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Review Article

A Comprehensive Review of Acne Vulgaris: Pathogenesis, Clinical Presentation, and Emerging Therapeutic Approaches

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ABSTRACT

Acne vulgaris is a multifactorial skin disorder influenced by inflammation, bacterial colonization, and hormonal imbalance. Conventional therapies, including topical and systemic treatments such as retinoids, antibiotics, and benzoyl peroxide, form the foundation of acne management but often cause skin irritation, bacterial resistance, and systemic side effects. In response, herbal medicines have gained popularity due to their long-standing use, minimal side effects, and anti-inflammatory and antimicrobial properties. Plants such as *Matricaria recutita*, *Calendula officinalis*, *Aloe vera*, and *Glycyrrhiza glabra* exhibit significant therapeutic benefits, either alone or in combination with synthetic drugs. In addition, advanced drug delivery systems have emerged to enhance efficacy and minimize adverse effects. Liposomes, niosomes, aspasomes, microsponges, solid lipid nanoparticles, hydrogels, and microemulsions improve topical bioavailability, stability, and skin penetration of active ingredients like tretinoin and clindamycin. Emulsifier-free formulations, fullerenes, and transdermal patches further provide innovative solutions for sustained and targeted delivery, enhancing patient compliance and reducing irritation. These technological advancements, alongside evidence-backed phytomedicine, present an integrated and personalized approach to acne therapy. Future research should focus on optimizing these systems for broader clinical application while ensuring safety and effectiveness across varying skin types and acne severities.

INTRODUCTION

Acne vulgaris is a prevalent and long-term inflammatory skin condition that mainly affects teenagers, although individuals of any age can

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develop it. The condition centers around the pilosebaceous unit and is characterized by various types of lesions, including blackheads, whiteheads, papules, pustules, and, in more severe instances, nodules and cysts. The development of acne is influenced by multiple interconnected factors, such as excessive sebum production, hormonal fluctuations—particularly increased

levels of androgens like DHEA—abnormal keratinization of hair follicles, and the proliferation of *Cutibacterium acnes*. Other contributing elements include genetic predisposition, dietary habits, environmental exposures, psychological stress, tobacco use, and the application of comedogenic products.

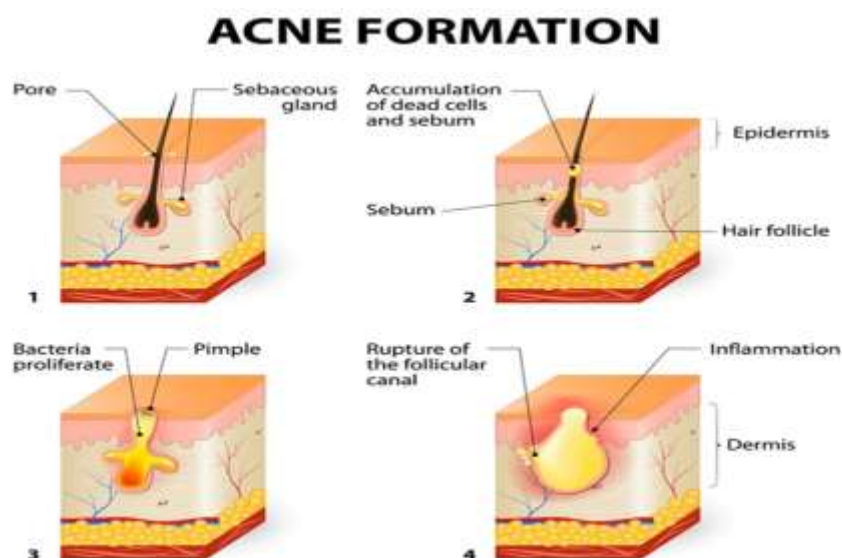


Fig. No. 1: Acne Formation

1.1. Epidemiology of Acne:

Acne vulgaris is a widespread chronic inflammatory disorder of the skin that primarily affects adolescents, though it can arise at any stage of life. It involves the pilosebaceous unit and presents with a variety of skin lesions, such as open and closed comedones (blackheads and whiteheads), inflammatory papules, pustules, and in more severe forms, nodules and cysts. The condition arises from a combination of factors, including heightened sebum secretion, hormonal shifts—especially increased androgen levels like dehydroepiandrosterone (DHEA)—disrupted follicular keratinization, and the overgrowth of *Cutibacterium acnes*. Additional risk factors that may trigger or aggravate acne include genetic factors, dietary influences, environmental triggers,

emotional stress, smoking, and the use of pore-clogging skincare or cosmetic products.

1.2. Clinical Presentation and Classification:

From a clinical standpoint, acne is divided into two main categories: non-inflammatory lesions, which include open and closed comedones, and inflammatory lesions, such as papules, pustules, nodules, and cysts. Closed comedones, commonly referred to as whiteheads, form when clogged pores remain beneath the skin's surface. In contrast, open comedones or blackheads are pores that are exposed to air, leading to oxidation and their characteristic dark color. Pustules are inflamed lesions filled with pus, typically with a red base, while nodules and cysts are deeper, more painful lesions that can result in long-term scarring. According to the American Academy of

Dermatology (2016), acne severity is assessed based on the type and number of lesions, their distribution across areas like the face, chest, back, and upper arms, and whether scarring is present. It

is estimated that around 20% of individuals with acne may develop permanent scars, underscoring the importance of prompt and appropriate treatment.

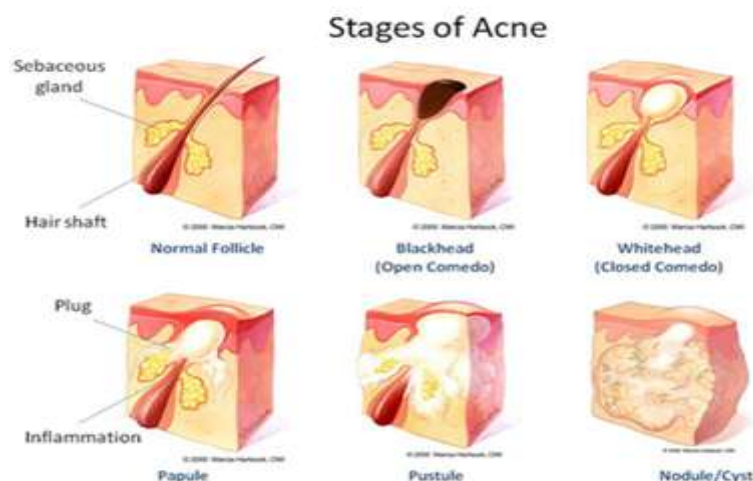


Fig. No.2: Stages of Acne

1. Pathophysiology and Etiology:

The development of acne vulgaris involves a complex interplay of four primary pathogenic mechanisms: excessive keratinization within the hair follicle, increased sebum production, microbial proliferation—particularly by *Propionibacterium acnes* (now reclassified as *Cutibacterium acnes*)—and an ensuing inflammatory immune response. These core processes can be further intensified by both

internal and external factors, including hormonal imbalances, psychological stress, perspiration, exposure to ultraviolet light, use of cosmetics, and specific medications such as corticosteroids, lithium, and anticonvulsants. Additionally, physical irritation from tight clothing or equipment may worsen acne lesions. Gaining a thorough understanding of these contributing elements is vital for developing effective strategies for both prevention and treatment.

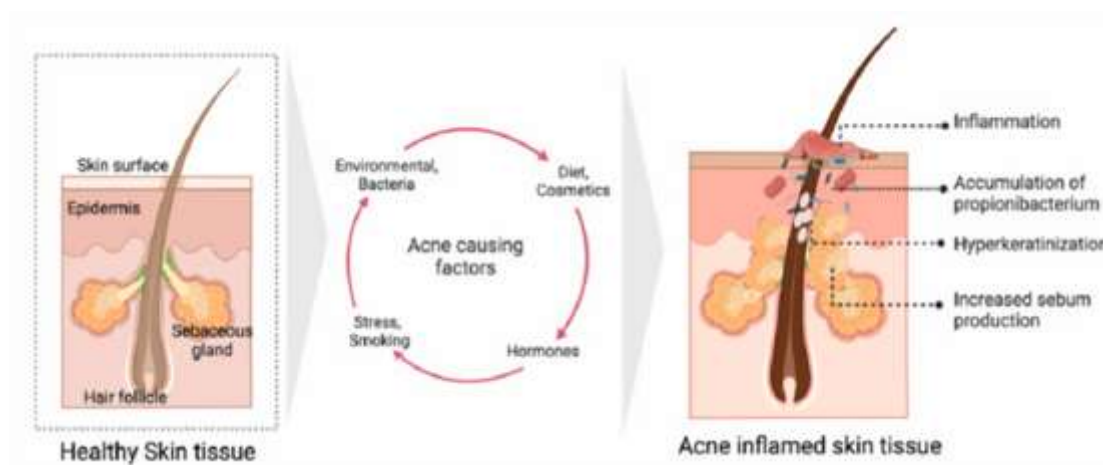


Fig. No. 3: Pathogenesis of Acne

1.1. Psychological and Social Impact:

Acne, especially during adolescence, can significantly affect mental health. Visible facial lesions, persistent inflammation, and the potential for scarring often contribute to diminished self-esteem, emotional discomfort, heightened anxiety, and, in severe cases, depression or suicidal ideation. These psychological repercussions highlight the need for a holistic approach to acne management—one that not only targets the physical manifestations but also incorporates appropriate mental health support.

1.2. Contributing and Risk Factors:

The development and severity of acne are influenced by a variety of intrinsic and extrinsic factors. Key contributors include hormonal changes—such as those occurring during puberty or the menstrual cycle—male sex, psychological stress, and the use of specific medications like corticosteroids, lithium, and androgens.

Additional aggravating factors include smoking and the application of comedogenic skincare or cosmetic products. A strong genetic component is also evident, with individuals who have a family history of acne being at greater risk.

2. Treatment Strategies:

Effective acne management involves a comprehensive, individualized strategy based on the condition's severity. Mild forms are typically managed with topical treatments, including retinoids, benzoyl peroxide, and topical antibiotics, which help regulate follicular keratinization, control inflammation, and suppress bacterial proliferation. In cases of moderate to severe acne, systemic therapies may be necessary. These include oral antibiotics such as doxycycline or minocycline, hormonal interventions like oral contraceptives and anti-androgens, and isotretinoin—a powerful retinoid reserved for severe, persistent, or treatment-resistant acne.

Table No. 1: Treatment. Methods of Acne

Treatment Methods	Examples
Topical	Retinoids: adapalene, isotretinoin, tretinoin Antibiotics: clindamycin, erythromycin Diverse: azelaic acid, benzoyl peroxide, chemical peels, corticosteroids, dapsone, hydrogen peroxide, niacinamide, salicylic acid, sodium sulfacetamide, sulfur, triclosan
Systemic	Retinoids: isotretinoin Antibiotics: azithromycin, clindamycin, co-trimoxazole, doxycycline, erythromycin, levofloxacin, lymecycline, minocycline, roxithromycin Hormonal: contraceptives Diverse: clofazimine, corticosteroids, ibuprofen, zinc sulfate
Complementary and Alternative Medicines (CAM)	Achillea millefolium, amaranth, antimicrobial peptides, arnica, asparagus, basil oil, bay, benzoin, birch, bittersweet nightshade, black cumin, black walnut, borage, Brewer's yeast, burdock root, calendula, celandine, chamomile, chaste tree, Commiphora mukul, copaiba oil, coriander, cucumber, duckweed, Du Zhong extract, English walnut, Eucalyptus dives, fresh lemon, garlic, geranium, grapefruit seeds, green tea, jojoba oil, juniper twig, labrador tea, lemon grass, lemon, minerals, neem, oak bark, onion, orange peel, orange, Oregon grape root, patchouli, pea, petitgrain, pine, pomegranate rind extract, poplar, probiotics, pumpkin, resveratrol, rose myrtle, rhubarb, Rosa damascena, rosemary, rue, safflower oil, sandalwood, seaweed, soapwort, Sophora flavescens, specific antibodies, stinging nettle, sunflower oil, Taraxacum officinale, taurine bromamine, tea tree oil, thyme, turmeric, vinegar, vitex, witch hazel, Withania somnifera and yerba mate extract
Physical Treatment	Comedone extraction, cryoslush therapy, cryotherapy, electrocauterization, intralesional corticosteroids and optical treatments



Advances in Management Strategies:

Contemporary acne treatment strategies are informed by a deeper understanding of the condition's complex pathophysiology. Management approaches are typically individualized based on the acne's severity and clinical presentation. For mild to moderate cases, topical therapies—such as benzoyl peroxide, retinoids, and topical antibiotics—remain the cornerstone of treatment. In contrast, more severe or treatment-resistant acne often necessitates systemic interventions, including oral antibiotics, hormonal therapies, and isotretinoin. Adjunctive physical treatments, such as phototherapy, comedone extraction, and various light-based modalities, may provide additional therapeutic value. Notably, combination regimens—particularly those incorporating topical retinoids, benzoyl peroxide, and antibiotics—have demonstrated superior efficacy in achieving clinical improvement.

Emerging and Complementary Therapies:

Recent developments in acne therapy have focused on enhancing treatment effectiveness while minimizing adverse effects. Innovative approaches include laser and light-based modalities, photodynamic therapy, and the incorporation of natural compounds such as probiotics and plant-derived extracts. The growing interest in complementary and alternative medicine (CAM) reflects a broader public preference for safer, more natural options; however, further scientific validation is necessary to confirm their efficacy and safety. Additionally, various procedural interventions—such as comedone extraction, cryotherapy, electrocautery,

and intralesional corticosteroid injections—are utilized in clinical settings to manage specific types of acne lesions.

Antimicrobial Resistance and Research Gaps:

As *Cutibacterium acnes* continues to develop resistance to commonly prescribed antibiotics, there is an escalating need to investigate alternative treatment options. Ongoing research aims to identify therapies that address bacterial resistance, minimize the long-term use of antibiotics, and provide more personalized treatment approaches. Furthermore, the effectiveness of many complementary and alternative medicine (CAM) therapies is still being studied, necessitating further clinical trials and evidence-based assessments.

3. Skin Structure and Drug Delivery Challenges:

The effectiveness of acne treatments is closely linked to the skin's unique structure and its barrier properties. The skin is composed of three primary layers: the epidermis, dermis, and hypodermis. The outermost layer of the epidermis, known as the stratum corneum (SC), serves as the principal barrier to the penetration of topical medications. For topical treatments to be effective, they must be able to penetrate the SC and reach the targeted area, while transdermal therapies aim for systemic absorption. Skin penetration occurs via two main pathways: the trans epidermal route (which is the primary path) and the trans appendageal route, which involves penetration through hair follicles and sebaceous glands—an important consideration for acne treatments.



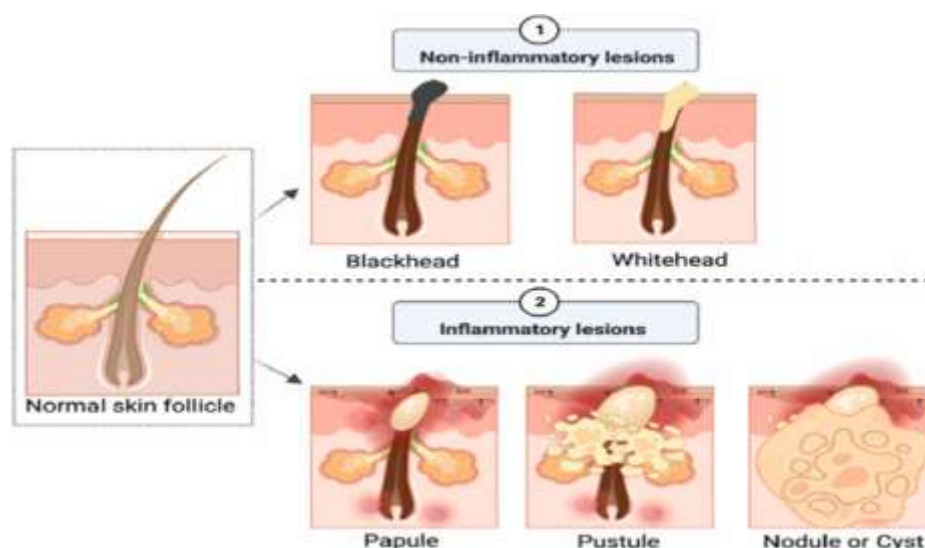


Fig. No. 4: Stages of Acne Formation

Physical Sequelae of Acne: Acne not only leads to immediate skin lesions but also has lasting physical consequences, including scarring and post-inflammatory hyperpigmentation (PIH). Even after the active lesions resolve, they can leave behind macules and irregular skin texture. While superficial scars and PIH may be addressed with topical treatments such as retinol or bleaching agents, more persistent scarring may necessitate dermatological procedures, including microdermabrasion or surgical interventions. Although complete restoration of the skin to its pre-acne state is often not possible, significant aesthetic and psychological improvements can be achieved through appropriate treatments.

Dietary and Hormonal Triggers: Recent studies have underscored the important influence of diet and hormones in the pathophysiology of acne. Foods with a high glycemic index, which lead to spikes in insulin levels, have been found to worsen acne by promoting sebum production and increasing follicular keratinization. Similarly, elevated insulin-like growth factor 1 (IGF-1), often associated with dairy consumption—particularly skim milk—has been linked to acne exacerbation. Hormonal fluctuations, such as those occurring before menstruation, are also

common triggers for acne in women. Additionally, warmer weather and increased sweating during the summer months are reported to aggravate acne in many patients.

Psychological and Quality of Life Impact: Acne has a profound impact on psychological health and can lead to a decline in health-related quality of life (HRQoL). Research indicates that individuals with acne, particularly adolescents and young adults, are more likely to experience depression, anxiety, and social isolation. The visible nature of the condition often exacerbates emotional distress, poor self-esteem, and psychiatric comorbidities. Additionally, behaviors like excessive cleansing, picking or squeezing lesions, and using comedogenic cosmetics can aggravate the condition and hinder the healing process.

Neonatal and Pediatric Acne: Although acne is most commonly linked to adolescence, it can also occur in neonates and young children. Neonatal acne, or acne neonatorum, typically develops within the first month of life and affects up to 20% of newborns, generally resolving on its own without treatment. However, acne that appears in children beyond infancy may indicate potential underlying endocrine issues and has been

associated with a higher risk of acne persisting into adolescence and adulthood. Therefore, early-onset acne in children may necessitate a clinical evaluation to rule out hormonal imbalances or other systemic conditions.

Role of Over-the-Counter Products: The use of over-the-counter (OTC) acne treatments is increasing due to their convenience and affordability. Referred to as "cosmeceuticals," these products include facial cleansers, creams, exfoliants, and even electronic devices. While popular, the effectiveness of OTC products can be inconsistent, and the wide range of available options can be overwhelming for both patients and healthcare providers. Choosing the most appropriate product often necessitates professional advice, particularly when OTC treatments do not provide adequate results.

Ongoing Challenges in Treatment: The growing popularity of over-the-counter (OTC) acne treatments is largely due to their accessibility and cost-effectiveness. These treatments, often termed

"cosmeceuticals," encompass products such as facial cleansers, creams, exfoliants, and even electronic devices. However, despite their widespread use, the effectiveness of OTC products can vary significantly, and the extensive range of available options can be overwhelming for both patients and healthcare providers. Selecting the most suitable product typically requires professional guidance, especially when OTC solutions fail to achieve satisfactory outcomes.

4. Benefits of Herbal Medicine in Acne Therapy:

Herbal medicines are gaining popularity due to their lower risk of side effects, affordability, and long-established use in traditional medicine. These treatments can be used either as standalone options or in conjunction with conventional therapies to improve treatment effectiveness and minimize side effects, making them especially beneficial in managing chronic conditions such as acne vulgaris.

Table No. 2: Herbal Medicine in Acne Therapy

Medicinal Plants	Family	Used Part(s)	Active Compound	Results
Aloe vera	Xanthorrhoeaceae	extracts	-	s anti-bacterial and anti-inflammatory properties
Azadirachta indica	Meliaceae	extracts	-	anti-bacterial and anti-inflammatory properties
Curcuma longa	Zingiberaceae	extracts	-	anti-inflammatory properties
Hemidesmus indicus	Apocynaceae	extracts	-	anti-bacterial and anti-inflammatory properties
Terminalia chebula	Combretaceae	extracts	-	anti-bacterial and anti-inflammatory properties
Withania somnifera	Solanaceae	extracts	-	anti-bacterial and anti-inflammatory properties
Melaleuca alternifolia	Myrtaceae	-	oil	anti-inflammation and Anti-bacterial
Salmalia malabarica	Malvaceae	-	-	anti-oxidant, anti-inflammation, anti-androgen and anti-bacterial activities
Andrographis paniculata	Acanthaceae	-	-	Andrographis paniculata Acanthaceae anti-oxidant, anti-inflammation, anti-androgen and anti-bacterial activities

Commonly Used Anti-Acne Medicinal Plants:

Numerous medicinal plants are recognized for their anti-inflammatory and antibacterial properties, making them particularly effective in acne treatment. Notable examples include *Matricaria recutita* (chamomile), *Calendula officinalis* (marigold), and *Triticum aestivum* (wheatgrass). These plants are commonly used topically, often in the form of creams or infusions, typically after cleansing or steam treatments.

Role of Tannin-Rich Plants:

Plants rich in tannins provide astringent and antimicrobial properties, making them valuable in acne treatment. *Hamamelis virginiana* (witch hazel) is one of the most commonly used botanicals, known for its safety in topical

applications. Other tannin-rich plants, such as *Quercus alba* (white oak), *Juglans regia* (walnut leaf), *Agrimonia eupatoria*, *Syzygium cuminum*, and *Hypericum perforatum*, are also included in skincare routines to help alleviate acne-related inflammation and inhibit microbial growth.

Traditional Topical Depuratives:

Depurative plants, traditionally recognized for their skin-purifying effects, have been utilized in acne treatment. Examples of these plants include *Bellis perennis* (daisy), *Viola tricolor* (wild pansy), *Elymus repens* (couch grass), and *Taraxacum officinale* (dandelion). Additionally, species of *Equisetum* (horsetail), which are rich in silicic acid, and *Aloe ferox*, known for its anthranoid content, are also recommended for their anti-inflammatory properties.

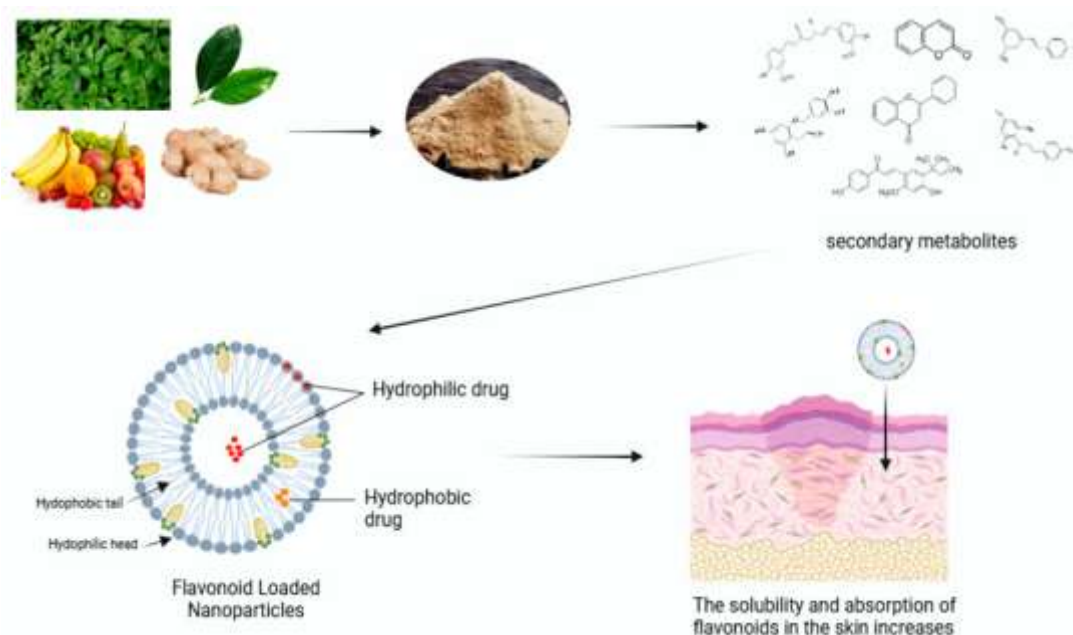


Fig. No. 6: Traditional Topical Depuratives

Hormonal Modulation with *Vitex agnus-castus*:

Vitex agnus-castus, commonly known as chaste tree, is especially effective in treating premenstrual acne. Its fruit extract influences hormonal activity by targeting the pituitary gland,

lowering prolactin levels, and balancing the estrogen-progesterone ratio. The typical recommended dosage is 40 mg per day; however, it is contraindicated in pregnant and breastfeeding women due to potential hormonal effects. Mild

side effects, such as skin rashes or gastrointestinal discomfort, may also occur.

Antibacterial Potential Against *P. acnes*:

Several plants have been shown to possess antibacterial properties effective against *Propionibacterium acnes*, a key contributor to acne development. *Glycyrrhiza glabra* (licorice) inhibits the growth of *P. acnes* without promoting bacterial resistance. *Usnea barbata*, which contains usnic acid, exhibits potent inhibitory effects against *P. acnes* at low concentrations (≥ 1 $\mu\text{g/mL}$) and also provides antioxidant benefits that enhance its effectiveness in acne treatment.

***Ocimum gratissimum* Clinical Evidence:**

A four-week clinical trial assessed the topical use of *Ocimum gratissimum* (African basil) at concentrations between 0.5% and 5%. The 2% extract, when formulated in a hydrophilic base, was more effective than both the placebo and standard treatments such as 10% benzoyl peroxide, showing quicker lesion resolution without causing side effects. However, the 5% concentration led to skin irritation, emphasizing the need for careful dose optimization.

***Aloe Vera*'s Synergistic Role:**

While yellow *Aloe vera* gel alone demonstrated limited effectiveness in treating acne, its combination with *Ocimum gratissimum* significantly boosted its therapeutic impact. Moreover, a randomized double-blind study with 60 participants revealed that a 50% *Aloe vera* gel combined with tretinoin cream was more effective and better tolerated than tretinoin alone over an eight-week period, indicating a potential synergistic effect in acne treatment.

Other Validated Herbal Remedies:

Solanum dulcamara (woody nightshade) has been authorized by the German Commission E for topical use in acne treatment, while *Saccharomyces cerevisiae* (brewer's yeast) has been recognized for its antibacterial properties when taken orally. *Lemna minor* (duckweed), a plant used in traditional Chinese medicine, is also applied topically for acne treatment, highlighting the widespread cultural significance of herbal remedies in acne care.

Gugulipid in Systemic Acne Treatment:

A standardized extract of *Commiphora mukul* (gugulipid) has been clinically proven effective for systemic acne treatment. When taken over a three-month period, it was especially beneficial for patients with oily skin, indicating its potential in sebum-regulating treatments. This positions gugulipid as a promising oral botanical option for comprehensive acne management.

Forms of Acne Treatment:

Acne treatment requires a multifaceted approach, encompassing topical treatments, systemic medications, physical therapies, laser interventions, and photodynamic therapies. The selection of the most appropriate modality is based on the severity of the acne and the individual's skin type, allowing for a personalized treatment strategy.

Topical Therapies for Mild to Moderate Acne:

Topical treatments, including retinoids, benzoyl peroxide, and antibiotics, are usually the first-line options for mild to moderate acne. These treatments are effective in preventing new lesions but may cause localized irritation. Choosing the right formulation—such as gels and solutions for oily skin or creams and ointments for dry skin—is essential to minimize irritation.



Treatment Goals and Duration:

For mild to moderate acne, topical treatments like retinoids, benzoyl peroxide, and antibiotics are typically the first choice. While these treatments effectively prevent new lesions, they can lead to local irritation. Selecting the appropriate formulation—gels and solutions for oily skin or creams and ointments for dry skin—is crucial for reducing irritation.

Challenges with Topical Antibiotics:

Topical antibiotics like erythromycin and clindamycin are frequently used in acne treatment, but they are not advised as standalone therapies because of their limited ability to penetrate the skin and the risk of developing bacterial resistance. To address these concerns, topical antibiotics are often combined with benzoyl peroxide.

Systemic Antibiotics for Moderate to Severe Acne:

Oral antibiotics are typically used for moderate to severe acne or when topical treatments are ineffective. Although they are effective, oral antibiotics can cause side effects like inflammatory bowel disease, pharyngitis, and fungal infections. As a result, their use must be closely monitored.

Recommended Use of Oral Antibiotics:

To minimize side effects and the risk of resistance, oral antibiotics should be prescribed for 6 to 8 weeks, with a maximum duration of 12 to 18 weeks. If retreatment is needed, the same antibiotic can be used again, but benzoyl peroxide should be co-administered for 5 to 7 days to help prevent the development of resistant strains.

Need for Safer and Effective Alternatives:

As concerns about the side effects of both topical and systemic treatments grow, there is a rising demand for safer formulations that provide enhanced therapeutic efficacy and better patient tolerance. This has sparked increased interest in alternative therapies, including botanical products, probiotics, and low-risk cosmetic formulations.

Topical Therapy in Acne Management:

Topical therapy is the mainstay of treatment for mild to moderate acne, with systemic medications added for more severe cases to enhance effectiveness. However, traditional topical treatments like tretinoin and benzoyl peroxide have drawbacks, including poor solubility, sensitivity to light, and skin irritation, all of which can affect patient adherence.

Table No. 3: Topical Therapy in Acne Management

Preparation	Function
Gel	Gel is used for patients with oily skin, because it is more comfortable and has a drying effect. However, it can cause burning-type irritation and prevent certain types of cosmetics from adhering to the skin
Solution	Its main solution is used with topical antibiotics dissolved in alcohol. Just like the gel, the solution is also used for patients with oily skin
Lotion	Lotions can be used on all skin types. The lotion spreads well all over the hair-bearing skin. However, usually lotions contain propylene glycol, causing a burning and drying effect.
Cream	Cream is used for patients with dry or sensitive skin, so it requires a formulation that does not dry out the skin and does not cause irritation to the skin. If it is given to patients with oily skin it will feel very oily with the use of cream.

5. Advanced Drug Delivery Systems for Acne Treatment:

To overcome the limitations of traditional topical treatments, new drug delivery systems have been created. These systems aim to enhance the delivery

of active ingredients, minimize side effects, and increase patient comfort. For instance, liposomes, which are first-generation vesicular systems, improve the penetration and prolonged release of active ingredients.

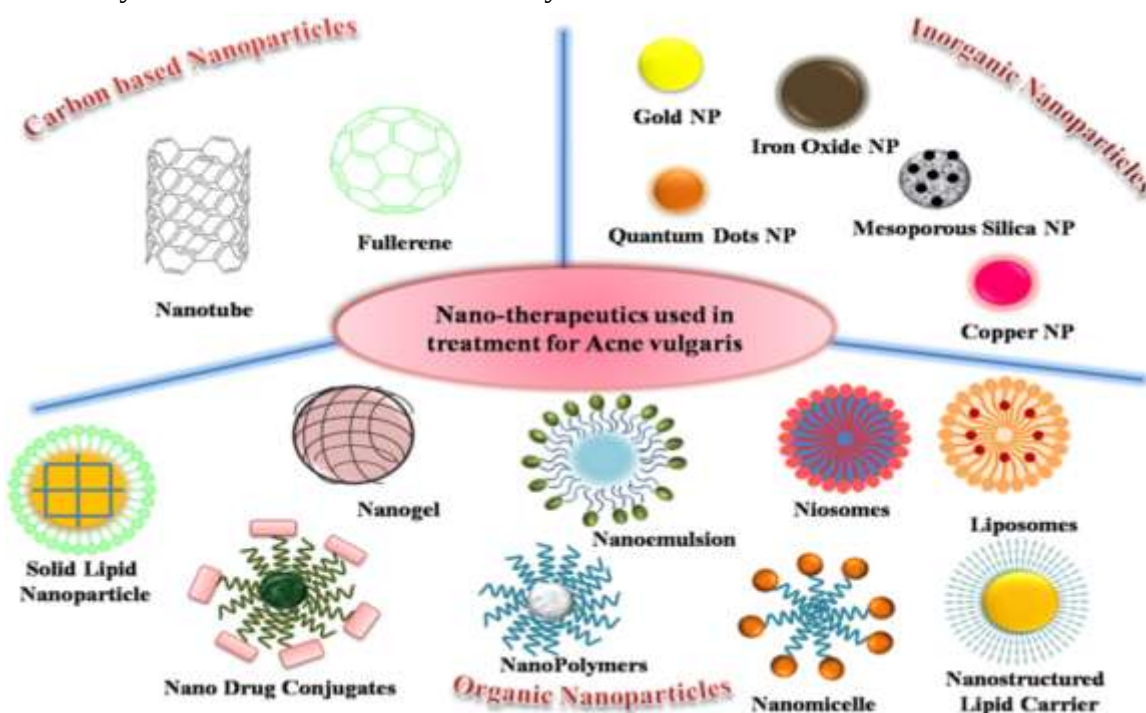


Fig. No. 7: Advanced Drug Delivery Systems for Acne Treatment

Niosomes and Aspasomes:

Niosomes, which are chemically more stable and cost-effective than liposomes, are bilayer vesicles created from non-ionic surfactants. They offer high encapsulation efficiency and improved skin penetration. A more recent development, aspasomes, are formed from ascorbyl palmitate, cholesterol, and dicetyl phosphate, and provide antioxidant benefits that enhance acne treatment.

Microsponges and Controlled Delivery:

Microsponges, which are porous polymer-based delivery systems, enable controlled release of active ingredients, helping to improve the

tolerability of irritating compounds such as benzoyl peroxide and tretinoin. Products like Retin-A Micro® utilize microsponges to enhance treatment efficacy while minimizing irritation.

Emulsifier-Free and Microemulsion Systems:

Emulsifier-free formulations and microemulsions are becoming increasingly popular because they can deliver medications without irritating the skin or damaging the skin barrier. Microemulsions, specifically, enhance the penetration of drugs and improve the therapeutic effects of treatments like azelaic acid.

Fullerenes and Hydrogels:

Fullerenes, spherical carbon molecules, possess powerful antioxidant properties and can aid in delivering active ingredients deeper into the epidermis. Hydrogels, which are hydrophilic polymer matrices, are effective in delivering irritant-sensitive agents such as retinoids, while providing moisturizing effects and minimizing side effects.

Solid Lipid Nanoparticles (SLNs) and Foams: Solid lipid nanoparticles (SLNs) combine the benefits of earlier drug delivery systems, providing better skin penetration, less irritation, and improved photostability. Moreover, aerosol foams have gained popularity for treating acne in areas with thick hair or large surface areas, enhancing bioavailability and ease of application.

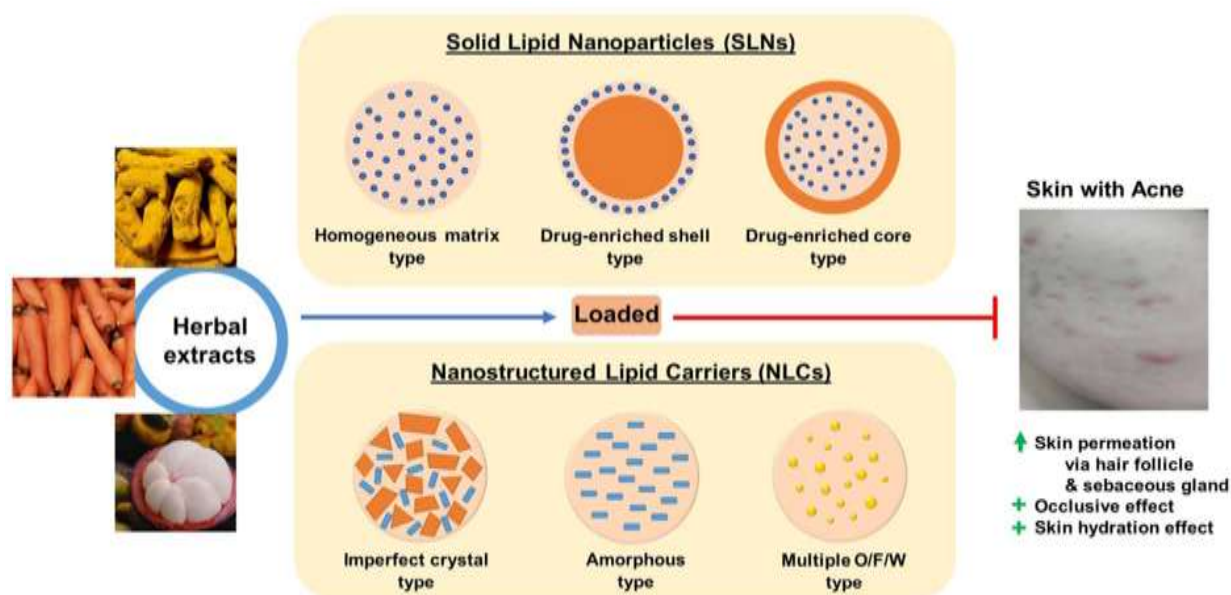


Fig. No. 8: Role of Solid Lipid Nanoparticles in Acne Management

Transdermal Therapeutic Systems (TDDS):

Transdermal drug delivery systems (TDDS), also known as medicated patches, provide controlled and continuous release of medication through the skin. This approach bypasses first-pass metabolism, ensuring sustained therapeutic effects with fewer systemic side effects, making it a promising future strategy for acne treatment.

CONCLUSION:

Acne vulgaris remains a significant dermatological condition, with multifactorial causes including hormonal imbalances, increased sebum production, and bacterial proliferation. Traditional treatments, such as topical retinoids, benzoyl peroxide, and oral antibiotics, offer relief

but are often associated with side effects like skin irritation, bacterial resistance, and systemic complications. In recent years, there has been a shift towards exploring herbal treatments, which offer anti-inflammatory, antimicrobial, and antioxidant properties with fewer adverse effects. Herbs such as *Aloe vera*, *Matricaria recutita*, and *Glycyrrhiza glabra* have demonstrated efficacy in managing acne, either as standalone therapies or in combination with conventional treatments. Furthermore, advances in drug delivery systems have revolutionized acne treatment. Novel formulations like liposomes, niosomes, microsponges, and solid lipid nanoparticles enhance the stability, bioavailability, and skin penetration of active agents, improving treatment outcomes and minimizing side effects. These

innovations also offer targeted, sustained, and controlled release of therapeutic agents, addressing key challenges in traditional acne management.

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