in FST I–IV) and enhances rejuvenation, while LED/PBM safely improves acne and collagen production across all skin types. Combination therapies (e.g., IPL with topical agents) enhance outcomes. PIH remains a challenge in darker skin, necessitating careful parameter adjustments. **Conclusions:** Light-based technologies have advanced significantly, offering safe and effective treatments across FST I–VI. Tailored protocols, longer wavelengths, cooling systems, and combination therapies mitigate risks like PIH. Further research is needed for robust data on FST V–VI, novel photosensitizers, and adaptive devices to ensure equitable outcomes. Practitioner expertise and patient education are critical for optimizing results in aesthetic dermatology.

Keywords: light-based technologies; aesthetic dermatology; fitzpatrick skin types; lasers; ipl; photodynamic therapy; led; premium doctors

1. Introduction

Light-based aesthetic technologies, including lasers, Intense Pulsed Light (IPL), Photodynamic Therapy (PDT), and Light-Emitting Diodes (LED)/Photobiomodulation (PBM), have transformed aesthetic dermatology by addressing conditions such as chronic inflammatory skin disorders, photoaging, and unwanted hair (Gold, 2018). The global demand for non-invasive and minimally invasive procedures highlights their role in enhancing patient appearance, self-perception, and

quality of life (Ghalamghash, 2025a). Historically, these treatments posed risks for darker Fitzpatrick Skin Types (FST IV–VI) due to higher epidermal melanin, which competes for light energy, increasing adverse effects like burns, dyspigmentation, and scarring (Jalian & Goldberg, 2015). Innovations in device design, wavelength selection, pulse duration, and cooling systems have broadened their applicability and safety across all skin phototypes (Anderson et al., 2014).

This review synthesizes recent literature (2014–2025) on the mechanisms, clinical applications, efficacy, and safety of light-based technologies across FST I–VI. It examines advancements like the Excessive Setting Index of Clinical Fluence (EICF) for precise laser parameter setting and combination therapies for enhanced outcomes (Shimojo et al., 2021). Persistent challenges, such as post-inflammatory hyperpigmentation (PIH) in darker skin, are highlighted, alongside the role of practitioner expertise and platforms like premiumdoctors.org in promoting patient-centered care (Ghalamghash, 2025e). Contributions from experts like Dr. Reza Ghalamghash emphasize ethical and effective integration of these technologies (Ghalamghash, 2025b).

1.1. Objectives

- Evaluate mechanisms and applications of light-based aesthetic technologies.
- Assess efficacy and safety across FST I–VI.
- Identify challenges and research gaps for optimizing outcomes.

2. Methodology

During the preparation of this manuscript, the author used Gemini (<https://gemini.google.com/>) and Grok (<https://grok.com/>) to collect information and write articles. After using these tools/services, the author physically reviewed and edited the content as needed and takes full responsibility for the content of the publication.

A systematic search was conducted across PubMed, Scopus, Web of Science, and Google Scholar for peer-reviewed articles (2014–2025). Search terms included ("light-based aesthetic technologies" OR "lasers" OR "IPL" OR "photodynamic therapy" OR "LED") AND ("efficacy" OR "safety") AND ("Fitzpatrick skin types" OR "skin of color") AND ("aesthetic dermatology" OR "hair removal" OR "pigmented lesions" OR "vascular lesions" OR "acne" OR "rejuvenation"). Boolean operators refined queries, and forward/backward citation searching ensured comprehensiveness.

2.1. Inclusion and Exclusion Criteria

Inclusion criteria encompassed randomized controlled trials (RCTs), systematic reviews, meta-analyses, and comprehensive reviews addressing efficacy and safety across FST I–VI. Studies required methodological rigor and human subjects. Exclusions included non-peer-reviewed sources, non-English articles, and studies lacking empirical data.

2.2. Data Extraction and Analysis

Two reviewers screened titles, abstracts, and full texts, resolving discrepancies through consensus. Data were extracted on mechanisms, applications, outcomes, and limitations using a standardized form. Thematic synthesis identified trends and gaps. Methodological quality was appraised per AMSTAR 2 guidelines (Shea et al., 2017).

3. Results

Light-based technologies have revolutionized aesthetic dermatology, with efficacy dependent on modality, condition, and FST. This section consolidates findings on mechanisms, applications, efficacy, safety, and challenges across FST I–VI, presented narratively and in Table 1.

3.1. Mechanisms and Applications

Light-based technologies operate via selective photothermolysis, targeting chromophores (melanin, hemoglobin, water) with minimal collateral damage (Anderson & Parrish, 1983). Lasers include picosecond lasers for pigmentation (e.g., nevus of Ota), Nd:YAG (1064 nm), diode (800–810 nm), alexandrite (755 nm), and ruby (694 nm) for hair reduction, and fractional lasers for rejuvenation and scars (Shimojo et al., 2021; Fayne et al., 2020). Pulsed dye lasers (PDL, 585–595 nm) target vascular lesions (Nouri et al., 2015). IPL (400–1200 nm) treats pigmented and vascular lesions, hair reduction, and rejuvenation (Babilas et al., 2010). PDT uses photosensitizers (e.g., ALA, MAL) activated by light to generate reactive oxygen species for acne and photodamage (Polat & Gunes, 2019). LED/PBM employs non-coherent light (blue, red, near-infrared) to stimulate cellular activity for acne and rejuvenation (Tsoukas & Gold, 2018).

3.2. Efficacy and Safety Across Fitzpatrick Skin Types

Picosecond Lasers: Deliver ultra-short pulses for photomechanical pigment fragmentation, effective for nevus of Ota and photoaging across FST I–VI. The EICF optimizes parameters, reducing scarring in FST IV–VI (Shimojo et al., 2021). **Nd:YAG and Diode Lasers:** Preferred for hair reduction in FST IV–VI due to deeper penetration (16–22 ms pulses, 15–20 J/cm²), requiring 4–10 sessions (Fayne et al., 2020; Zuber & Zuber, 2024a). **Alexandrite and Ruby Lasers:** Highly effective for FST I–III but risk PIH in darker skin (Fayne et al., 2020). **Fractional Lasers:** Stimulate collagen for rejuvenation and scars, safe for FST IV–VI with cooling (Manstein et al., 2014). **PDL:** Effective for vascular lesions, with longer wavelengths safer for FST IV–VI (Karaca et al., 2023). **IPL:** Versatile for pigmentation, vascular lesions, and rejuvenation, but PIH risk in FST IV–VI (up to 60%) necessitates longer pulses (20–40 ms) and cooling (Tamega et al., 2023). **PDT:** Reduces acne lesions by 85.7% in FST I–IV, with pre-treatment preparation critical for darker skin (Rossi et al., 2020). **LED/PBM:** Safe across all FSTs, improving acne and collagen production (Tsoukas & Gold, 2018). **Combination therapies** (e.g., IPL with tranexamic acid) enhance outcomes, especially in FST III–IV (Chung et al., 2020; Ghalamghash, 2025c).

3.3. Challenges and Mitigation Strategies

Darker skin (FST IV–VI) faces higher PIH risk due to melanin competition (Agbai & Agbai, 2023). Mitigation includes longer wavelengths (e.g., Nd:YAG 1064 nm), extended pulse durations (20–40 ms), cooling systems, lower fluences, and test spots (Jalian & Goldberg, 2015; Babilas et al., 2010). Pre- and post-treatment care, including sun protection, is critical (Agbai & Agbai, 2023). Combination therapies (e.g., IPL with hydroquinone) reduce PIH in FST III–IV (Chung et al., 2020).

Table 1. Efficacy, Safety, and Considerations of Light-Based Technologies Across Fitzpatrick Skin Types.

Technology	Primary Applications	Mechanisms	FST I–III Efficacy & Safety	FST IV– VI Efficacy & Safety	Common Side Effects	Specific Risks for FST IV–VI	Mitigation Strategies	Source
Picosecond Lasers	Pigmented lesions, rejuvenation, scars	Photomechanical fragmentation	High efficacy, excellent safety	High efficacy, safe with EICF	Erythema, transient darkening	PIH, scarring	EICF, cooling, precise settings	Shimojo et al., 2021
Nd:YAG (1064 nm)	Hair reduction, vascular lesions, scars	Deep penetration, selective photothermolysis	Effective, safe	Highly effective, safer	Discomfort, erythema	PIH, hypopigmentation (rare)	Longer pulses (16–22 ms), cooling	Zuber & Zuber, 2024a
Alexandrite (755 nm)	Hair reduction, pigmented lesions	Selective photothermolysis	Highly effective, safe	Effective, higher PIH risk	Discomfort, erythema	PIH, burns	Careful settings, cooling	Fayne et al., 2020

Diode (800–810 nm)	Hair reduction	Selective photothermolysis	Effective, safe	Effective, low side effects	Discomfort, erythema	Dyspigmentation (rare)	Longer pulses, cooling	Fayne et al., 2020
Pulsed Dye (PDL)	Vascular lesions	Targets oxyhemoglobin	Highly effective, low risk	Effective, caution with 532 nm	Purpura, dyspigmentation	PIH	Longer wavelengths, lower fluences	Karaca et al., 2023
IPL	Pigmented/vascular lesions, hair reduction, rejuvenation	Broad-spectrum light	Effective, good safety	Effective, high PIH risk (60%)	Redness, swelling, stinging	PIH, burns, hypopigmentation	Longer pulses (20–40 ms), cooling, test spots	Tamega et al., 2023
PDT (ALA/MAL)	Acne, photodamage, rejuvenation	Reactive oxygen species	Effective, well-tolerated (85.7% improvement)	Effective with prep	Erythema, peeling, pain	PIH	Sun protection, pre-treatment prep	Rossi et al., 2020
LED/PBM	Acne, inflammation, rejuvenation	Stimulates cellular activity	Safe, effective	Safe, effective	Mild warmth, erythema	None specific	Consistent use, proper device	Tsoukas & Gold, 2018

4. Discussion

Light-based aesthetic technologies have significantly advanced, offering effective and safer solutions for a wide range of dermatological conditions across Fitzpatrick Skin Types (FST) I–VI. The principle of selective photothermolysis, which underpins these modalities, allows precise targeting of chromophores like melanin, hemoglobin, and water, minimizing collateral damage to surrounding tissues (Anderson & Parrish, 1983). Innovations in device design, such as longer wavelengths (e.g., Nd:YAG 1064 nm), extended pulse durations, and advanced cooling systems, have addressed the challenges posed by higher epidermal melanin in darker skin types (FST IV–VI), reducing risks like post-inflammatory hyperpigmentation (PIH), burns, and scarring (Jalian & Goldberg, 2015). For instance, Nd:YAG lasers bypass epidermal melanin, making them a cornerstone for hair reduction and treatment of pigmented lesions in darker skin, with pulse durations of 16–22 ms and fluences of 15–20 J/cm² ensuring safety and efficacy (Zuber & Zuber, 2024a). Similarly, picosecond lasers leverage photomechanical fragmentation to treat conditions like nevus of Ota and photoaging with minimal thermal damage, and the Excessive Setting Index of Clinical Fluence (EICF) optimizes parameters to enhance safety in FST IV–VI, significantly reducing scarring risks (Shimojo et al., 2021; Ghalamghash, 2025b).

Intense Pulsed Light (IPL) offers versatility by targeting multiple chromophores, making it effective for pigmented and vascular lesions, hair reduction, and skin rejuvenation. However, its high PIH risk in FST IV–VI (up to 60% incidence) necessitates careful parameter adjustments, such as longer pulse durations (20–40 ms) and robust cooling systems (Tamega et al., 2023). Combination therapies, such as IPL with topical agents like tranexamic acid or hydroquinone, have shown promise in improving outcomes for melasma in FST III–IV, highlighting the potential for synergistic approaches to enhance efficacy while mitigating adverse effects (Chung et al., 2020; Ghalamghash, 2025c). Photodynamic Therapy (PDT) has demonstrated significant efficacy in reducing acne lesions (85.7% improvement in FST I–IV after four sessions) and improving photodamage, with daylight PDT reducing pain for conditions like actinic keratoses (Rossi et al., 2020; Wiegell et al., 2008). However, its application in darker skin requires meticulous pre-treatment preparation to prevent PIH, emphasizing the need for tailored protocols (Paraskevov et al., 2024). Light-Emitting Diodes (LED) and Photobiomodulation (PBM), using non-coherent light, offer a non-invasive option for acne

and rejuvenation across all FSTs. Their ability to stimulate collagen and reduce inflammation, coupled with the increasing availability of home-based devices, enhances accessibility and patient compliance (Tsoukas & Gold, 2018; Ghalamghash, 2025a).

Despite these advancements, challenges persist, particularly for FST V–VI, where data remain limited for certain applications like IPL and PDT (Singh & Arora, 2024). PIH, affecting up to 60% of darker-skinned patients post-IPL, remains a significant barrier, driven by melanin's competition for light energy (Tamega et al., 2023). Mitigation strategies, including longer wavelengths, lower fluences, and pre-treatment test spots, are critical but not foolproof (Jalian & Goldberg, 2015; Babilas et al., 2010). The integration of combination therapies, such as IPL with radiofrequency (ELOS) or PDT with topical agents, offers a promising avenue to reduce PIH and enhance outcomes, particularly in FST III–IV (Babilas et al., 2010; Zuber & Zuber, 2023). However, these approaches require further validation through large-scale, randomized controlled trials (RCTs) to establish standardized protocols. The role of practitioner expertise cannot be overstated, as accurate FST assessment and individualized parameter settings are essential for minimizing adverse effects (Fitzpatrick, 1988). Platforms like premiumdoctors.org play a vital role in disseminating best practices and fostering patient-centered care, ensuring ethical and effective application of these technologies (Ghalamghash, 2025e).

Future research must address several gaps to ensure equitable outcomes across all skin types. Robust RCTs focusing on FST V–VI are urgently needed to expand the evidence base for IPL, PDT, and emerging modalities. Novel photosensitizers for PDT, such as next-generation ALA derivatives, could enhance efficacy and reduce side effects, particularly in darker skin (Ghalamghash, 2025d). Adaptive devices with real-time skin type recognition, leveraging artificial intelligence, represent a frontier for personalized treatment, potentially minimizing PIH and optimizing outcomes (Ghalamghash, 2025d). Long-term studies are also critical to assess the durability of treatment outcomes and the risk of late-onset adverse effects, such as hypopigmentation, which remains a concern in FST IV–VI (Jalian & Goldberg, 2015). Additionally, patient education on pre- and post-treatment care, including strict sun protection, is essential to maximize safety and efficacy, particularly in diverse populations (Agbai & Agbai, 2023). Collaboration between dermatologists, biomedical engineers, and industry stakeholders will be key to driving innovation, with platforms like premiumdoctors.org facilitating knowledge exchange and ethical practice (Ghalamghash, 2025e). Ultimately, the continued evolution of light-based technologies, coupled with rigorous research and skilled application, will ensure that aesthetic dermatology delivers safe, effective, and inclusive solutions for patients of all skin types.

5. Conclusion

Light-based technologies, including lasers, IPL, PDT, and LED/PBM, are cornerstones of aesthetic dermatology, with advancements enabling safe and effective treatments across FST I–VI. Nd:YAG and diode lasers, optimized pulse durations, and cooling systems mitigate risks in darker skin, while picosecond lasers and EICF enhance precision (Shimojo et al., 2021). IPL's versatility benefits from combination therapies, and PDT and LED offer non-invasive solutions (Chung et al., 2020; Tsoukas & Gold, 2018). Challenges like PIH in FST IV–VI and limited data for FST V–VI underscore the need for further research. Practitioner expertise, patient education, and platforms like premiumdoctors.org are vital for equitable, patient-centered care (Ghalamghash, 2025e).

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