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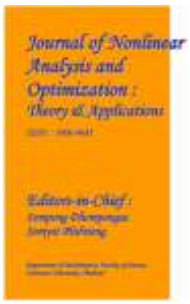

A COMPARATIVE STUDY ON NANO-FORMULATIONS FOR TREATING SKIN DISORDERS

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ABSTRACT

Skin disorders, from inflammatory conditions such as psoriasis and atopic dermatitis to microbial infections and acne vulgaris, indeed impact quality of life. Traditional treatments by means of creams and ointments suffer from poor penetration in the skin, low residence time, and do not provide desirable side effects such as irritation or greasiness. To overcome these difficulties, drug delivery systems that are based on nanotechnology have emerged as a promising alternative. These new formulations in the form of liposomes, niosomes, ethosomes, solid lipid nanoparticles, and polymeric micelles are designed to enhance the solubility of the drug with greater stability and targeted delivery. They provide localized and efficient treatments for different skin disorders. The nanocarrier-based formulations include improved therapeutic efficacy, controlled drug release, and better patient compliance. For example, ethosomes and liposomes enhance the skin permeation in psoriasis. Nano lipid carriers and nano emulsions increase the retention of drugs and their anti-inflammatory effect in atopic dermatitis. In acne vulgaris, solid lipid nanoparticles and microspheres ensure increased stability of the drug and prolonged action. For fungal infections, ethosomes and polymeric micelles improve bioavailability and antifungal efficacy. These developments show the versatility and effectiveness of nano-formulations in overcoming the limitations of conventional treatments. Nanotechnology is still revolutionizing dermatology through the most accurate and efficient drug delivery systems. These novel approaches are specifically tailored to meet the specific needs of a particular disorder, thus optimizing the outcome while reducing side effects. In this respect, nano-formulations will represent the future of dermatological therapies that will lead to innovation based on both efficacy and comfort.

Keywords: Nanotechnology, skin disorders, nano-formulations, psoriasis, atopic dermatitis, acne vulgaris, fungal infections, liposomes, ethosomes, solid lipid nanoparticles, controlled drug release.

I. INTRODUCTION

The skin is the biggest organ in the human body. It works like a protective shield against external aggressors, helps regulate the temperature of the body, and helps synthesize vital compounds that include vitamin D. Despite its resilience, it often suffers from a wide

spectrum of diseases, such as psoriasis, atopic dermatitis, fungal infections, and acne vulgaris. Such conditions do not only affect the health of the skin but the condition could also have severe psychological and social impacts on the individual. Effective management of skin disorders requires treatments that can penetrate through the skin barrier to the target sites and preferably retain therapeutic concentration with minimum adverse effect.

The most commonly known traditional topical formulation includes creams, ointments, and lotions for the management of skin conditions. However, these conventional treatments have certain disadvantages in the form of poor skin penetration, short retention time, and other unpleasant features like greasiness, irritation, and unpleasant odor. Also, in many treatments, nonspecific drug delivery occurs, which leads to lower therapeutic outcomes as well as other systemic effects. It thus creates a huge demand for these innovative drug delivery systems that could end up helping overcome all these challenges and give efficient solutions that are friendly to patients.

The new drug delivery systems introduced into the treatment of dermatology have revolutionized nanotechnology with better therapeutic outcomes and fewer side effects. Nano-formulations, such as liposomes, niosomes, ethosomes, and solid lipid nanoparticles, have been designed to overcome the drawbacks of conventional therapy. The targeted delivery of drugs by these systems along with controlled release might bring controlled drug delivery and improved bioavailability, promising other alternates in management options of various skin disorders in a better precision and efficacy. As such, the potentiality of nanotechnology with respect to dermatological applications of interest to the prevention and treatment of specific skin conditions is discussed in the paper.

II. REVIEW OF LITERATURE

Raszewska-Famielec, M., & Flieger, J. (2022). Nanomaterials (NM) generate attention across several scientific and industrial domains owing to their adjustable properties and the simplicity of manipulation. They currently exist as constituents in several consumer products, including sunscreen, dressings, athletic apparel, surface cleaners, electronic gadgets, paints, and pharmaceutical and cosmetic formulations. The incorporation of nanoparticles in topical treatments enhances the absorption of bioactive chemicals into the deeper skin layers, facilitating a depot effect that ensures continuous drug release and targeted delivery to specific cellular and subcellular sites. "Nanocarriers facilitate advancements in dermatological and systemic therapies." Examples include non-invasive immunization methods, sophisticated diagnostic techniques, and transdermal drug administration. The mechanisms of action of nanoparticles, their efficacy in skin penetration, and possible risks to human health remain unresolved and inadequately elucidated. This article provides a concise overview of recent advancements in nanotechnology applied to products for the prevention and treatment of skin disorders. We emphasized factors including the penetration of nanoparticles through the skin (the impact of the physicochemical features of nanoparticles, experimental models for skin penetration, techniques employed to enhance nanoparticle penetration through the skin, and methodologies used to examine nanoparticle skin

penetration). The study encapsulates many therapies employing nanoparticles for the diagnosis and treatment of dermatological conditions (melanoma, acne, alopecia, vitiligo, psoriasis) as well as anti-aging and UV-protective nano-cosmetics.

Raina et al. (2023). The skin, being the biggest organ in humans, serves as an effective pathway for medication delivery, bypassing the drawbacks associated with oral and parenteral methods. The benefits of skin have captivated researchers in recent decades. Topical drug delivery involves transferring the medicine from a topical formulation to a specific localized area, utilizing dermal circulation to reach deeper tissues throughout the body. Nevertheless, the skin's barrier function complicates transdermal delivery. Conventional formulations for drug delivery to the skin, such as lotions, gels, ointments, and creams containing micronized active ingredients, yield inadequate penetration. The utilization of nanoparticulate carriers is a potential strategy, as it facilitates efficient drug delivery via the skin and mitigates the limitations of conventional formulations. Nanoformulations with reduced particle sizes enhance the permeability of therapeutic agents, targeting, stability, and retention, rendering them optimal for topical medication administration. The use of nanocarriers for sustained release and localized action can effectively cure various infections or skin problems. This article intends to assess and analyze the latest advancements in nanocarriers as therapeutic agents for skin disorders, including an overview of patent technology and market trends that will inform future research strategies. Given the promising preclinical outcomes of topical drug delivery systems for dermatological issues, we foresee future research focusing on comprehensive investigations of nanocarrier dynamics in tailored therapies to address the phenotypic diversity of the condition.

Ivanova et al. (2023). Acne is a prevalent chronic dermatological disorder with significant physical and psychosocial ramifications. The emergence of pimples, whiteheads, or blackheads on the face, neck, and back can result in scarring, disfigurement, despair, frustration, and anxiety among individuals. Current therapies depend on antibiotics to eliminate Cutibacterium acnes (C. acnes), the bacterium implicated in this dermatological disorder. Nonetheless, these methods fail to eliminate the reactive oxidative species (ROS) produced during illness progression and raise apprehensions over the escalation of antibiotic resistance. This study utilized an eco-friendly and economical self-assembly nanoencapsulation technology utilizing zein, a bio-derived hydrophobic protein, to create multifunctional essential oil (EO)-loaded nanocapsules (NCs) exhibiting enhanced antioxidant and bactericidal efficacy against C. acnes. The NCs exhibited a 'smart' release of the active cargo just under conditions favorable to acne growth on the skin. When integrated into creams, the essential oil-loaded nanocarriers resulted in total suppression of C. acnes and exhibited the ability to scavenge reactive oxygen species, so safeguarding human skin cells from injury. The in vitro permeation investigations shown that the nanoformulated essential oil could traverse the epidermis, suggesting its potential for treating skin disorders, including acne.

Dereiah et al. (2025). Context/Aims: Spironolactone (SP), an aldosterone antagonist commonly employed for the management of androgen-dependent conditions such as acne, hirsutism, and alopecia, has exhibited therapeutic efficacy in both oral and topical preparations. Nonetheless, the limited solubility and inadequate bioavailability of SP in traditional formulations have prompted the creation of innovative nanocarriers to improve its effectiveness. This study methodically evaluates current progress in SP-loaded nanocarriers, encompassing lipid nanoparticles (LNPs), vesicular nanoparticles (VNPs), polymeric nanoparticles (PNPs), and nanofibers (NFs). Methods: A search strategy was created, and pertinent material was carefully explored utilizing databases such as Scopus, PubMed, and Google Scholar. The review process, encompassing screening, inclusion, and exclusion criteria, conformed to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Outcomes: An extensive examination of 13 qualifying research publications, pertaining to 15 investigations, underscores critical factors like encapsulation efficiency, stability, particle size, and both in vitro and in vivo efficacy. Six research examined lipid nanoparticles (LNPs), encompassing solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs), which demonstrated enhanced bioavailability and skin absorption of SP. Six other research examined vesicular nanoparticles (VNPs), including ethosomes and niosomes, which exhibited enhanced skin targeting and penetration efficacy. Two studies on polymeric nanoparticles (PNPs) shown efficacy in transporting SP to hair follicles for the treatment of alopecia and acne. Furthermore, a study using SP-loaded nanofibers demonstrated considerable promise for the topical treatment of rosacea. Conclusions: SP-loaded nanocarrier devices signify significant progress in targeted topical therapy. Nevertheless, additional clinical research are necessary to enhance their safety, efficacy, and delivery methods.

III. OBJECTIVES OF THE STUDY

The main objectives of the research study are stated as follows:

1. To emphasize the limits of traditional dermatological treatments.
2. To discuss the role of nanotechnology in dermatology.
3. Investigate the use of nano-formulations for specific skin conditions.
4. Analyze the impact of nano-formulations on drug delivery.

III. TYPES OF SKIN DISORDERS

As skin sheath the external surface of the body. Skin contributes in thermoregulation; serve as water repellent and synthesis of many useful compounds like vitamin D and acts as a

preventing barrier between external environment and internal tissue. There are different disorders of skin as mentioned in figure 1.

1. Inflammatory skin diseases
2. Bacterial skin diseases
3. Viral skin diseases
4. Fungal skin disease.

Epithelial layers and follicles consist of several important components as tight junction proteins whose localization and expression have been shown to be altered in the diseases characterized by a compromised skin barrier, such as psoriasis.

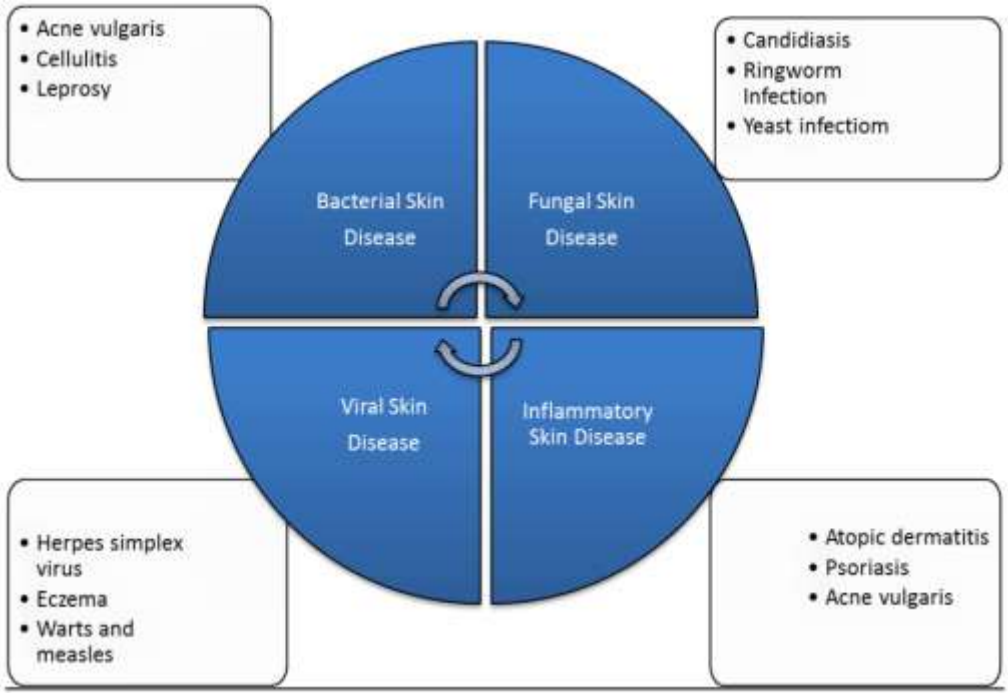

Figure1: Types of skin disorders

Psoriasis:

Psoriasis is an autoimmune skin condition that presents as a chronic, rapid proliferation of skin cells. This causes the formation of thick, scaly patches on the skin, with redness, itching, and inflammation often occurring in the area. The common types of psoriasis are:

- **Plaque psoriasis:** It is a raised patch covered with silvery scales.
- **Guttate psoriasis:** Small, drop-shaped lesions.

- **Psoriatic arthritis:** Psoriasis both affecting the joints and the skin. It occurs due to abnormal immune system behavior, genetic or even environmental factors caused by stress and infections.

Atopic dermatitis:

Atopic dermatitis, also called eczema, is an inflammatory skin disorder characterized by very itchy and dry skin; it usually appears in childhood, often in the context of asthma and hay fever.

- **Symptoms:** Dry, scaly or crusty rash, intense itching.
- **Causes:** A combination of genetic and environmental factors disrupts the skin's barrier, which allows allergens or irritants to penetrate more easily.

Impaired Wound healing:

Impaired wound healing is delay or failure of the normal course of wound healing. This is due to the following intrinsic factors:

- Diabetes mellitus, Ageing and Other impaired immunity conditions.
- Extrinsic factors include infection, compromised blood supply, or repeated trauma to the wound. Impaired healing is illustrated by chronic wounds, such as diabetic ulcers. Wound healing is an orderly process of inflammation, tissue formation, and remodeling.

Acne Vulgaris:

Acne vulgaris is characterized by clogging hair follicles with oil and dead skin cells on the skin's surface, mainly manifesting with pimples, blackheads, whiteheads, nodules, and cysts on the epidermis surface.

- **Causes:** Hormonal change (the condition during the period of onset during puberty); excessive growth of specific bacteria in such skin pores and the increased excretion of natural oil.
- Chest, shoulder, and also facial skin mainly.

Melanoma skin cancer:

Melanoma is a serious form of skin cancer that starts in melanocytes, which are pigment-producing cells in the skin. It is much less common than other types of skin cancers such as basal cell carcinoma, but much more dangerous and prone to spreading to other parts of the body.

- **Symptoms:** New or changing moles with irregular borders, multiple colors and asymmetry, or even moles more than 6mm in diameter that have recently changed.

- High exposure to UV radiation, fair skin, tendency due to family history, or too many moles.

Stages of Melanoma:

The most common progression states for melanoma include the following:

- **Stage 0 or in situ:** The affected cells are found in the epidermis and have not spread.

- **Stage I:** The melanoma is small and has minimally invaded surrounding tissue.

- **Stage II:** Larger or thicker melanoma; still localized; increased risk of spreading

- **Stage III:** Melanoma that has invaded nearby lymph nodes or tissues.

- **Stage IV:** Advanced stage where melanoma has metastasized to distant organs such as the lungs, liver, or brain.

These conditions illustrate the wide range of dermatological issues and the urgent need for specific treatments, like nano-formulations, to target certain skin conditions.

Conventional Therapies:

An optimal dosage regimen in pharmacotherapy is one that promptly achieves the desired therapeutic plasma concentration of a drug, sustaining it throughout the treatment duration, which can be accomplished through the administration of conventional dosage forms at specific doses and times. "However, it possesses several limitations; Conventional topical medications are hindered by limits concerning patient compliance, safety, and therapeutic efficacy." Conventional therapies are employed to work upon the epidermal layer of the skin. Traditional topical treatments for the skin involve the application of ointments or lotions. Topical formulations, including ointments, creams, and lotions, create a concentrated layer of active ingredients upon application to the skin, which is rapidly absorbed. This can lead to diminished patient compliance due to issues such as stickiness and greasiness, and may also occasionally provoke irritation and allergic reactions. The administration of these medicines is generic, and dermal absorption is minimal. Notable disadvantages include unregulated evaporation of the active component and a disagreeable odor. In psoriasis, normal moisturizing factors (NMFs), such as water, are nearly absent in the psoriatic skin. Targeting psoriatic tissues via the topical method presents a significant challenge due to many variables. Alternative topical therapeutic agents, such as liposomes, are accessible for psoriasis treatment. Nevertheless, none of these can be considered an optimal medicinal molecule. This may result from their intrinsic negative effects or their inadequate concentration in traditional vehicles. In certain dermatological conditions, the application of penetration enhancers accelerates the transdermal transport rate; nevertheless, it also elevates adverse effects due to

increased systemic drug levels. The adverse or potentially harmful side effects of penetration enhancers warrant an examination of their application in topical medication administration.

IV. NOVEL DRUG DELIVERY SYSTEMS FOR SKIN DISORDERS [NDDS]

The NDDS, with their distinctive characteristics, facilitate appropriate skin interactions as required in pathological circumstances. Examine the advantages; there have been multiple new endeavors utilizing the NDDS technique to enhance current topical medication formulations for skin conditions. Innovative carriers such as liposomes, niosomes, ethosomes, silver nanoparticles, and solid lipid nanoparticles are employed via nearly all methods of administration due to their reduced pain compared to injections. Nevertheless, the topical route has been employed as one of the most suitable methods for the effective treatment of dermatological problems. Despite traditional formulas reliant on creams and ointments, these innovative dermatological systems differ in their composition and concentration. Various pharmacological and dermatological factors determine the selection of the system based on the requirements of the medication and the condition. "Novel nano-vehicle technologies can precisely deliver powerful medications to targeted sites." The formulation of nanomedicines utilizing nanosystems effectively regulates the release of a therapeutic agent to the targeted area of the skin, achieving localized effects through the establishment of skin reservoirs. The skin functions as a negatively charged membrane; the charge present on the surfaces of nano carriers affects their drug diffusion through the skin. A positively charged delivery method exhibits robust interactions with cells and demonstrates enhanced permeability and extended pharmacological activity.

Novel Formulations:

Development of nanotechnology has been explored for treatment and diagnosis of various skin related diseases as given in table 1.

Table 1: Novel formulation for different skin disorders

Dosage form Type	Drug	Disease	Impact
Ethosome	Methotrexate	Psoriasis	Favorable skin permeation characteristics
Liposome	Methotrexate	Psoriasis	Improved therapeutic index
Liposomes	Dithranol	Psoriasis	Higher solubility
Niosome	Methotrexate	Psoriasis	Better efficacy and tolerance
Liquid crystalline nanoparticles	Tacrolimus	Psoriasis	Higher solubility, better anti-inflammatory
Niosomes	Dithranol	Psoriasis	Better permeation
Ethosomes	Resveratrol	Psoriasis	High permeation

Microemulsion	Tacrolimus	Psoriasis	Higher drug skin penetration
Transfersomes	Resveratrol	Psoriasis	High permeation
Liposomes	Resveratrol	Psoriasis	Higher stability and loading efficiency
Nanostructured lipid carrier	Betamethasone dipropionate	Atopic dermatitis	Improved skin retention
Nano lipid carrier	Tacrolimus	Atopic dermatitis	Enhance drug solubility
Nano emulsion	Clobetasol propionate	Atopic dermatitis	Increased anti-inflammatory activity
Polymer nanoparticles	Hydrocortisone acetate	Atopic dermatitis	Increase in therapeutic efficacy
Nano emulsion	Nadifloxacin	Acne vulgaris	Improved zone inhabitation
Nano emulsion	Predincarbate	Atopic dermatitis	Increase retention time and bioavailability
Nano emulsion	Isotretinoin	Acne vulgaris	Controlled release
Nano emulsion	Dapsone	Acne vulgaris	Improved epidermal penetration
Solid lipid nanoparticles	Eugenol	Fungal infections	Increase in membrane permeability
Ethosomes	Econazole nitrate	Skin fungal infections	Controlled drug release, better anti- inflammatory activity
Microspheres	Benzoyl peroxide	Acne vulgaris	Favorable efficacy
Microspheres	Insulin	Cutaneous wound	Promote tissue healing
Solid lipid nanoparticles	Triclosan	Acne vulgaris	Increase stability
Polymeric micelles	Clotrimazole	Superficial fungal infections	Improved drug bioavailability

Specific Nano formulations:

Nanotechnology is at the forefront of swiftly advancing treatments for diseases. For instance, in the case of dermatological conditions such as psoriasis, atopic dermatitis, impaired wound healing, and acne vulgaris. "Nano carrier-based drug delivery is effectively employed to enhance the efficacy of therapeutic medicines, utilizing diverse nanosystems such as liposomes, inorganic nanoparticles, niosomes, ethosomes, solid lipid nanoparticles, and transferosomes to treat skin problems." Nanoparticles facilitate targeted medication delivery and site-specific administration of dosage forms to designated receptor sites, hence improving the absorption of poorly soluble medicines and their bioavailability.

Psoriasis:

Nano-formulations have really improved well in the case of psoriasis, an autoimmune disease. Ethosomes with Methotrexate take up favorable skin permeation characteristics and ensure drug absorption into the epidermis effectively. Similarly, Liposomes with Methotrexate bring improved therapeutic indexes that are better in outcomes with systemic effects. For solubility issues, Liposomes with Dithranol enhance the solubility of the drug such that it is accessible to the skin. Methotrexate-loaded niosomes maximize efficacy and tolerate the patient. The treatment would be less irritating, and the whole process is considered to be safe. Tacrolimus delivery system, in the form of Liquid Crystalline Nanoparticles, enhances drug solubility and has pronounced anti-inflammatory activity. Resveratrol with Ethosomes and Transfersomes delivery systems have shown higher skin permeability ensuring drug delivery, hence providing more therapeutic effect. Microemulsions and Liposomes also proved their importance as they increase drug penetration and drug stability, respectively.

Atopic Dermatitis:

Nano-formulations have significantly enhanced the treatment of atopic dermatitis, a chronic inflammatory disease with resultant itching of the skin. Improved skin retention leads to prolonged drug action at the site of effect by nanostructured Lipid Carriers. Tacrolimus nano Lipid Carriers enhance the solubility of poorly soluble drugs, leading to better absorption and efficacy. The action of nano emulsions of Clobetasol propionate increases anti-inflammatory activity and represents more rapid resolution of symptoms. Moreover, Polymer Nanoparticles (Hydrocortisone Acetate) increase the therapeutic efficacy, thereby ensuring a stronger response to treatment. The retention time and bioavailability of Nano Emulsions (Predincarbate) increase, which helps in better management of this complex skin disorder.

Acne Vulgaris:

Nano-formulations have changed the face of acne vulgaris treatment by increasing drug penetration and stability. Nano Emulsions with Nadifloxacin increase bacterial inhibition, thereby targeting the bacteria causing acne. Similarly, Isotretinoin-loaded Nano Emulsions permit the controlled delivery of drugs without any side effect while maintaining a therapeutic effect. Dapsone-loaded Nano Emulsions enhance permeation through epidermis targeting the affected areas of the epidermis. The Solid Lipid Nanoparticles of Triclosan ensures stability and a drug that persists in its concentration for a prolonged period. The Microspheres of Benzoyl Peroxide provide more efficacy as drug delivery is smooth over the area of skin thereby less chance of irritation and further increases the chances of therapy.

Fungal Infections:

Such formulations of fungi infections enhance the drug delivery and lower the systemic side effects by nano-formulation. Solid Lipid Nanoparticles formulation with Eugenol increases membrane permeability, thus ensuring better penetration of the antifungal agent into infected areas. Ethosomes formulation with Econazole Nitrate provides sustained drug release with improved anti-inflammatory response, ensuring extended periods for efficacy. Another

formulation is Polymeric Micelles loading with Clotrimazole that enhances bioavailability of the drug, hence offering higher usefulness for topical applications.

Cutaneous Wounds:

Nano-formulations play a key role in wound healing. Insulin-releasing microspheres are promising in healing tissue repair within a short period. By stimulating cellular growth and the repair mechanisms, these formulations hold promise for chronic or severe wounds that call for effective and localized treatment.

These sections bring out the prospect of nanotechnology in the field of dermatological treatment. They address limitations of the traditional treatments with their novel approaches, which involve enhanced solubility, stability, permeability, and targeted drug delivery to offer improved options in managing skin disorders.

V. CONCLUSION

Nanotechnology has been added to the treatment of skin diseases, which has revolutionized the management of dermatological diseases. The nano-formulations that have been used in the form of liposomes, niosomes, ethosomes, and solid lipid nanoparticles will significantly advance beyond traditional therapy with respect to solubility, stability, and targeted delivery. It addresses critical concerns in the treatment of skin disorders: low penetration in the skin, short retention times, and unacceptable side effects; they improve the outcome of the treatment and adherence of the patients.

Dermatological conditions benefit highly by delivering drugs using nanocarriers on account of their peculiar characteristics. Improved permeation of drugs and anti-inflammatory actions are achieved in psoriasis and atopic dermatitis, with enhanced stability and bioavailability achieved in the case of acne vulgaris and fungal infections. Their property for localized and controlled drug release inside the body allows a sustained level of treatment with minimum side effects from drugs, opening up new avenues for a more patient-centric approach in dermatology.

With further developments in research and development in the field of nanotechnology, there seems to be more promising solutions related to skin disorders that are much more potent and innovative. Nano-formulations will soon be poised to become the gold standard for dermatological treatments, bringing the hope of disease management and subsequently enhancing the quality of life among patients worldwide due to the increased precision of drug delivery that combines with enhanced pharmacokinetics and pharmacodynamics.

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