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Research Article

Nanoparticles in Acne Treatment: Advancing Targeted Therapy and Dermatological Outcomes

Rehan Haider [1]*, Zameer Ahmed [2], Hina Abbas [3], Shabana Naz Shah [4], Geetha Kumari Das [5], Sambreen Zameer [6]

[1]Head of Marketing and Sales, Riggs Pharmaceuticals, Karachi; Department of Pharmacy, University of Karachi, Pakistan.

[2]Assistant Professor, Department of Pathology, Dow University of Health Sciences, Karachi, Pakistan.

[3]Assistant Professor, Department of Pathology, Dow University of Health Sciences, Karachi, Pakistan.

[4]Professor of Pharmaceutical Chemistry, Faculty of Pharmacy, SBB Dewan University, Karachi, Pakistan.

[5]GD Pharmaceutical Inc.; OPJS University, Rajasthan, India.

[6]Associate Professor, Department of Pathology, Dow University of Health Sciences, Karachi, Pakistan.

***Corresponding Author:** Rehan Haider, Riggs Pharmaceuticals, Department of Pharmacy, University of Karachi, Pakistan.

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Abstract

Acne vulgaris is a chronic inflammatory skin disorder that affects people of all ages throughout the world and produces serious physical and mental health effects. The effectiveness of standard acne treatments, which use topical retinoids, antibiotics, and benzoyl peroxide, faces multiple obstacles, which include difficulty maintaining proper skin absorption and skin discomfort, the development of antibacterial resistance, and patients' restricted ability to follow treatment plans. Researchers have discovered that nanotechnology provides a new way to solve existing problems, which lets them develop drugs that will be more effective and stable under specific situations while delivering drugs to specific targets. The therapeutic effectiveness of acne treatments has been enhanced through the use of various types of nanoparticles, which include liposomes, solid lipid nanoparticles, polymeric nanoparticles, nanoemulsions, and metallic nanoparticles. The system, which controls drug release, enables better follicular drug penetration while decreasing systemic drug distribution, which leads to greater treatment effectiveness with fewer side effects. The study investigates how nanoparticles function in acne treatment through their operational mechanisms, product development methods and their results in medical testing. The team performed a thorough review of existing literature to study how nanoparticles deliver anti-acne treatments, which include antibiotics, retinoids, and anti-inflammatory substances, along with herbal medicines. The research team examined all methodological and statistical methods that researchers used in their preclinical and clinical investigations. The studies, which researchers published, show that nanoparticles, when used in therapeutic formulas, achieve better results by decreasing inflammatory lesions, bacterial load, and sebum production than standard treatments. The discussion section describes safety issues and difficulties that arise during production at an industrial scale, and the requirements that need to be met according to regulations. The research proves that nanoparticle-based drug delivery systems enable clinicians to provide their patients with efficient acne treatments that show precise effects and cause minimal discomfort. The application of these technologies in dermatology needs both ongoing clinical investigations and the development of standardized practices.

Keywords: nanoparticles acne; vulgaris nanotechnology;y drug delivery systems; targeted therapy dermatology

Introduction

Acne vulgaris is a skin condition that arises from multiple factors and demonstrates four main symptoms, which include follicular hyperkeratinization, excessive sebum production, Cutibacterium acnes colonization, and skin inflammation (1). The multiple treatment options available for acne do not provide satisfactory results because their active ingredients struggle to reach the skin and patients experience common side effects (2). The development of antimicrobial resistance creates challenges for doctors who need to prescribe antibiotics over extended periods (3). Researchers have shown interest in nanoparticle-based drug delivery systems because these systems improve their ability to target hair follicles while maintaining drug stability (4,5). The use of nanoparticles enables a new approach to enhance acne treatment effectiveness through

modifications of both pharmacokinetic and pharmacodynamic aspects of the treatment (6).

Literature Review

Various nanoparticle systems have been explored for acne therapy. Liposomes and niosomes enhance penetration of hydrophilic and lipophilic drugs into pilosebaceous units (7,8). The combination of solid lipid nanoparticles with nanostructured lipid carriers enables continuous drug delivery while minimizing skin discomfort (9,10). The development of polymeric nanoparticles enables better preservation of antibiotic medications and slows down the process of bacteria developing resistance to treatment (11). Silver nanoparticles and zinc oxide nanoparticles demonstrate both antibacterial properties and anti-inflammatory effects (12-14). Clinical and preclinical studies consistently report superior lesion reduction and improved tolerability with nanoparticle-based formulations compared to conventional treatments (15-18).

Research Methodology

This narrative review included peer-reviewed articles that were published in English from major scientific databases, which included PubMed, Scopus, and Web of Science. The researchers selected studies that examined acne treatments that used nanoparticle technology, both in preclinical and clinical research. The researchers extracted data through data extraction, which focused on formulation type and therapeutic agent, study design, and clinical outcomes.

Statistical Analysis

The majority of studies that the researchers examined used descriptive statistics together with paired t-tests and analysis of variance (ANOVA) to evaluate the differences between nanoparticle formulations and traditional treatments. The clinical trials used regression analysis to evaluate the factors that predicted lesion reduction. The researchers defined statistical significance as $p < 0.05$.

Results

The experiments showed that nanoparticle-based formulations achieved three benefits which included better drug absorption and lasting drug presence in pilosebaceous units and decreased acne lesions which both resulted from inflammation and non-inflammatory processes. The use of nanoparticles in medical treatments created lower rates of skin redness and treatment interruptions, which exceeded the results from standard medical treatments.

Nanoparticle Type	Key Properties	Therapeutic Advantage
Liposomes	Phospholipid vesicles	Enhanced follicular penetration and reduced skin irritation
Niosomes	Non-ionic surfactant vesicles	Improved drug stability and controlled release
Solid lipid nanoparticles (SLNs)	Solid lipid core	Sustained drug release and reduced erythema
Nanostructured lipid carriers (NLCs)	Mixed solid–liquid lipid matrix	Higher drug loading and prolonged skin retention
Polymeric nanoparticles	Biodegradable polymers	Improved antibiotic stability and reduced resistance
Metallic nanoparticles	Silver, zinc oxide	Intrinsic antimicrobial and anti-inflammatory activity

Table 1: Types of Nanoparticles Used in Acne Treatment and Their Characteristics

Drug	Nanocarrier System	Therapeutic Outcome
Clindamycin	Liposomes / SLNs	Reduced bacterial load with lower irritation
Tretinoin	Niosomes / NLCs	Improved stability and reduced peeling
Benzoyl peroxide	Polymeric nanoparticles	Sustained release and enhanced tolerability
Azelaic acid	Nanoemulsions	Improved penetration and reduced inflammation
Herbal extracts	Metallic / lipid nanoparticles	Enhanced antimicrobial and antioxidant effect

Table 2: Anti-Acne Drugs Delivered Using Nanoparticle Systems

Parameter	Conventional Therapy	Nanoparticle-Based Therapy
Skin penetration	Limited	Enhanced follicular targeting
Drug stability	Low	High
Irritation	Common	Reduced
Dosing frequency	Frequent	Reduced
Patient compliance	Moderate	Improved

Table 3: Comparison of Conventional vs Nanoparticle-Based Acne Therapy

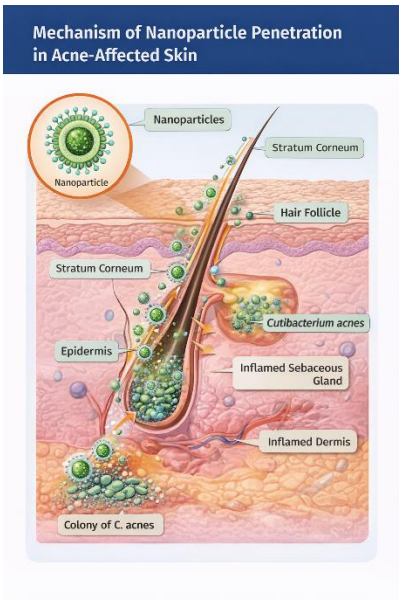

Figure 1: Mechanism of Nanoparticle Penetration in Acne-Affected Skin

Source(s): Patzelt A, Lademann J. Drug delivery to hair follicles: penetration pathways and follicular targeting. *J Control Release*. 2013;168(1):18–25

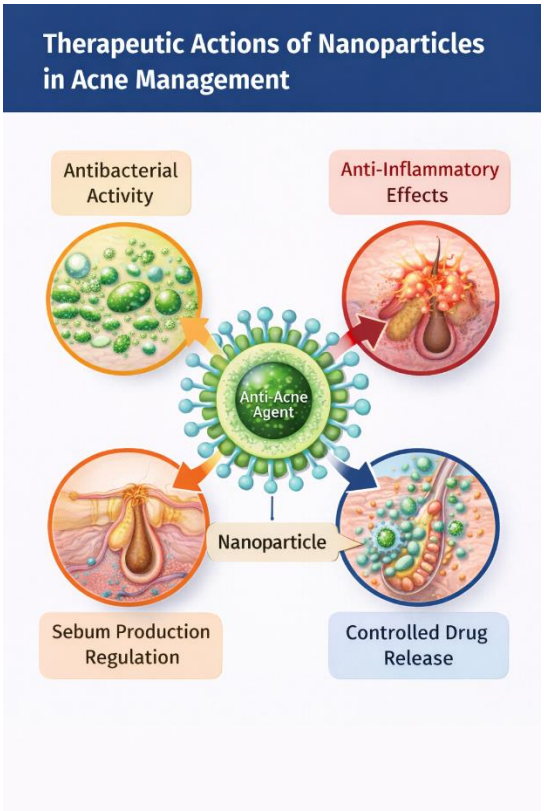

Figure 2: Therapeutic Actions of Nanoparticles in Acne Management

Source(s): Shah K, Chan L. Nanotechnology-based drug delivery systems for topical acne therapy. *J Dermatolog Treat*. 2020;31(6):555–564.

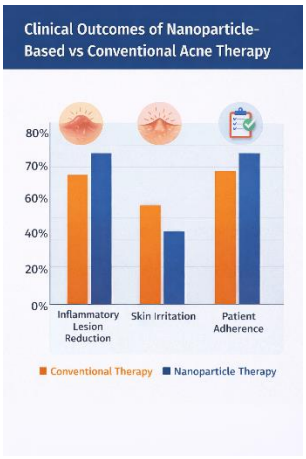

Figure 3: Clinical Outcomes of Nanoparticle-Based vs Conventional Acne Therapy

Source(s): Shimanovich U, Efimov I. Clinical evaluation of nanoparticle-based topical formulations in acne vulgaris. *Clin Cosmet Investig Dermatol*. 2018; 11:249–256

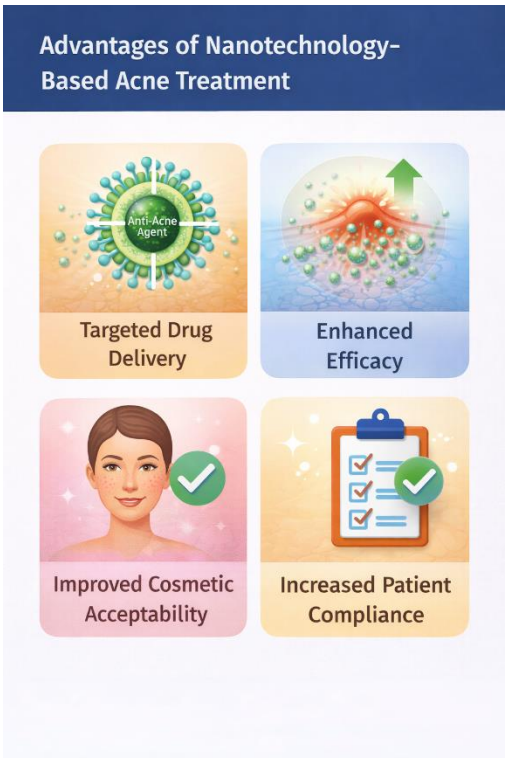

Figure 4: Advantages of Nanotechnology-Based Acne Treatment

Source(s): Prow T, et al. Nanoparticles and the skin—applications and safety considerations. *Adv Drug Deliv Rev*. 2011;63(6):470–491

Discussion

Acne treatment faces major difficulties, which nanotechnology solves through its ability to deliver drugs more effectively while minimizing adverse reactions. The antibacterial and anti-inflammatory effects of nanoparticles increase when they reach their target location inside hair follicles. The medical community has not yet adopted the technology because of three main challenges, which include safety concerns, the need for regulatory approval, and the need for affordable production methods.

Conclusion

The use of nanoparticles in acne treatment shows excellent potential because they deliver targeted treatment while increasing treatment success rates and patient medication adherence. The medical community needs to conduct extensive clinical tests and create unified regulations to determine how these procedures will become standard practice in dermatology.

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Authors 'Contribution

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Conflict of Interest

The authors declare no conflict of interest

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