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MODERN APPROACHES TO ACNE MANAGEMENT: FROM PATHOGENESIS-BASED THERAPY TO PERSONALIZED TREATMENT STRATEGIES

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Abstract

Background:
Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit that affects a significant proportion of adolescents and adults worldwide, leading to substantial physical, psychological, and social burden. Conventional acne management has traditionally relied on topical and systemic antibiotics, retinoids, and hormonal agents. However, increasing concerns regarding antibiotic resistance, treatment-related adverse effects, and variable patient responses have prompted the development of modern, mechanism-based therapeutic strategies.

Objective:
This article aims to evaluate contemporary acne treatment methods with an emphasis on pathogenesis-based, combination, and personalized approaches, and to assess their clinical effectiveness and safety in comparison with traditional treatment models.

Methods:
A comprehensive narrative review of recent clinical trials, systematic reviews, and international guidelines published in peer-reviewed journals was conducted. Data regarding advanced topical formulations, systemic innovations, energy-based and device-assisted therapies, chemical and regenerative procedures, and microbiome-oriented interventions were critically analyzed.

Results:
Modern acne therapies demonstrated improved clinical outcomes, enhanced patient adherence, and favorable safety profiles when applied in individualized, multimodal treatment protocols. Combination regimens integrating new-generation retinoids, non-antibiotic anti-inflammatory agents, laser and light-based technologies, and microbiome-modulating strategies showed superior lesion reduction and lower relapse rates compared with monotherapy.

Conclusion:
Current evidence supports a paradigm shift in acne management from uniform treatment algorithms toward personalized, pathogenesis-driven strategies. The integration of pharmacological, device-based, and microbiome-focused therapies represents a promising direction for achieving sustained disease control while minimizing adverse effects and antibiotic resistance.

Keywords: Acne vulgaris; personalized therapy; retinoids; laser therapy; microbiome; combination treatment.

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Introduction

Acne vulgaris is a chronic, multifactorial inflammatory disease of the pilosebaceous unit and represents one of the most common dermatological conditions worldwide. Although traditionally considered a disorder of adolescence, acne increasingly affects adults, particularly women, and is frequently characterized by a chronic or relapsing course. Beyond its visible clinical manifestations, acne exerts a profound psychosocial impact, contributing to reduced quality of life, anxiety, depression, and social withdrawal.

The pathogenesis of acne is complex and involves the interaction of several key mechanisms, including increased sebaceous gland activity, abnormal follicular keratinization, colonization by *Cutibacterium acnes*, and activation of innate and adaptive inflammatory pathways. Recent advances have further highlighted the role of hormonal influences, genetic predisposition, immune dysregulation, and alterations in the skin microbiome, challenging the traditional view of acne as a purely infectious condition.

Conventional acne treatment strategies have largely focused on topical and systemic antibiotics, retinoids, and hormonal agents. While these approaches remain effective for many patients, their long-term use is limited by adverse effects, poor tolerability, suboptimal adherence, and the global rise of antibiotic resistance. Moreover, standardized treatment algorithms often fail to account for individual variations in acne severity, lesion distribution, age, sex, hormonal status, and psychosocial factors.

In recent years, acne management has undergone a significant paradigm shift toward pathogenesis-based and personalized therapeutic models. Modern approaches emphasize rational combination therapy, early anti-inflammatory intervention, reduced reliance on antibiotics, and the integration of novel topical agents, systemic innovations, energy-based devices, chemical procedures, and microbiome-oriented strategies. These developments aim not only to improve clinical outcomes but also to enhance patient satisfaction and achieve long-term disease control.

The purpose of this article is to provide a comprehensive overview of contemporary acne treatment methods, highlighting their scientific rationale, clinical effectiveness, and role within personalized management strategies. By synthesizing current evidence, this review seeks to support a modern, individualized approach to acne therapy aligned with international dermatological practice standards.

Materials and Methods

Study Design

This study was designed as a comprehensive academic review with an analytical and comparative framework, focusing on modern acne treatment modalities. The methodology follows international standards for narrative and evidence-based dermatological reviews and is structured to meet the requirements of European peer-reviewed medical journals.

Data Sources and Search Strategy

A systematic literature search was conducted using internationally recognized scientific databases, including PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. Publications from the last 10–12 years were prioritized to ensure relevance to contemporary acne management. The search strategy employed combinations of keywords such as *acne vulgaris*, *modern acne treatment*,

personalized acne therapy, *laser and light-based treatment*, *topical retinoids*, *microbiome and acne*, and *combination therapy*.

Only full-text articles published in English in peer-reviewed journals were included. Reference lists of selected articles were manually screened to identify additional relevant studies.

Eligibility Criteria

Inclusion criteria:

- Clinical trials, randomized controlled trials, systematic reviews, and high-quality observational studies
- Studies evaluating modern topical, systemic, device-based, or microbiome-oriented acne therapies
- Adult and adolescent patient populations with mild, moderate, or severe acne vulgaris

Exclusion criteria:

- Case reports with limited clinical relevance
- Studies lacking clearly defined outcome measures
- Non-peer-reviewed publications and conference abstracts without full data

Data Extraction and Analysis

Data were independently extracted and analyzed according to predefined parameters, including:

- Study design and sample size
- Acne severity classification methods
- Type and duration of treatment
- Clinical efficacy outcomes
- Safety and tolerability profiles
- Patient-reported outcomes and quality-of-life measures

Extracted data were synthesized qualitatively, with emphasis on comparative effectiveness between traditional monotherapy approaches and modern combination or personalized treatment strategies.

Assessment of Acne Severity and Outcomes

Across the reviewed studies, acne severity was assessed using validated dermatological tools such as lesion counts (inflammatory and non-inflammatory), global acne grading systems, and investigator global assessment (IGA) scores. Treatment outcomes were evaluated based on:

- Reduction in total lesion count
- Improvement in inflammatory activity
- Time to clinical response
- Relapse rates following treatment completion

Patient satisfaction and quality-of-life improvement were assessed using standardized dermatology-specific questionnaires where available.

Evaluation of Treatment Modalities

Modern acne treatment methods were categorized into the following groups for structured analysis:

1. Advanced topical therapies
2. Systemic pharmacological approaches
3. Energy-based and device-assisted treatments

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4. Chemical and regenerative procedures
5. Microbiome-modulating strategies

Each category was evaluated in terms of mechanism of action, clinical efficacy, safety, and suitability for personalized treatment planning.

Ethical Considerations

As this study is based exclusively on previously published data, ethical approval and informed consent were not required. All included studies were assumed to have been conducted in accordance with the Declaration of Helsinki and relevant ethical guidelines.

Methodological Limitations

Potential limitations include heterogeneity among study designs, variations in treatment protocols, and differences in outcome assessment tools. These factors were considered during data interpretation and addressed in the discussion section.

Results

Study Selection and Characteristics

The literature search yielded a substantial number of publications addressing modern acne treatment approaches. After screening titles, abstracts, and full texts according to the inclusion and exclusion criteria, high-quality clinical trials, randomized controlled studies, and systematic reviews were included in the final analysis. The selected studies encompassed adolescent and adult patient populations with mild, moderate, and severe forms of acne vulgaris and represented a wide range of contemporary therapeutic modalities.

Clinical Efficacy of Modern Treatment Approaches

Across the analyzed studies, modern acne treatment strategies demonstrated a statistically and clinically significant improvement in disease outcomes compared with conventional monotherapy-based approaches.

- **Topical combination therapies**, particularly those integrating new-generation retinoids with non-antibiotic anti-inflammatory agents, resulted in a marked reduction in both inflammatory and non-inflammatory lesion counts. Early clinical response and improved long-term disease control were consistently reported.
- **Systemic innovations**, including low-dose isotretinoin protocols and hormonally targeted therapies in adult female patients, showed high efficacy with reduced incidence of adverse effects and improved treatment adherence.
- **Energy-based and device-assisted therapies** (laser, IPL, and photodynamic therapy) were associated with significant decreases in inflammatory lesion activity, sebaceous gland output, and post-inflammatory erythema, especially when used as adjuncts to pharmacological treatment.

Impact of Combination and Personalized Therapy

Studies employing **multimodal and individualized treatment protocols** reported superior outcomes compared with single-modality therapy. Personalized regimens tailored according to acne severity, lesion type, patient age, hormonal status, and skin sensitivity achieved:

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- Faster clinical improvement
- Lower relapse rates during follow-up
- Higher patient satisfaction scores

Combination therapy was particularly effective in moderate-to-severe acne, where simultaneous targeting of follicular hyperkeratinization, inflammation, and sebaceous activity proved essential for sustained disease control.

Microbiome-Oriented and Antibiotic-Sparing Outcomes

A notable finding across recent studies was the positive impact of **microbiome-modulating strategies**. Treatments designed to restore microbial balance rather than eradicate *Cutibacterium acnes* demonstrated:

- Reduced inflammatory response
- Lower risk of antibiotic resistance
- Improved long-term skin barrier function

Antibiotic-sparing regimens were associated with comparable or superior efficacy relative to prolonged antibiotic use, supporting current recommendations to limit antibiotic exposure in acne management.

Safety and Tolerability

Modern acne therapies generally exhibited favorable safety profiles. Adverse effects were predominantly mild to moderate and transient in nature. Personalized dosing strategies and combination regimens contributed to improved tolerability, particularly in systemic treatments. Device-based therapies showed minimal downtime and high acceptance among patients.

Patient-Reported Outcomes

Quality-of-life assessments revealed significant improvement following modern acne treatment interventions. Reductions in disease severity correlated with enhanced psychological well-being, increased self-esteem, and improved social functioning, underscoring the importance of holistic treatment approaches.

Summary of Key Findings

Overall, the results indicate that contemporary acne management strategies—characterized by combination therapy, personalization, and reduced antibiotic reliance—offer superior clinical efficacy, improved safety, and enhanced patient-centered outcomes compared with traditional treatment models.

Discussion

The findings of this review support the growing consensus that effective acne management requires a shift from traditional, uniform treatment algorithms toward **pathogenesis-driven and personalized therapeutic strategies**. Modern approaches that integrate pharmacological, device-based, and microbiome-oriented interventions demonstrate superior clinical outcomes, improved tolerability, and enhanced patient satisfaction when compared with conventional monotherapy-based regimens.

A central observation across the analyzed studies is the **declining role of long-term antibiotic therapy** in acne management. While antibiotics remain useful for short-term control of inflammatory

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lesions, their prolonged use is increasingly limited by antimicrobial resistance and disruption of the skin microbiome. Contemporary guidelines therefore emphasize antibiotic-sparing regimens, favoring early initiation of topical retinoids, benzoyl peroxide–based combinations, and non-antibiotic anti-inflammatory agents. The reviewed evidence confirms that such strategies achieve comparable or superior efficacy while reducing the risk of resistance and relapse.

The emergence of **new-generation topical retinoids** represents a significant advancement in acne therapy. These agents provide targeted modulation of follicular keratinization and inflammation with improved tolerability, allowing earlier and broader use across different acne severities. When combined with adjunctive therapies, retinoids form the cornerstone of modern acne treatment and support long-term disease control rather than short-term symptom suppression.

Another important development highlighted in this review is the expanding role of **energy-based and device-assisted therapies**. Laser, intense pulsed light, and photodynamic treatments address multiple pathogenic factors, including sebaceous gland activity, inflammatory pathways, and post-inflammatory erythema. Although these modalities are rarely used as standalone treatments, their adjunctive application within personalized treatment protocols has been shown to accelerate clinical improvement and enhance patient adherence, particularly in moderate-to-severe or treatment-resistant acne.

The growing focus on the **skin microbiome** further reflects a paradigm shift in acne pathophysiology. Rather than viewing *Cutibacterium acnes* solely as a pathogenic organism, recent evidence suggests that acne is associated with microbial imbalance and altered host–microbe interactions. Microbiome-modulating therapies, including selective topical agents and oral probiotics, appear to reduce inflammation while preserving microbial diversity. This approach aligns with broader trends in dermatology toward barrier restoration and immune modulation.

From a patient-centered perspective, modern acne management also prioritizes **quality-of-life outcomes**. Acne-related psychosocial distress is increasingly recognized as a critical component of disease burden. The reviewed studies consistently report that personalized and combination therapies not only improve clinical severity but also lead to meaningful improvements in self-esteem, emotional well-being, and social functioning. These findings underscore the importance of holistic treatment planning that extends beyond lesion clearance.

Despite these advances, several limitations must be acknowledged. The heterogeneity of study designs, outcome measures, and treatment protocols limits direct comparison across studies. In addition, access to advanced device-based therapies may be restricted by cost and availability, particularly in low-resource settings. Future research should focus on standardized outcome measures, long-term follow-up data, and cost-effectiveness analyses to further refine personalized acne treatment algorithms.

Conclusion

Modern acne management has evolved significantly from conventional, symptom-oriented treatment models toward **pathogenesis-based, personalized, and multimodal therapeutic strategies**. Current evidence clearly demonstrates that addressing the multiple biological mechanisms involved in acne—including follicular hyperkeratinization, sebaceous gland activity, inflammation, hormonal influences, and microbiome imbalance—results in superior and more sustainable clinical outcomes.

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The integration of **new-generation topical retinoids**, antibiotic-sparing combination regimens, optimized systemic therapies, and adjunctive **energy-based and procedural interventions** allows for more precise and effective disease control across different acne severities and patient populations. Importantly, microbiome-oriented approaches represent a promising advancement, shifting the therapeutic focus from microbial eradication to restoration of cutaneous homeostasis and long-term skin health.

Personalized treatment planning, guided by acne severity, lesion type, patient age, hormonal status, skin sensitivity, and psychosocial impact, is central to modern acne care. Such individualized strategies not only enhance therapeutic efficacy and tolerability but also improve patient adherence, reduce relapse rates, and significantly enhance quality of life.

Despite ongoing challenges related to treatment accessibility, cost, and heterogeneity of clinical evidence, the current paradigm emphasizes rational combination therapy, early anti-inflammatory intervention, and reduced reliance on prolonged antibiotic use. Future research should prioritize long-term outcome studies, standardized assessment tools, and cost-effectiveness analyses to further refine evidence-based, personalized acne treatment algorithms.

In summary, contemporary acne therapy should be viewed as a **dynamic, patient-centered process** that integrates pharmacological innovation, procedural techniques, and emerging microbiome science. This modern approach offers a robust framework for achieving sustained disease control and represents the future direction of acne management in clinical dermatology.

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