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INNOVATIVE LASER TECHNOLOGIES IN THE TREATMENT OF ACNE AND POST-ACNE SCAR: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction and Objective: Aesthetic medicine is a rapidly developing field of medicine that significantly improves patients' quality of life in terms of self-esteem and psychological well-being. Modern laser technologies are not only used for rejuvenation, regeneration, or skin pigmentation removal procedures. Laser treatments play a crucial role in the treatment of acne and post-acne changes, allowing not only to reduce disease symptoms but also to minimize the risk of recurrence.
The aim of this article is to analyze the course and effectiveness of acne and skin scar therapy through the use of laser technologies, as well as the complexity of potential benefits and possible limitations of their risks.
Materials and Methods: This work is based on an analysis of scientific literature concerning the use of laser therapy in the treatment of acne and post-acne scars.
A review of existing bibliography was conducted regarding individual types of laser therapy in relation to post-acne scars and acne dermatosis. The course and effectiveness of therapy using lasers were analyzed.
Results: Literature analysis showed that modern laser technologies provide effective and relatively safe options for treating acne and post-acne scars. Laser therapy yields moderate but clinically relevant improvements in inflammatory lesions, post-acne scarring, and overall skin texture, with minimal risk when appropriate patient selection and operator expertise are ensured.
Conclusions: Laser therapy can substantially enhance outcomes in acne and post-acne scar treatment and contribute to improved patient quality of life. Further studies are needed to establish optimal treatment protocols and to compare the effectiveness of specific laser types across different clinical forms of acne.

KEYWORDS

Acne Vulgaris, Post-Acne Scars, Laser Therapy, Fractional Lasers, Ablative Lasers, Non-Ablative Lasers, Intense Pulsed Light (IPL), Innovative Laser Technologies, Dermatologic Procedures, Aesthetic Dermatology

CITATION

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Introduction

Acne vulgaris is the most common dermatosis, manifested by the presence of papules, comedones, or purulent cysts. It occurs in areas with increased sebum secretion. It most commonly appears in young people up to 30 years of age. The highest incidence affects girls between 14 and 17 years of age and boys between 16 and 19 years of age. Usually, acne presents with moderate or mild severity. Approximately 15% of cases have a severe course[1,2].

Etiopathogenesis

The causes and mechanisms of this dermatosis are diverse. The most important factors are considered to be genetic predisposition and hormonal changes typical of puberty. There is a belief that the predisposition to acne development is inherited in an autosomal dominant manner with variable gene penetration. This individual predisposition determines the size of sebaceous glands, seborrhea intensity, 5α-reductase enzyme activity, and androgen receptor reserves[1,2].

Hormonal system activity during puberty can cause increased sebaceous gland function, escalation of sebum production, sebaceous gland blockage through keratinization, and formation of hair follicle infundibular infiltrates. Hormone secretion, mainly androgens, can generate sebaceous gland enlargement and excessive sebum secretion. The greatest role is played by testosterone and its active metabolite dihydrotestosterone (DHT). Elevated levels of steroid hormones with androgenic activity may be responsible for acne formation in women over 30 years of age. Increased 5α-reductase activity causes acne lesions in areas of excessive expression of this enzyme[1,3].

The only bacterial factor contributing to acne development is Propionibacterium acnes bacteria. They release chemotactic factors that attract polymorphonuclear leukocytes forming inflammatory infiltrate. Neutrophils, through bacterial phagocytosis, release hydrolytic enzymes damaging gland walls. Sebaceous gland components penetrate the dermis, intensifying the inflammatory reaction and accumulation of nucleated cells, macrophages, and giant cells. Propionibacterium acnes causes the formation of free fatty acids as a result of triglyceride hydrolysis present in sebaceous gland secretions. Fatty acids exhibit irritating effects, resulting in keratinization of hair follicle openings[1,3].

The role of linoleic acid, responsible for the development and adhesion of corneocytes in sebaceous gland ducts, should also be mentioned. When linoleic acid content is reduced, intensified and abnormal sebum excretion appears[1].

Other factors contributing to acne development include: medications (some contraceptive preparations, antiepileptic drugs, steroid hormones, barbiturates, anabolics), lithium, iodine, vitamin B12, diet mainly carbohydrates, environmental factors[1,3].

Clinical Forms of Acne

Mild and Moderate:

Comedonal acne (acne comedonica) — mildly severe lesions appear, with closed and open comedones, sometimes pustules or papules. Acne is easy to treat and most often resolves without scar formation.

Papular acne (acne papulosa) — in this form of acne, small, raised, and reddened lesions appear, persisting for approximately 10 days.

Papulopustular acne (acne papulopustulosa) — the most common type of acne. Small eruptions, pustules, and red papules form. Scars may appear.

Pustular acne — pustules with yellow coloration form. After pustule resolution, hyperpigmentation and scars develop[4].

Severe Forms of Acne:

Nodulocystic form (acne nodulocystic) — characterized by the presence of comedones, nodules, and cysts filled with purulent content. Healing of these lesions leaves scars.

Acne conglobata — in this form, grouped comedones, cysts, skin fistulas, abscesses, and inflammatory lesions with serous or purulent discharge occur. Atrophic or hypertrophic scars are present. The treatment course is severe and prolonged.

Acne fulminans — the clinical picture of this form is severe. Inflammatory nodules, cysts, and plaques occur. Sometimes abscesses and hemorrhagic necrosis may develop. Lesions always leave scars. General symptoms accompanying this disease include: general discomfort, weight loss, fever, joint and muscle pain, proteinuria, and elevated erythrocyte sedimentation rate.

Keloid acne (acne keloidea) — acne eruptions transform into hypertrophic scars and keloids.

Induced acne — forms as a result of some triggering factor.

Cosmetic acne (acne cosmetica) — some cosmetics contain comedogenic substances causing comedone formation. Acne develops as a result of sebaceous gland opening blockage.

Occupational acne (acne professionalis) — characterized by the formation of large comedones, papules, pustules, cysts, and nodules. It develops as a result of contact with chemical compounds.

Drug-induced acne (acne postmedicamentosa) — occurs as a result of taking many medications: corticosteroids, psychotropic drugs, progestins, antiepileptic drugs, iodides, bromides, vitamins B2, B6, B12. Characteristic for this form are inflammatory lesions without the presence of comedones[4].

Mechanism of Action and Types of Lasers in Acne and Post-Acne Scar Therapy

Laser — Light Amplification by Stimulated Emission of Radiation — emits a highly focused beam of monochromatic light of one strictly defined color. Laser devices utilize the effect of interactive electromagnetic radiation with an active medium, i.e., matter. As a result of this reaction, radiation amplification and generation occur[5,6].

A laser emits an electromagnetic wave possessing characteristics such as:

Wavelength in nanometers — a factor determining light color

Amplitude — which determines the strength of emitted radiation[7]

Basic Characteristics of Laser Radiation

Monochromaticity — single-color radiation with very narrow spectral line width

Coherence — spatial and temporal systematization of electromagnetic radiation oscillations

Beam collimation — minimal beam divergence

Intensity — high energy intensity in a narrow spectral line[7]

Currently, laser therapy is used due to characteristics such as: non-invasiveness, simplicity of procedure execution, painlessness, and effectiveness[7].

Lasers used in medicine are low-energy (stimulating) lasers emitting radiation not exceeding 500 mW. They are used for treating wounds and scars, pain syndromes, and many disease conditions. For biostimulation, it is necessary to deliver a specific amount of energy to an appropriate depth. The ability to absorb and the depth of radiation penetration depend on the structure of the irradiated tissue, its characteristics such as blood supply, hydration, pH, pigmentation, melanin and hemoglobin content, as well as radiation wavelength and therapy duration[7].

Depending on the mode of action, lasers used in acne therapy are divided into: Pulsed lasers — average radiation power is set by changing radiation frequency. These include nanosecond, picosecond, femtosecond lasers, as well as Er:YAG and Ho:YAG lasers, and continuous-wave lasers[7].

Classification of Lasers According to Energy Delivery Technique to Tissue

Non-ablative lasers (Nd:YAG 1064 nm; diode 675 nm, 810-1450 nm; 1440 nm; Er:Glass 1540 nm, 1559 nm) — cause controlled damage in the dermis without epidermal deformation.

Ablative lasers (CO_2 10600 nm; Er:YAG 2940 nm) — cause vaporization of outer tissue layers.

Full-spot lasers — conventional lasers irradiating entire surfaces with a full spot.

Fractional lasers (micro thermal zones, MTZ; micro ablative zones, MAZ) — generate micro-zones of thermal damage or ablation, with zones of healthy tissue between these areas. Faster healing and minimization of complications due to tissue overheating occur[4].

Lasers emitting blue light combat Propionibacterium acnes, while infrared light and radio waves act on sebaceous glands. Laser therapy works in two ways: treating acne and preventing or reducing scarring through neocollagenogenesis regulation[8].

Acne Therapy

1450 nm diode laser — acts on the pilosebaceous unit, but due to connective tissue heating, neocollagenogenesis also occurs, which may prevent post-acne scarring to some extent.

1540 nm erbium-glass laser — photopneumatic therapy, selective destruction of Propionibacterium acnes. Combines vacuum with simultaneous delivery of broadband pulsed light. Elevates the sebaceous area closer to the skin surface and removes sebaceous area contents.

Photodynamic therapy (PDT) with ALA (5-aminolevulinic acid) and indocyanine green — utilizes three factors: photosensitizer, light source, and oxygen dissolved in tissues.

The application of radio waves in acne treatment involves generating electric current that produces heat through resistance in subcutaneous tissue and dermis, thereby stimulating neocollagenogenesis and collagen remodeling[8].

Table 1. Types of Lasers Used in Acne Treatment

Device Type	Endogenous Chromophore	Effect
Diode laser 1726 ms	Sebaceous glands	Sebaceous gland denaturation, sebum production limitation, C. acnes multiplication inhibition
Diode laser 1450 ms	Water, sebaceous glands	Sebaceous gland minimization
Nd:YAG laser	Sebaceous glands	Sebaceous gland degradation, minimization of perifollicular corneal layer and epithelium
IPL device 420-430	Porphyrins	C. acnes reduction, light thermolysis of sebaceous glands, porphyrin photoexcitation
Thulium laser 1927 μs	Water	Natural skin regeneration stimulation, collagen production, cell renewal
CO_2 laser 10600 ms	Water	Sebaceous gland photothermolysis

Table 1: Types of laser devices in acne therapy (adapted from Surgiel-Giemza, 2025)

When discussing the topic addressed in this work, it is necessary to discuss scar types and laser therapy selection.

A scar (cicatrix) is the result of wound healing. Causes of scar formation include mechanical, thermal, chemical injuries, as well as inflammatory conditions.

In terms of chronology, scars are divided into immature and mature.

Immature scars are characterized by thick, hard tissue structure. The scar is convex, poorly elastic, red or pink in color. They appear up to one year after formation.

Mature scars are characterized by soft, flat, elastic tissue, properly vascularized. They appear more than 1 year after formation.

In terms of appearance and health problems, scars are divided into:

Normal scars — are light-colored with flat structure.

Abnormal scars — characterized by convex structure, red color, may cause pain or itching sensations.

Linear hypertrophic scars — typically have red coloration, are convex but do not exceed the wound line. Sometimes they may cause itching or pain. The formation process lasts up to 2 years and creates a contracting, convex scar. Lesion regression is possible.

Large-area hypertrophic scars — are extensive, convex lesions causing itching.

Small keloid — may develop up to one year after formation, size up to 0.5 cm, convex, extends beyond the original lesion outline.

Large keloid — extensive lesion exceeding 0.5 cm, extends beyond the initial wound boundary. It is convex, may cause pain, itching, and other paresthesias, may enlarge, does not regress spontaneously[4].

Post-acne scars — result from chronic inflammation and skin damage during healing. There are atrophic and hypertrophic scar types. 80% to 90% of post-acne scars are atrophic scars (with low collagen content), the remainder are hypertrophic scars and keloids.

Atrophic scars are scars that develop as a result of acute inflammation. Collagen loss and skin tissue atrophy occur. These lesions are characterized by depressed structure.

Hypertrophic scars — are lesions characterized by increased collagen deposition with simultaneously decreased collagenase activity. Hypertrophic scars are convex, firm, pink in color with bundles of hyalinized collagen. Keloids have the appearance of red-purple nodules extending beyond the original wound area. They are characterized by bundles of hyalinized acellular collagen arranged around each other[4].

Laser therapy technique allows for the implementation of optional scar treatment and coexisting symptoms. The therapeutic effect is maximized when the laser type is matched to the scar type and treatment type. For immature scars, pulsed dye laser (PDL) is used, which causes coagulation in capillary vessels. For mature scars, ablative CO_2 laser is used, which works by evaporating water in abnormal collagen forms. Through scar irradiation, tissue undergoes ablation and formation of the desired collagen form occurs[9].

Table 2. Types of Laser Therapy in Scar Treatment

Device Type	Endogenous Chromophore	Scar Type	Symptom
Pulsed dye laser 585/595 ms	Hemoglobin	Rolling type, hypertrophic, keloids	Erythema
Alexandrite laser 755 ms	Melanin	Various pigmented scars	Erythema, hyperpigmentation
KTP laser 532 ms	Hemoglobin	Scars with erythematous background	Erythema
Nd:YAG laser 1064 ms	Melanin, blood vessels, water	Scars with erythematous background	Erythema, dilated blood vessels, collagen deficiency
Q-switched Nd:YAG laser 1064 ns	Melanin	Papular various pigmented scars	Post-inflammatory hyperpigmentation
Q-switched Nd:YAG laser 532 ns	Hemoglobin	Scars with erythematous background, post-inflammatory hyperpigmentation, post-acne hyperpigmentation	Erythema, hyperpigmentation
Thulium laser 1927 μs	Water	Rolling, boxcar, ice pick type scars, post-inflammatory hyperpigmentation	Collagen deficiency, inflammatory changes
Er:Glass laser 1550 ms	Water	Rolling, boxcar, ice pick type scars, rolling type hypertrophic scars	Collagen deficiency or excess, erythema, hypopigmentation
Er:YAG laser 2940 ms	Water	Rolling, boxcar, ice pick type scars, hypertrophic scars	Collagen deficiency/excess
CO_2 laser 10600 ms	Water	Rolling, boxcar, ice pick type scars, hypertrophic scars	Collagen deficiency/excess

Device Type	Endogenous Chromophore	Scar Type	Symptom
Volumetric laser (NAFL) 675 ms	Collagen, melanin	Rolling, boxcar, ice pick type scars, pigmented scars	Scars with erythematous background, post-acne hyperpigmentation, post-inflammatory hyperpigmentation
Endolift diode laser 1470 ms	Water	Rolling, boxcar, ice pick type scars	Collagen deficiency, adhesions
IPL (intense pulsed light) 590/610/650/660-1200 ms	Hemoglobin, melanin	Pigmented scars, scars with erythematous background	Scars with erythematous background, post-acne hyperpigmentation, post-inflammatory hyperpigmentation, collagen deficiency
Narrowband nIPL 500-600 ms	Hemoglobin, melanin	Scars with erythematous background, post-inflammatory hyperpigmentation, post-acne hyperpigmentation	Scars with erythematous background, post-acne hyperpigmentation, post-inflammatory hyperpigmentation

Table 2: Classification of laser therapy methods in scar treatment (adapted from Surgiel-Giemza, 2025, p. 157)

Discussion

Analyzing the literature, the complexity of potential benefits and possible limitations and risks of using laser therapy in the treatment of acne and post-acne scars was observed. The effectiveness of individual methods for treating post-acne scars using devices available on the market was also analyzed.

According to Dubielecka, significant limitations in using lasers in acne therapy include: pregnancy, unstabilized diabetes, hormonal disorders such as thyroid diseases, cardiovascular diseases, epilepsy, use of certain medications containing silver, iron, bismuth. Various viral, bacterial, and fungal diseases[10].

Surgiel-Giemza indicates as contraindications a number of factors: age under 18 years (legal guardian consent required), blood-thinning medications, neoplastic diseases, radiotherapy, chemotherapy, autoimmune diseases, skin pigmentation disorders, pregnancy, lactation, solar urticaria, epilepsy, photosensitizing medications, dietary supplements, herbs, tanned skin in the treatment area, neurological diseases, multiple sclerosis, viral, bacterial and fungal infections, sensory disorders, connective tissue disorders, diseases impairing platelet function, diabetes, cardiac diseases, migraines, claustrophobia, mental disorders, hepatitis B and C, HIV, AIDS (with attending physician consent), venous-lymphatic insufficiency, healing process disorders, fibrinogen deficiency, porphyria, Ehlers-Danlos syndrome[4].

When discussing laser therapy, the possibility of adverse effects should be addressed. According to Surgiel-Giemza, these include elevated body temperature, pain, erythema, swelling of the treatment site or surrounding tissues, blisters, crusts, burns, atrophic or hypertrophic scars[4].

Christian Raulin and Wolfgang Kimmig write that a disadvantage of lasers is that they can cause post-inflammatory hyperpigmentation during treatment when the epidermis was damaged. CW (Continuous Wave) and quasi-CW lasers in some cases may cause scarring and structural changes due to thermal diffusion. Lasers built according to the selective photothermolysis concept, i.e., DFB, DBR, VCSEL, fiber lasers with FBG, have varying probabilities of treatment-induced scars, epidermal damage, pigment changes, structural changes, and crust formation[9].

Kopeć J. and Przewratil P. in their work concluded that laser therapy complications are rare, transient, and reversible[11].

Ensieh Khalkhal and colleagues demonstrate that scientists have found that laser therapy shows a low complication rate. Adverse effects are transient, not drastically increased, and do not lead to chronic consequences[12].

Analyzing the literature, it is impossible not to notice that laser therapy shows many advantages.

D. Haykel and colleagues describe laser action, demonstrating as advantages the fact that they can effectively treat a wide range of problems of the discussed dermatosis. Advances in laser design have resulted in patients showing high satisfaction levels, improved quality of life, and improved skin condition. Speaking

of the advantages of this form of treatment, they present a relatively short recovery period and a small number of side effects[13].

According to Surgiel-Giemza, from research conducted by Vitale et al., in the case of a laser with 675 nm wavelength, reduction of acne lesions, decrease in inflammatory lesions, and improved skin condition were observed. Patients were satisfied with the therapy, and pain was felt to a minor degree. The aforementioned author also cites results of other scientists, indicating that laser application caused reduction of inflammatory and non-inflammatory lesions, hair follicle remodeling, and tissue renewal. In long-term observations, they demonstrated significant reduction in inflammatory lesion numbers and patient satisfaction[4].

According to Valeska Gozali et al., treatment using non-ablative lasers is gaining increasing popularity in treating post-acne scars because the probability of adverse effects and the need for continued post-procedure care are reduced. They also mentioned currently available fractional bipolar radiofrequency (RF), using radio waves, whose action is based on sublative rejuvenation working on the principle of creating micro-damage while simultaneously generating dermal remodeling to increase therapy effectiveness and minimize adverse effects to the greatest extent[14].

Randomized studies conducted among Asians by Ru Dai et al. were analyzed, comparing the action of Nd:YAG picosecond laser with 1064 nm wavelength using fractional micro-lenses and Er:YAG fractional ablative laser with 2940 nm wavelength in atrophic post-acne scar therapy. The study involved subjecting patients to four laser therapy sessions using Nd:YAG laser (1064 nm) in P-MLA protocol and Er:YAG laser (2940 nm) in AF-Er protocol on two different face halves. The time between successive sessions was four weeks. Comparable effectiveness in changing the clinical picture of post-acne scars was found. In safety profile assessment, no serious adverse effects were noted on either side. The area treated with P-MLA protocol was characterized by less pain intensity, shortened crust and edema persistence time, and lower post-inflammatory hyperpigmentation (PIH) frequency. Simultaneously, after P-MLA therapy, more pronounced purpura and erythema were observed. However, patient satisfaction subjected to the studies proved higher for the face side subjected to AF-Er method therapy. The conclusion of the mentioned study authors is that P-MLA and AF-Er in scar therapy are characterized by comparable effectiveness, but P-MLA shows a more favorable safety margin[15].

Essamelden M. Mohamed et al. conducted a randomized study involving laser therapy of two different parts of the face affected by symmetrically occurring acne lesions. Nd:YAG laser therapy with 1064 nm wavelength and diode laser with 577 nm wavelength were used. The study authors describe significant improvement in papule occurrence and erythema after diode laser application. In contrast to the diode laser, Nd:YAG laser acts mainly on sebaceous glands, thereby reducing sebum secretion through photothermal effect. Due to limited melanin absorption, this technique shows greater safety of use in people with higher skin phototypes. Positive effects in inflammatory lesion and comedone occurrence were observed after Nd:YAG laser therapy. Summarizing, the authors stated that no significant differences were observed between the two laser therapy techniques in terms of treatment effectiveness, adverse effect profile, or patient satisfaction level[16].

Tasneem Muhammad Hammoda et al. compare fractional CO_2 laser action and Nd:YAG laser with 1064 nm wavelength in acne vulgaris therapy. They conducted randomized clinical studies. Patients underwent studies during four laser therapy sessions. Each took place at fourteen-day intervals on two different parts of the patient's face. Certain differences occurring between the face part subjected to CO_2 laser therapy and the side where Nd:YAG laser was used were observed. However, no significant discrepancies in the obtained effect were found. On the other hand, after three months, fractional CO_2 laser contributed to significant reduction in inflammatory and non-inflammatory lesion numbers compared with the effect obtained from Nd:YAG laser action[17].

Comparison of thulium laser effects with 1927 nm wavelength and Er:YAG laser with 2940 nm wavelength in atrophic post-acne scar treatment was conducted by Kuna Lu et al. They performed a prospective clinical study involving three laser therapy sessions at intervals of 4-6 weeks. Persons subjected to studies showed good clinical response to the aforementioned therapies. The morphological picture of post-acne scars improved without distinct differences between applied methods. In the group of studied persons, side effects were pain, edema, erythema, and acne exacerbation. The only difference between thulium laser and Er:YAG laser is the degree of pain intensity. Pain symptoms during Er:YAG treatment were slightly more severe[18].

Paweł Kubik et al. conducted prospective studies whose aim was to analyze the effectiveness and safety profile of non-ablative laser therapy with 1470 nm wavelength. In post-acne scar therapy localized on facial skin, the primary endpoint was assessment of skin surface and its elasticity, as well as reduction of scar depth

and extent, with simultaneous verification of clinically significant therapy side effects. The study included forty healthy women aged 18 to 42 years with post-acne scars on facial skin. Participants underwent three laser therapy treatments. Intervals between sessions were two weeks. Obtained results showed statistically significant improvement in all analyzed criteria. Skin elasticity systematically increased. Ultrasonographic analysis showed significant scar flattening. Similar effects were observable regarding scar diameter. Clinical assessment based on photographic documentation confirmed the aforementioned results, showing clear improvement in appearance and overall skin structure. No side effects were observed during the described studies. Obtained results indicate significant therapeutic benefits and a favorable safety profile. Described results make this method a valuable therapeutic option in cases of pigmentation and skin structure disorders associated with post-acne scar presence[19].

Prospective studies conducted by Anna Szymańska et al. aimed to analyze low-energy laser therapy action with 785 nm wavelength. The experiment involved conducting a series of six treatments at two-week intervals in 27 women in the age range from 18 to 45 years who struggled with acne of varying symptom intensity. Laser therapy of skin in acne lesion locations was performed using Vitalaser Hannover GmbH laser for 10 minutes. During this time, the device produced radiation with 785 nm wavelength. Sebometric analysis and analysis of acne skin lesion numbers were performed. As a result of therapy, significant improvement in skin condition regarding the occurrence of aforementioned eruptions (according to IGA scale) and significant decrease in sebum secretion (in this case, the most significant decrease was observed between the 3rd and 6th treatment series) were observed. No negative therapy effects were observed[20].

Results and Conclusions

Literature analysis demonstrated that modern laser technologies have introduced broad possibilities for treating patients with acne and post-acne scars. They have enabled patients suffering from this dermatosis to be treated more safely and effectively. Laser therapy effects are moderate and require a series of treatments, depending on the patient's skin type. The risk of using lasers exists but is minimal. The most apparent clinical effects are observed in treating inflammatory lesions, post-acne scars, and improving skin structure. Laser treatments are characterized by a high level of safety; however, they require proper categorization of patient condition and operator skills. The state of knowledge in light of the latest research indicates that laser therapy can significantly improve acne treatment outcomes, post-acne scars, and improves patients' quality of life. In my assessment, further research is necessary to obtain optimal treatment protocols and evaluate the effectiveness of individual laser types in different acne types.

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