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ACNE VULGARIS: PATHOGENESIS AND MANAGEMENT WITH LONG-PULSED ND: YAG (1064 NM) LASER THERAPY – A SYSTEMATIC REVIEW

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Abstract

Introduction. Acne vulgaris is a common chronic inflammatory skin disease that mainly affects adolescents and young adults but is also increasingly recognized in adults. It can cause physical discomfort, permanent scarring, and significant psychosocial distress. Conventional topical and systemic therapies often lead to slow or incomplete improvement and are frequently associated with adverse effects, poor compliance, and relapse. Consequently, there is an increasing interest in innovative treatment modalities such as long-pulsed Nd: YAG (1064 nm) laser therapy, which has shown promising efficacy and safety.
Aim. This systematic review aims to summarize and critically evaluate current knowledge on epidemiology, pathogenesis, clinical presentation, and treatment of acne vulgaris, with a special focus on the role of advanced laser technologies such as the long-pulsed neodymium-doped yttrium aluminum garnet (1064 nm) laser (Nd: YAG) therapy.
Materials and methods. A structured search of PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and SpringerLink databases was performed using the keywords «acne vulgaris,» «pathogenesis,» «laser therapy,» «Nd: YAG,» and «moderate-to-severe acne.» The initial search yielded 680 records, with 12 additional articles identified through manual reference screening. After removing duplicates and applying inclusion and exclusion criteria, 40 peer-reviewed studies published between 2015 and 2025 were included in the final qualitative synthesis. These provided relevant data on epidemiology, pathogenesis, diagnostic classification, and therapeutic approaches to moderate-to-severe acne vulgaris, with a particular focus on long-pulsed Nd: YAG (1064 nm) laser therapy.
Results. The analyzed literature indicates a multifactorial pathogenesis involving sebaceous gland hyperactivity, hormonal dysregulation, microbial colonization by *Cutibacterium acnes*, immune system activation, oxidative stress, and microbiome imbalance. Several therapeutic approaches are available, ranging from topical and systemic agents to light- and laser-based modalities. The long-pulsed Nd: YAG (1064 nm) laser demonstrates promising efficacy and safety, especially in recalcitrant cases and scar-prone individuals.
Conclusions. Acne vulgaris remains a complex dermatologic condition with evolving pathophysiological insights and therapeutic strategies. The long-pulsed Nd: YAG (1064 nm) laser represents a valuable addition to conventional therapy for acne vulgaris, warranting further integration into routine clinical practice.

Keywords: **acne vulgaris, epidemiology, severe acne, pathogenesis, Nd: YAG laser, laser therapy, *Cutibacterium acnes*, quality of life**

INTRODUCTION

Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit and remains one of the most prevalent dermatologic conditions worldwide. Its medical concept has evolved over centuries: as described by Tilles (2014) [1], early dermatologists such as Alibert, Hebra, and Kaposi established the foundation for recognizing acne as a chronic inflammatory disease of the sebaceous glands [2]. According to Heng and Chew (2020) [3], global epidemiological data reveal substantial geographic and methodological variations,

with an estimated lifetime prevalence of 85-90% among adolescents and 20-30% among adults, particularly women aged 25-45 years [4]. In Ukraine and Eastern Europe, dermatological registries indicate that moderate-to-severe forms account for 35-40% of dermatology consultations in individuals aged 18-40 years [5, 6]. Although once regarded as a self-limiting adolescent disorder, acne frequently persists into adulthood, causing irreversible scarring, pigmentation, and considerable psychosocial burden. Emotional consequences – such as anxiety, depression, and reduced self-esteem – often outweigh visible lesions and necessitate a multidisciplinary approach [7]. The pathogenesis of acne is multifactorial, involving genetic predisposition, hormonal imbalance (notably elevated androgens and IGF-1), microbial dysbiosis, and environmental triggers [8, 9]. Key mechanisms include sebaceous hyperactivity, follicular hyperkeratinization, *Cutibacterium acnes* proliferation, and TLR-mediated cytokine release (IL-1β, IL-8, TNF-α), further amplified by oxidative stress and skin–gut microbiome imbalance. Diagnosis is primarily clinical, supported by standardized grading systems such as GAGS and the Leeds Scale [10, 11]. Treatment depends on severity and includes topical and systemic agents (benzoyl peroxide, retinoids, antibiotics, isotretinoin, hormonal therapy), often combined with procedural methods – chemical peels, phototherapy, or laser therapy [12, 13]. Growing antibiotic resistance and isotretinoin contraindications have accelerated the shift toward non-pharmacologic modalities. Among these, the long-pulsed Nd: YAG laser (1064 nm) provides deep dermal penetration and selective photothermal targeting of sebaceous glands, reducing sebum, microbial load, and inflammation with minimal downtime. Clinical studies report 40-70% lesion reduction and high patient satisfaction after 4-6 sessions [14-16]. Given the global burden of moderate-to-severe acne and expanding evidence for laser-based therapies, this systematic review aims to synthesize current data on epidemiology, pathogenesis, and management, emphasizing the efficacy and safety of long-pulsed Nd: YAG (1064 nm) laser as an emerging cornerstone of modern acne treatment.

AIM

This systematic review aims to summarize and critically evaluate current knowledge on the epidemiology, pathogenesis, clinical presentation, and treatment of acne vulgaris, with a special focus on the role of advanced laser technologies such as long-pulsed Nd: YAG (1064 nm) therapy.

MATERIALS AND METHODS

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement [49] to synthesize and critically evaluate contemporary literature on the epidemiology, pathogenesis, clinical presentation, and treatment of moderate-to-severe acne vulgaris, with a particular focus on the clinical application of long-pulsed Nd: YAG laser therapy (1064 nm). A structured and transparent methodology was adopted following PRISMA 2020 guidelines to ensure comprehensive coverage and reproducibility. A systematic search was performed across major electronic databases PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and SpringerLink for the period January 2015 to August 2025. The following keywords and Boolean operators were applied: «acne vulgaris,» «moderate acne» OR «severe acne,» «pathogenesis of acne,» «laser therapy» OR «Nd: YAG laser,» «inflammatory acne,» «acne treatment guidelines,» «sebaceous glands» AND «Cutibacterium acnes,» and «quality of life in acne.» In addition, manual cross-referencing of bibliographies was performed to identify any further relevant publications. Studies were included if they met the following criteria: peer-reviewed full-text papers in English (2015-2025); original research, systematic reviews, meta-analyses, or clinical guidelines addressing moderate-to-severe acne vulgaris; and studies focusing on epidemiology, pathogenesis, diagnosis, or treatment, particularly Nd: YAG (1064 nm) laser-based interventions. Exclusion criteria comprised case reports with fewer than five participants, studies limited to mild acne or pediatric populations, non-human or *in vitro* research, and non-peer-reviewed or promotional materials. All eligible studies underwent independent screening by two reviewers using standardized data-extraction forms to ensure methodological consistency and minimize selection bias. Quality assessment was performed using validated instruments: the Newcastle–Ottawa Scale (NOS) for observational studies and the Cochrane Risk of Bias Tool (RoB 2) for randomized controlled trials. Discrepancies between reviewers were resolved by consensus, and only studies rated as having low or moderate risk of bias were retained for qualitative synthesis. The systematic search initially identified 680 records through database queries and 12 additional records through manual reference screening. After removing duplicates, 340 unique articles remained for title and abstract screening. Following the exclusion of 220 irrelevant studies (mild acne, pediatric cases, *in vitro* or cosmetic research), 120 full-text articles were assessed for eligibility. Of these, 80 were excluded for insufficient methodological quality or lack of relevant outcomes. Ultimately, 40 peer-reviewed articles met all inclusion criteria and were incorporated into the final qualitative synthesis. The 12 studies identified manually were included within this total. The complete selection and screening process is summarized in Table 1 and illustrated in Figure 1 (PRISMA Flow Diagram). The review was not prospectively registered in PROSPERO.

Table 1

Summary of Literature Search and Screening Process (PRISMA Framework)

Stage	Description	Number of Publications (n)
Identification	Records identified through database search (the PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and SpringerLink)	680
	Additional records identified through manual reference checking	12
Duplicates Removed	After removing duplicates	340
Screening	Records screened by title and abstract	340
	Records excluded (mild acne, pediatric, non-clinical, cosmetic)	220
Eligibility	Full-text articles assessed for eligibility	120
	Full-text articles excluded (incomplete data, non-relevant outcomes, non-human studies)	80
Included	Studies included in qualitative synthesis (narrative synthesis)	40

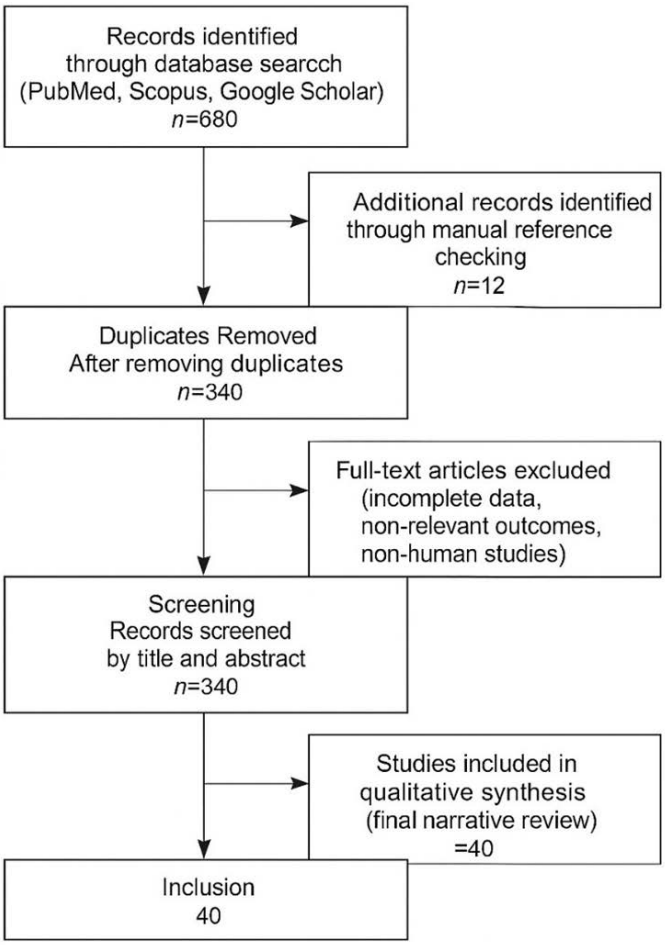

Figure 1. PRISMA Flow Diagram of the Literature Search and Study Selection Process.

The PRISMA 2020 flow diagram summarizes the process of literature identification, screening, eligibility assessment, and inclusion for this systematic review on moderate-to-severe acne vulgaris treated with the Nd: YAG (1064 nm) laser between 2015 and 2025. A total of 680 records were retrieved from PubMed/ MEDLINE, Scopus, Web of Science, Google Scholar, and SpringerLink, with 12 additional sources identified through manual reference screening. After removing duplicates, 340 unique studies were screened. Following title, abstract, and full-text evaluation, 40 studies fulfilled all inclusion criteria and were incorporated into the qualitative synthesis. Table 2 summarizes the temporal distribution of the included publications according to the hierarchy of evidence (Levels I-III). A progressive shift toward higher-quality clinical research is evident, with the greatest concentration of Level III studies published during 2024-2025, highlighting the growing scientific and clinical interest in Nd: YAG laser applications for moderate-to-severe acne vulgaris. Figure 2 further illustrates this temporal pattern of evidence levels across the 2015-2025 publication period.

Table 2

Distribution of Included Studies by Evidence Level and Publication Period (2015-2025)

Publication Period	Level I	Level II	Level III	Comment
2015-2017	0	1	2	Early clinical observations
2018-2020	1	2	3	First randomized controlled trials (RCTs) appear
2021-2023	1	3	5	Active implementation of Nd: YAG laser therapy
2024-2025	1	4	6	Peak of publications, including new reviews and combined treatment protocols

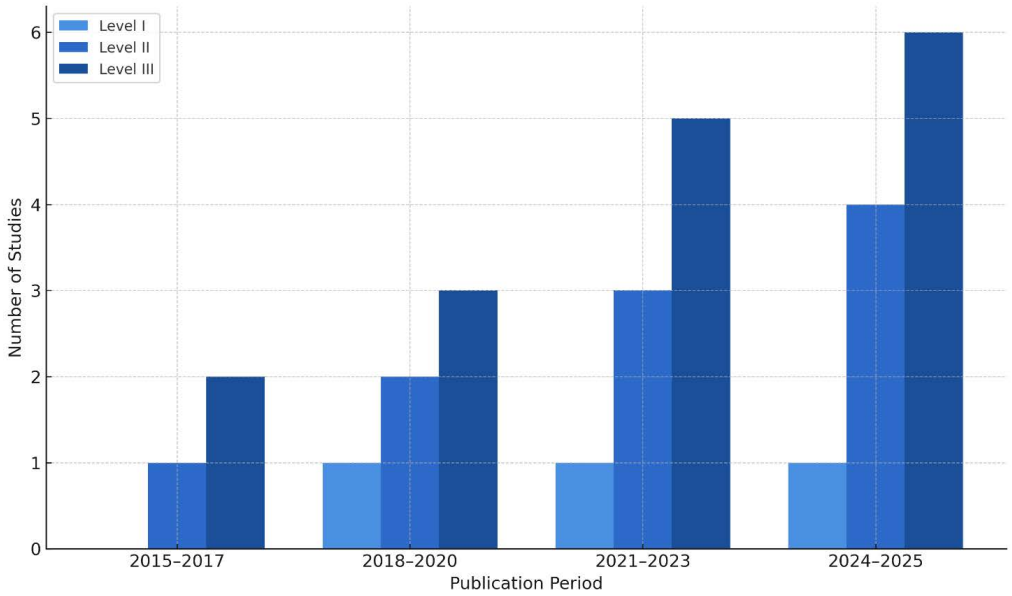

Figure 2. Distribution of Included Studies by Evidence Level and Publication Period (2015-2025).

The bar chart illustrates the progressive increase in both the number and quality of studies on Nd: YAG laser therapy for moderate to severe acne vulgaris over the 2015-2025 period. A marked rise in publications with higher levels of evidence (particularly Level III) was observed in 2024-2025, indicating the growing clinical validation and scientific integration of laser-based approaches in modern acne management.

Risk of Bias and Methodological Quality Assessment. The methodological quality of the included studies was assessed using the Cochrane Risk of Bias Tool (RoB 2) for randomized controlled trials and the Newcastle–Ottawa Scale (NOS) for observational studies. Overall, most randomized trials were judged as having low risk of bias or some concerns, primarily related to performance bias (limited blinding) and incomplete reporting of allocation concealment. Observational studies generally demonstrated moderate-to-high methodological quality, with the most frequent limitations being short follow-up duration and heterogeneity in outcome measures. These assessments were considered when interpreting the direction and consistency of the reported clinical effects.

RESULTS

In their comprehensive 2025 review, Guguluș et al. [17] emphasized that acne vulgaris remains one of the most prevalent dermatological conditions worldwide, with a global prevalence of ≈ 9.4% and a growing trend among adult women. The Global Burden of Disease (GBD) project identified acne as a notable contributor to disability-adjusted life years (≈ 5 million YLDs annually) due to its psychological and social impact [50]. Acne has undergone an epidemiological transition – from a disorder of adolescence to one that increasingly affects adults. Westernized diet, urban stress, and cosmetic misuse act as major external triggers, whereas hormonal imbalance and genetic susceptibility serve as intrinsic determinants. Kutlu et al. [18] highlighted distinct epidemiological differences between adolescent and adult acne. Adolescent acne predominates in males (≈ 28% boys vs 21% girls) due to androgenic activity, while adult acne-affecting 80-90% of female cases-is associated with hormonal imbalance, stress, and cosmetics. Shared risk factors include family history, high-glycemic diet, dairy consumption, and insulin resistance. Adult acne manifests mainly as chronic inflammatory lesions on the chin and jawline, whereas adolescent acne is comedonal and localized to the T-zone. Scarring occurs more often in adults (20-76%), reflecting prolonged inflammation and therapeutic resistance. Shah et al. [19] performed one of the largest Indian observational studies on adult-onset acne. Among >24 000 dermatology patients, prevalence was 0.74%, confirming clinical relevance

despite lower frequency. The mean age was 30 years, with ≈ 82% female predominance and ≈ 70% chronic disease course. Inflammatory papular acne predominated (85% cheek involvement; 63% scarring). Major aggravating factors included cosmetics, high-glycemic diet, stress, premenstrual flares (62%), and hirsutism (16%). These findings underline the multifactorial etiology of adult acne and the importance of early targeted management. In a large cross-sectional analysis, Heng et al. [20] examined 3 888 Singapore Chinese participants aged 17-71 years. Parental acne emerged as the strongest predictor of both occurrence and severity, while sibling acne correlated with grade 3-4 scarring. Younger age and female sex were associated with greater severity; underweight BMI appeared protective, whereas atopic comorbidities (asthma, allergic rhinitis, eczema) increased susceptibility. Prolonged screen exposure and alcohol intake worsened acne, while milk showed a protective effect and butter consumption aggravated scarring. These results highlight the complex interplay between genetic, environmental, and behavioral factors. The Rotterdam Generation R Study [21] provided one of the largest multiethnic European analyses of adolescent acne. Among 4 561 participants (median age 13.5 years), prevalence was ≈ 50%, with higher severity in girls (GEA 3-5 in 14% of girls vs 9% of boys), reflecting earlier puberty. Severity correlated with advanced Tanner stage, elevated BMI (in boys), and darker Fitzpatrick phototype (V-VI), suggesting biological and pigment-related modulation of inflammation. Socioeconomic status and ethnicity were not independent predictors after adjustment. These data identify puberty progression, body composition, and phototype as central determinants of acne severity and underscore the need for ethnically inclusive models. A summary of representative epidemiological studies published 2021-2025 is presented in Table 3.

Table 3

Major Epidemiological Studies on the Prevalence, Risk Factors, and Clinical Characteristics of Acne Vulgaris

Author (Year)	Region / Sample	Study Design / Focus	Main Findings
Guguluș D.L. et al. (2025)	Global (multi-regional review)	Narrative review of global epidemiology, prevalence, and psychosocial burden of acne vulgaris	Global prevalence ≈ 9.4%; >3.5 million new cases annually. Acne affects ≈ 80% of individuals aged 11-30. Increasing adult-female incidence (20% women vs 8% men). 20% of cases = severe forms causing scarring. Acne ranks 19th worldwide for DALYs (≈ 5 million YLDs). Western diet & urban lifestyle = main extrinsic risk factors. Marked psychosocial impact (depression, anxiety, stigma).
Kutlu Ö., Karadağ A. S., Wollina U. (2022)	Turkey / Europe (narrative review, multi-study synthesis)	Comparative analysis of adult vs adolescent acne, including epidemiology, etiopathogenesis, triggers, and clinical patterns	Adolescent acne: 27.9% of boys, 20.8% of girls. Adult acne: predominantly women (≈ 82%). Hormonal and stress-related factors play a major role in adult acne. Family history present in 38.8-70% of cases. Western diet, insulin resistance, and dairy intake significantly aggravate both types. Premenstrual flares in 78% of adult females vs 53% of adolescent females. Adult acne shows higher scarring (20-76%) and chronic inflammatory lesions on chin / jawline.
Shah N. et al. (2021)	India / 24,056 adults (180 acne cases)	Prospective observational study of adult acne prevalence and clinico-epidemiologic characteristics	Adult acne prevalence = 0.74%; mean age = 30.1 yrs; 81.7% female, 68.3% persistent type. Inflammatory papular acne = 72.8%; cheeks = most common site (85%). Scarring in 62.8%. Family history = 60.6%; chronic stress = 23.9%; aggravation by cosmetics = 43.5% and high-glycemic foods = 42.8%. Premenstrual flare in 61.9% and hirsutism in 16.3% of females.
Heng A.H.S. et al. (2022)	Singapore / 3,888 subjects (2,090 acne cases; 1,798 controls; age 17-71)	Cross-sectional epidemiological study assessing risk factors for acne presentation, severity, and scarring	Parental acne significantly associated with both acne occurrence and moderate–severe forms; sibling acne correlated with grade 3-4 scarring. Female gender and younger age increased acne severity. Underweight BMI protective; atopic diseases predisposed to acne. Screen time and alcohol correlated with higher severity; milk intake protective, while butter intake worsened scarring. Family history and lifestyle factors were dominant predictors.
Generation R Study Group (2023)	Multiethnic adolescent cohort, n = 4,561 (51% girls, median age = 13.5 years)	Cross-sectional, population-based analysis within the *Generation R* prospective cohort using Global Evaluation Acne (GEA) scale; assessment of demographic, pubertal, and lifestyle determinants	Visible acne prevalence: girls 62%, boys 45%; moderate–severe acne: 14% vs 9%. Severity positively correlated with advanced Tanner puberty stage, darker skin types (V-VI) (OR ≈ 2.0-2.4), and overweight status in boys (OR 1.58). No significant association with socioeconomic status or ethnicity after adjustment. Findings underscore hormonal and biological triggers at puberty onset.

Pathogenesis and Molecular Mechanisms. Recent studies demonstrate significant global and regional variability in acne prevalence, driven by hormonal, environmental, and lifestyle factors that determine its clinical expression across populations. Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit and remains among the most prevalent dermatological conditions worldwide. Branisteanu et al. [22] reported

a rising incidence among adults, particularly women aged 25-45 years, associated with hormonal fluctuations, polycystic ovary syndrome (PCOS), psychological stress, and endocrine dysfunctions. Hormonal factors, especially androgens, play a pivotal role in stimulating sebaceous gland activity and promoting inflammation, explaining the increased susceptibility of adult females with hyperandrogenic states. The Global Burden of Disease (GBD) project identifies acne as a major cause of disability-adjusted life years (DALYs) due to its psychological and cosmetic burden. Large-scale epidemiological data confirm that acne is a chronic inflammatory disease with significant mental health implications. Singam et al. [23] demonstrated that individuals with acne have substantially higher odds of comorbid depression, anxiety, and impulse-control or personality disorders compared with controls (adjusted OR 13.02; 95% CI 11.75-14.42). These psychosocial effects are largely age-independent, highlighting the need for multidisciplinary management integrating dermatologic and psychological care. Geographical variability is also evident, with higher prevalence in urbanized and industrialized regions, reflecting the influence of environmental pollution, Westernized diets, and lifestyle stressors. Intrinsic determinants such as genetic predisposition, family history, Fitzpatrick phototype, and ethnicity further modify disease risk and severity. On the molecular level, Cong et al. [24] described four interrelated mechanisms underlying acne pathogenesis: sebaceous hypersecretion, follicular hyperkeratinization, microbial colonization by *Cutibacterium acnes*, and immune-mediated inflammation. These processes are modulated by PI3K/Akt/mTORC1, NF-κB, and Wnt/β-catenin signaling pathways, influenced by endocrine and metabolic regulators such as androgens and IGF-1. Li et al. [25] further demonstrated that the skin microbiome composition correlates with acne severity, showing marked dysbiosis in grade 4 acne with enrichment of Gram-negative genera (*Klebsiella, Odoribacter, Bacteroides*). Such imbalance perpetuates chronic inflammation and impairs the epidermal barrier. Collectively, these findings emphasize the multifactorial nature of acne vulgaris, integrating endocrine, microbial, immunologic, and psychosocial dimensions, and underline the importance of personalized, multidisciplinary therapeutic approaches. Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit involving four major mechanisms: androgen-induced sebaceous hyperactivity, follicular hyperkeratinization, proliferation of *Cutibacterium acnes*, and inflammation mediated by cytokines such as IL-1β, IL-8, and TNF-α. Recent studies emphasize the role of the gut–skin axis and insulin-like growth factor-1 (IGF-1) from high-glycemic diets in stimulating sebum production and keratinocyte proliferation. Moderate-to-severe acne is characterized by inflammatory papules, pustules, nodules, and cysts that often result in post-inflammatory hyperpigmentation and scarring. Clinical evaluation is based on standardized tools such as the Global Acne Grading System (GAGS), the Leeds photographic scale, and the Visual Analog Scale (VAS). Differential diagnosis includes rosacea, bacterial folliculitis, gram-negative acne, and hidradenitis suppurativa [26]. According to GAGS, severity is graded as mild (1-18), moderate (19-30), or severe (≥31). Conventional treatments include topical retinoids, benzoyl peroxide, and clindamycin, along with systemic agents such as doxycycline, minocycline, isotretinoin, combined oral contraceptives, and anti-androgens (e.g., spironolactone). Isotretinoin remains the most effective drug [27, 28] but is limited by mucocutaneous dryness, hepatotoxicity, hyperlipidemia, and teratogenicity, requiring strict monitoring [28, 29]; hence, interest has shifted toward safer non-systemic alternatives. Laser-based therapies, particularly the long-pulsed Nd: YAG laser (1064 nm), have shown high efficacy and tolerability through deep dermal penetration that enables selective photothermolysis of sebaceous glands and thermal anti-inflammatory modulation. Clinical studies consistently demonstrate reductions in lesion count, improved GAGS scores, and high patient satisfaction with minimal adverse effects. Evidence supports its safety across all Fitzpatrick skin types [30]. Thus, the Nd: YAG (1064 nm) laser represents a safe, effective, and sustainable alternative to isotretinoin, especially for patients unable or unwilling to use systemic therapy. Table 4 provides a comparative overview of the main therapeutic modalities used in the management of moderate-to-severe acne vulgaris, emphasizing their relative efficacy, adverse effects, and practical limitations. Topical retinoids remain a cornerstone of initial therapy, offering moderate efficacy but requiring long-term use due to slow clinical response and frequent irritation or dryness. Oral antibiotics demonstrate similar moderate effectiveness yet are limited by gastrointestinal discomfort and the growing problem of bacterial resistance, restricting their duration of use. Oral isotretinoin provides the highest efficacy among pharmacologic options and induces long-term remission by targeting all major pathogenic mechanisms. However, its application is limited by teratogenic risk and mucocutaneous adverse effects that necessitate strict laboratory monitoring. In contrast, evidence from the included studies indicates that long-pulsed Nd: YAG laser therapy (1064 nm) is associated with high levels of reported efficacy and a favorable safety profile, with predominantly minimal and transient adverse effects such as mild erythema. Although higher cost and limited availability of laser devices may restrict widespread use, this modality has been described as a well-tolerated non-pharmacological option for patients in whom systemic therapies are contraindicated. Table 4 summarizes the available evidence on conventional and laser-based treatment modalities.

Table 4

Summary of Evidence on Common Treatment Modalities for Acne Vulgaris

Treatment Type	Efficacy	Side Effects	Limitations
Topical Retinoids	Moderate	Irritation, dryness	Requires long-term use
Oral Antibiotics	Moderate	Resistance, gastrointestinal discomfort	Limited duration of use
Oral Isotretinoin	High	Teratogenicity, mucocutaneous side effects	Requires monitoring
Nd: YAG Laser (1064 nm)	High	Minimal and transient erythema	Cost, limited availability

The diagnostic classification of acne is based on clinical morphology and severity assessment. Key lesion types include inflammatory papules, pustules, nodules, and cysts, often accompanied by post-inflammatory changes such as hyperpigmentation and atrophic scars. Standardized diagnostic tools – namely the Global Acne Grading System (GAGS), the Leeds photographic scale, and the Visual Analog Scale (VAS) – are used to evaluate disease severity and treatment response. In selected cases, laboratory investigations help identify underlying hormonal imbalances, such as elevated serum androgens or DHEAS levels. Differential diagnosis should consider rosacea, bacterial folliculitis, gram-negative acne, and hidradenitis suppurativa [31]. The long-pulsed Nd: YAG (1064 nm) laser penetrates deeply into the dermis, producing selective photothermolysis of sebaceous glands and thermal coagulation of perifollicular vessels. These mechanisms collectively decrease sebum production, suppress *Cutibacterium acnes* colonization, and attenuate perifollicular inflammation, resulting in a marked improvement of both active acne lesions and post-inflammatory sequelae. Clinical evidence from prospective and randomized studies conducted between 2015 and 2025 consistently confirms the high efficacy and safety of long-pulsed Nd: YAG laser therapy in the management of moderate-to-severe acne. Across diverse treatment protocols (fluence 8-150 J/cm², pulse 20-50 ms, 3-6 sessions), lesion counts decreased by more than 50%, with significant improvements in GAGS and IGA scores and reduction of post-inflammatory erythema and hyperpigmentation. Validated clinical outcome tools including GAGS, IGA, GEA, AGSS, and CEAS – consistently demonstrated substantial clinical improvement, high patient satisfaction exceeding 80%, and excellent tolerability, with only transient erythema or mild edema observed. In contrast to systemic isotretinoin, Nd: YAG laser therapy does not induce mucocutaneous dryness, hepatotoxicity, or teratogenic risk and does not require laboratory monitoring. As summarized in Table 5, comparative and combination studies (Kesty & Goldberg, 2020; Chalermsuwiwattanakan et al., 2021; Ibrahim et al., 2022; Saedi et al., 2024; Albalat et al., 2024; Eltanany et al., 2025) indicate that long-pulsed Nd: YAG laser therapy is associated with clinically meaningful improvements in acne severity and outcomes comparable to those reported for pharmacological and other laser-based modalities. Across the included studies, Nd: YAG laser treatment demonstrated a favorable safety profile and was well tolerated across a wide range of Fitzpatrick skin phototypes. Overall, the available evidence suggests consistent reductions in inflammatory lesion counts, improvements in standardized acne severity scores, and high patient satisfaction, with predominantly minimal and transient adverse effects reported.

DISCUSSION

This systematic review critically synthesized current evidence regarding the epidemiology, pathogenesis, clinical presentation, and therapeutic strategies for moderate-to-severe acne vulgaris, with a special emphasis on the clinical potential of the long-pulsed Nd: YAG (1064 nm) laser. Across the reviewed studies, the Nd: YAG laser consistently demonstrated robust clinical efficacy, high patient satisfaction, and an excellent safety profile – positioning it as a promising alternative or adjunct to conventional pharmacologic therapy [40, 41]. Epidemiological data confirm that acne vulgaris remains a global health concern, with a growing prevalence among adults, particularly women aged 25-45 years. This shift underscores the influence of hormonal, lifestyle, and environmental factors that contribute to disease persistence and psychosocial burden [42]. From a pathogenic perspective, acne vulgaris is a multifactorial inflammatory disease of the pilosebaceous unit involving sebaceous hyperactivity, follicular blockage, microbial colonization by *Cutibacterium acnes*, and immune dysregulation. These interrelated processes lead to local inflammation and lesion formation characteristic of acne [43, 44]. These insights have stimulated the development of targeted, technology-driven treatments designed to address these mechanisms with greater precision and fewer systemic risks [45]. Traditional pharmacologic options – topical retinoids, oral antibiotics, and systemic isotretinoin remain effective but are limited by antimicrobial resistance, relapse after discontinuation, and dose-dependent adverse effects [46, 47]. In contrast, laser-based modalities, especially the long-pulsed Nd: YAG laser, offer a non-invasive approach capable of directly modulating sebaceous-gland activity, reducing *Cutibacterium acnes* colonization, and attenuating inflammatory cytokine expression. Clinical evidence between 2015 and 2025 demonstrates that Nd: YAG laser treatment achieves a ≥50% reduction in inflammatory lesions after 3-6 sessions, with minimal erythema and no systemic toxicity. Comparative trials further indicate that Nd: YAG therapy yields outcomes equivalent or superior to pulsed-dye laser, fractional CO_2 laser, or isotretinoin monotherapy.

Mechanistically, the 1064 nm wavelength allows deep dermal penetration and selective photothermolysis of hyperactive sebaceous glands, resulting in long-term improvement without epidermal damage. These physiological effects are particularly advantageous for patients with darker Fitzpatrick skin types, who are at higher risk of post-inflammatory pigmentation when treated with ablative lasers. The reviewed studies consistently confirm the reproducibility of results across different protocols, highlighting the versatility of Nd: YAG technology in both monotherapy and combination regimens (e.g., with low-dose isotretinoin). Importantly, the psychosocial dimension of acne should not be overlooked. Improvements in self-esteem, social confidence, and quality of life were repeatedly reported following Nd: YAG laser therapy, emphasizing its broader therapeutic value beyond lesion clearance. This aligns with the current paradigm of holistic dermatologic care that integrates clinical and psychological outcomes. In summary, the collective evidence underscores that long-pulsed Nd: YAG (1064 nm) laser therapy represents a safe, effective, and sustainable modality for managing moderate-to-severe acne vulgaris. It addresses multiple pathogenic pathways, minimizes systemic risks, and achieves durable clinical and aesthetic outcomes. Future research should aim to standardize treatment parameters, optimize session frequency, and explore synergistic protocols combining Nd: YAG with pharmacologic or photodynamic therapies to maximize long-term remission and patient satisfaction [48].

Table 5

Summary of Representative Clinical Studies Evaluating the Efficacy and Safety of Long-Pulsed Nd: YAG (1064 nm) Laser Therapy for Acne Vulgaris (2015-2025)

Author (Year)	Study Design / Sample Size	Treatment Protocol (Nd: YAG Parameters)	Outcome Measure	Main Findings / GAGS or Equivalent Reduction
[32] Kesty K, Goldberg DJ (2020)	Randomized controlled trial, n = 20	650 μs 1064 nm Nd: YAG (Aerolase Neo); 3 sessions biweekly + 1 booster at 4 weeks	IGA + Lesion count + Sebum index + Porphyrin score	IGA improved by 26% vs 7% (sham); inflammatory lesions reduced by 42% vs 26%; no serious adverse events reported
[33] Chalermsuwiwattanakan N et al. (2021)	Split-face randomized controlled trial, n = 34	1064 nm Nd: YAG vs 595 nm PDL; fluence 25-35 J/cm²; pulse 30 ms; 3 sessions every 2 weeks	Lesion count / IGA	1064 nm Nd: YAG laser achieved comparable efficacy to 595 nm PDL in reducing inflammatory acne and erythema ($p > 0.05$), with better patient comfort and fewer side effects
[34] Artzi O et al. (2021)	Prospective case series, n = 19	Quasi long-pulsed (micro-pulsed) 1064 nm Nd: YAG; fluence 8 J/cm²; ≈ 6 sessions every 2 weeks	AGSS + PGIC + Satisfaction score	Significant AGSS reduction after 2 sessions ($p<0.001$) maintained through 8 weeks; mean 6.6 treatments to reach AGSS 1-2; high patient satisfaction; no pain or downtime
[35] Ibrahim AM et al. (2022)	Split-face randomized comparative study, n = 30	Long-pulsed Nd: YAG 1064 nm vs intralesional BTX-A; 1 session monthly × 3 sessions	IGA + Lesion count	Significant improvement on both sides ($p<0.001$ vs baseline); Nd: YAG showed more prolonged efficacy and lower recurrence after 3 months
[36] Hammoda TM et al. (2023)	Randomized split-face clinical trial, n = 30	1064 nm long-pulsed Nd: YAG vs fractional CO_2; 4 sessions every 2 weeks (Jul 2021–Sep 2022); Ethics approval No. 2021121145	GEA Scale + Lesion count + Patient satisfaction	Both lasers were safe and effective ($p<0.001$ vs baseline); fractional CO_2 showed greater GEA reduction and higher satisfaction ($p=0.006$); Nd: YAG remained well-tolerated with minimal erythema
[37] Saedi N et al. (2024)	Prospective single-center clinical study, n = 23	650 μs pulsed 1064 nm Nd: YAG (Neo Elite, Aerolase); 5 sessions every 2 weeks; no cooling or anesthesia	IGA + Lesion count + Patient satisfaction + Self-esteem survey	Median lesion count reduction 48% after 1 session and >80% after 3 sessions ($p<0.001$); IGA ≈ 1.0 by week 6; 90% patient satisfaction; no adverse effects across skin types I-VI
[38] Albalat W et al. (2024)	Randomized comparative trial, n = 48	1064 nm long-pulsed Nd: YAG (Deka Motus AY) + low-dose isotretinoin (10 mg/day) vs isotretinoin alone; fluence 150 J/cm²; pulse 20-25 ms; spot 5 mm; 6 sessions biweekly	CEAS + Optical density + Improvement score	Combined therapy produced greater reduction in erythema and CEAS scores ($p<0.01$) vs isotretinoin alone; >70% rated good–excellent improvement; minimal side effects
[39] Eltanany HHM et al. (2025)	Split-face randomized comparative study, n = 30	1064 nm long-pulsed Nd: YAG vs intralesional TXA; 4 sessions every 2 weeks; 3-month follow-up	IGA + Lesion count + Erythema score	Both modalities significantly reduced IGA and lesion counts ($p<0.001$); Nd: YAG showed greater improvement in IGA and non-inflammatory lesions ($p<0.05$) with prolonged effect and minimal erythema

CONCLUSIONS

This systematic review highlights that moderate-to-severe acne vulgaris remains a multifactorial inflammatory condition with complex etiopathogenesis and significant psychosocial impact. Traditional pharmacologic treatments – while effective – are often limited by relapse, antibiotic resistance, and systemic adverse effects.The long-pulsed Nd: YAG (1064 nm) laser represents a clinically validated, safe, and effective non-invasive therapeutic modality that addresses multiple pathogenic mechanisms simultaneously. Evidence from prospective and randomized clinical studies (2015-2025) demonstrates consistent lesion reduction exceeding 50%, significant improvement in standardized severity scores (GAGS, IGA), and minimal transient side effects. Its ability to target sebaceous glands, modulate inflammation, and improve post-inflammatory sequelae makes the Nd: YAG laser a valuable option for patients who cannot tolerate or prefer to avoid systemic therapy. Furthermore, high patient satisfaction and excellent safety across all Fitzpatrick skin types underscore its suitability for diverse clinical settings. In conclusion, long-pulsed Nd: YAG (1064 nm) laser therapy should be considered a safe, effective, and sustainable cornerstone in the modern management of moderate-to-severe acne vulgaris, either as a stand-alone or adjunctive treatment.

Perspectives for Further Research. Future studies should aim to expand the clinical evidence on the efficacy and safety of long-pulsed Nd: YAG (1064 nm) laser therapy compared with conventional pharmacologic treatments. Large, multicenter randomized controlled trials are needed to establish standardized treatment parameters, including fluence, pulse duration, and session intervals, to enhance reproducibility and comparability across studies.

Mechanistic investigations integrating histological and microbiome analyses are recommended to clarify how laser energy modulates sebaceous gland activity and inflammatory pathways. Additionally, combination approaches – such as Nd: YAG with fractional Er: YAG, photodynamic therapy, or low-dose isotretinoin – should be explored for potential synergistic benefits. Finally, future research should incorporate patient-reported outcomes such as quality of life and satisfaction scores to ensure a comprehensive, patient-centered evaluation of therapeutic success.

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COMPLIANCE WITH ETHICAL REQUIREMENTS

This review was based exclusively on the systematic analysis of previously published clinical and scientific literature obtained from peer-reviewed journals and open-access databases. Therefore, ethical committee approval was not required, as the study did not involve new patient recruitment or any clinical interventions. All analyzed data were publicly available and used solely for academic and research purposes.

During the preparation of this manuscript, the authors adhered to the principles of academic integrity and research transparency, including accurate referencing, avoidance of plagiarism, and exclusion of any falsified or manipulated data. The work was prepared in accordance with international ethical standards, particularly the Committee on Publication Ethics (COPE) recommendations and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, ensuring scientific accuracy, objectivity, and reproducibility of the presented results.

Statement on the Use of Artificial Intelligence Tools:

During the preparation of this manuscript, the authors used the ChatGPT language model (OpenAI, USA) exclusively for language editing and improving the clarity of the English text. All scientific concepts, data interpretation, conclusions, and the structure of the review were independently developed by the authors. All AI-generated suggestions were critically evaluated, corrected, and approved by the authors, who take full responsibility for the final content. No artificial intelligence tools were used for data collection, statistical analysis, or formulation of scientific conclusions.

AUTHOR CONTRIBUTIONS

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Резюме

ВУЛЬГАРНІ ВУГРІ: ПАТОГЕНЕЗ ТА ЛІКУВАННЯ З ВИКОРИСТАННЯМ ДОВГОІМПУЛЬСНОГО ЛАЗЕРА ND: YAG (1064 НМ) – СИСТЕМАТИЧНИЙ ОГЛЯД

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Вступ. Вульгарні вугрі це поширене хронічне запальне захворювання шкіри, яке переважно вражає підлітків і молодих дорослих, однак усе частіше спостерігається і в осіб зрілого віку. Захворювання може спричиняти фізичний дискомфорт, стійкі рубці та значний психосоціальний дистрес. Традиційні місцеві та системні методи лікування часто забезпечують повільне або неповне покращення й нерідко супроводжуються побічними ефектами, низькою прихильністю пацієнтів та рецидивами. У зв'язку з цим зростає інтерес до інноваційних терапевтичних методів, зокрема до довгоімпульсного Nd: YAG (1064 нм) лазера, який демонструє перспективні результати щодо ефективності та безпеки.

Мета. Провести систематичний огляд сучасних даних щодо епідеміології, патогенезу, клінічних проявів і підходів до лікування вульгарних вугрів, приділивши особливу увагу ролі сучасних лазерних технологій, зокрема довгоімпульсного неодимового лазера на ітрієво-алюмінієвому гранаті (Nd: YAG, 1064 нм).

Матеріали та методи. Проведено структурований пошук у базах даних PubMed/MEDLINE, Scopus, Web of Science, Google Scholar і SpringerLink із використанням ключових слів: «acne vulgaris», «pathogenesis», «laser therapy», «Nd: YAG», «moderate-to-severe acne». Початковий пошук виявив 680 записів; ще 12 статей було додано після ручного аналізу списків літератури. Після видалення дублікатів і застосування критеріїв включення та виключення у фінальний якісний аналіз включено 40 рецензованих досліджень, опублікованих у 2015-2025 рр. Ці джерела містили актуальні дані щодо епідеміології, патогенезу, діагностичної класифікації та терапевтичних підходів до лікування вугрової хвороби середнього та тяжкого ступеня з акцентом на застосування довгоімпульсного Nd: YAG (1064 нм) лазера.

Результати. Аналіз літератури засвідчив багатофакторний характер патогенезу захворювання, що включає гіперактивність сальних залоз, гормональні порушення, мікробну колонізацію *Cutibacterium acnes*, активацію імунної системи, оксидативний стрес і дисбіоз мікробіому. Існують різні терапевтичні підходи – від місцевих і системних засобів до світлових і лазерних технологій. Довгоімпульсний Nd: YAG (1064 нм) лазер демонструє високу ефективність і сприятливий профіль безпеки, особливо у пацієнтів із резистентними формами акне або схильністю до рубцювання.

Висновки. Вульгарні вугрі залишаються складним дерматологічним захворюванням із постійно оновлюваними уявленнями щодо патогенезу та методів лікування. Довгоімпульсний Nd: YAG (1064 нм) лазер є цінним доповненням до традиційної терапії та заслуговує на ширше впровадження в клінічну практику.

Ключові слова: **вульгарні вугрі, епідеміологія, тяжкі форми акне, патогенез, лазер Nd: YAG, лазерна терапія, *Cutibacterium acnes*, якість життя**

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