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Nanotechnology in the Treatment of Skin Disorders Such as Psoriasis

Purva U Chandorkar[1], Akash A Podutwar[1], Swati C Jagdale[1]*.

[1]School of Health Sciences and Technology, Department of Pharmaceutical Sciences, Dr. Vishwanath Karad MIT World Peace University, MIT Campus, Kothrud, Pune, India.

***Corresponding Author E-mail: swati.jagdale@mitwpu.edu.in**

ABSTRACT

Psoriasis is a chronic, immune-mediated inflammatory skin condition that markedly impacts patients' quality of life and presents difficulties for efficient therapy because to inadequate medication penetration, systemic adverse effects, and restricted therapeutic retention. Traditional treatments, such as topical corticosteroids, systemic medications, and phototherapy, often demonstrate inadequate effectiveness and side effects, prompting the investigation of innovative drug delivery methods. Nanotechnology has emerged as a viable methodology in dermatology, providing nanoscale drug delivery systems including liposomes, niosomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles. Pre-clinical studies utilizing murine and rodent models of psoriasis have shown that these nanocarrier systems improve skin penetration, facilitate controlled and sustained drug release, enhance the stability of therapeutic agents, and modulate inflammatory and oxidative pathways, leading to superior lesion healing, diminished epidermal hyperplasia, and reduced cytokine expression relative to conventional treatments. Notwithstanding their potential effectiveness, issues such as intricate synthesis, possible immunogenicity, unpredictability in drug loading, and insufficient long-term safety evidence must be resolved to guarantee their use in clinical practice. Nanotechnology-based formulations provide a revolutionary and precise approach to pre-clinical psoriasis care, offering insights into the creation of safer, more effective, and patient-centric medications.

Key Words:

Keywords: Psoriasis, Nanotechnology, Nanocarriers, Liposomes, Solid Lipid Nanoparticles, Nanostructured Lipid Carriers

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1. INTRODUCTION

Psoriasis is a long-term, immune-mediated inflammatory skin condition that affects millions of people globally. It is characterized by aberrant keratinocyte proliferation, excessive scaling, and erythematous plaques[1]. Even though the illness is not communicable, it causes a great deal of physical and mental suffering for those who are afflicted, which often results in a worse quality of life and social isolation[2]. While topical corticosteroids, systemic medications, and phototherapy are examples of conventional therapeutic approaches that have offered some relief, their efficacy is frequently constrained by issues like low bioavailability, systemic toxicity, poor skin penetration, and short duration of action. Long-term usage of these treatments may also result in negative side effects, medication resistance, and non-

adherence from patients. For psoriasis and other chronic skin conditions, these disadvantages highlight the critical need for cutting-edge therapeutic approaches that may provide focused, secure, and long-lasting therapy results.

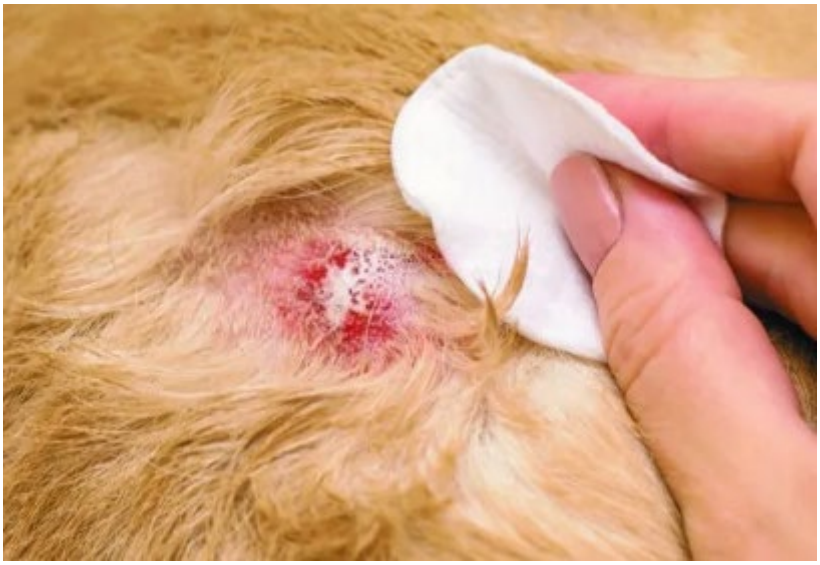

Figure 1: Dog Psoriasis

In dermatological research, nanotechnology has become a cutting-edge and exciting area in recent years, especially for medication delivery in the treatment of psoriasis. In pre-clinical animal models, a variety of nanocarriers have been thoroughly studied, including liposomes, nanoemulsions, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, dendrimers, and metallic nanoparticles[3]. Their special physicochemical characteristics, such as their high surface area-to-volume ratio and nanoscale size, minimize systemic exposure by enabling deeper penetration into psoriatic lesions, improved solubility, increased drug stability, and regulated and sustained release. Drug delivery using nanocarrier systems has been shown to significantly increase treatment effectiveness in animal-based trials, particularly those involving murine models of psoriasis. These trials show longer drug retention, less epidermal hyperplasia, and better anti-inflammatory effects than traditional formulations. With a focus on pre-clinical research results, this study aims to provide a thorough analysis of the possible use of nanotechnology in psoriasis management[4]. While purposefully omitting data from human trials to keep the focus on animal-model research, it also seeks to critically assess the advantages, disadvantages, and prospects for the future of nanotechnology-based interventions, emphasizing how these developments could be converted into workable therapeutic approaches.

1.1. Background Information and Context

A chronic inflammatory skin condition caused by the immune system, psoriasis has garnered a lot of scientific interest because of its intricate pathophysiology and detrimental effects on health[5]. This multifactorial syndrome, which is characterized by aberrant keratinocyte proliferation, excessive scaling, erythematous plaques, and immune cell infiltration, is influenced by both hereditary and environmental factors. Psoriasis is a significant disorder that goes beyond aesthetic issues since it is linked to chronic inflammation that may impact not only the skin but also the total physiological balance[6]. This is true even though the condition is not communicable. Its repeated nature often causes long-term physical pain and psychological stress for those who are afflicted, and its frequency across many groups suggests that psoriasis is a common dermatological issue. Topical corticosteroids, systemic medications, and phototherapy are examples of traditional treatment techniques that have shown limited success because of their poor skin penetration, short drug retention, systemic adverse

effects, and low patient compliance[7]. The clinical and histological characteristics of human psoriasis are replicated in a number of animal models, especially murine models, which researchers have used to better understand the processes underlying this condition and investigate novel therapeutic approaches. By highlighting the immunological dysregulation and epidermal changes that are hallmarks of the illness, these pre-clinical investigations have been crucial in offering useful platforms for assessing new treatment approaches. Through improved drug distribution, prolonged therapeutic activity, and improved results in animal-based models of psoriasis, nanotechnology has emerged as a promising way to address the drawbacks of traditional therapies.

1.2. Objective of the review

- To provide a comprehensive overview of psoriasis as a chronic inflammatory skin disorder, highlighting its pathophysiology, limitations of conventional therapies, and the need for advanced drug delivery systems.
- To critically review various nanotechnology-based drug delivery systems (such as liposomes, solid lipid nanoparticles, nanostructured lipid carriers, polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles) explored in pre-clinical animal models for psoriasis management.
- To analyze and synthesize findings from animal-based studies evaluating the therapeutic efficacy, safety, and pharmacological advantages of nanocarriers over conventional treatments.
- To identify the strengths, challenges, and gaps in current pre-clinical research, and to suggest future directions for the development of nanotechnology-driven therapeutic strategies for psoriasis and related skin disorders.

1.3. Importance of the Topic

Investigating nanotechnology for the treatment of psoriasis is crucial because it overcomes the significant drawbacks of traditional treatments and opens the door to more effective and specialized medication delivery methods[8]. Because of its systemic adverse effects, limited patient compliance, and poor medication penetration through the skin, psoriasis, a chronic inflammatory skin illness, continues to provide treatment problems. Accordingly, formulations based on nanotechnology, including liposomes, solid lipid nanoparticles, nanostructured lipid carriers, polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles, mark a substantial breakthrough in pre-clinical dermatological trials. When compared to conventional formulations, animal-based research has repeatedly shown that these nanocarrier systems improve therapeutic effectiveness, lengthen retention, enable controlled release, and increase drug solubility. This issue is significant not only because it evaluates these developments but also because it critically examines their advantages and disadvantages, which may inform future research aimed at creating safer, more efficient, and more patient-friendly therapies. Through the identification of pre-clinical evidence gaps and the presentation of novel approaches, this review highlights the potential of nanotechnology to revolutionize the treatment of psoriasis and expand its use to other chronic skin conditions, making it an essential area of research in dermatological therapeutics.

2. OVERVIEW OF NANOTECHNOLOGY IN DERMATOLOGY

In biomedical sciences, nanotechnology has become a ground-breaking subject that provides creative answers to long-standing dermatological problems, especially when it comes to the management of inflammatory and chronic skin conditions[9]. Through the use of nanoscale materials and carriers, which are generally between 1 and 100 nanometers, nanotechnology makes it possible to deliver drugs precisely, increase the solubility of agents that are poorly soluble in water, regulate release, and stabilize therapeutic substances. Nanocarriers such liposomes, nanoemulsions, solid lipid nanoparticles, nanostructured lipid carriers, polymeric nanoparticles, dendrimers, and metallic nanoparticles have all

been extensively studied in pre-clinical research for dermatological applications[10]. Because to their nanoscale size, they can more easily pass through the skin barrier and deliver medication to deeper levels of the epidermis and dermis. This is especially helpful for conditions like psoriasis, eczema, and skin cancer. In addition to improving therapeutic results, research using animal models has shown that these systems lessen the toxicity and systemic adverse effects of traditional medicines. Because it has the ability to change current therapy approaches into more efficient, secure, and patient-friendly ones, nanotechnology is becoming more widely acknowledged as a promising dermatological frontier.

2.1. Summary of Key Research Studies

Studies using pre-clinical animal models have shed important light on the potential of drug delivery systems based on nanotechnology for the treatment of psoriasis and other skin conditions. In comparison to traditional therapies, these studies demonstrate how various nanocarriers increase medication penetration, boost therapeutic effectiveness, and lessen adverse effects[11].

1. Compared to traditional topical treatments, liposome-based formulations dramatically increase the epidermal penetration of anti-psoriatic medications, decrease the production of inflammatory cytokines, and speed up lesion healing, according to pre-clinical research conducted in murine models.
2. Studies on psoriatic animal models have demonstrated that solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs) provide prolonged drug retention in psoriatic plaques, improved skin hydration, and sustained drug release, all of which minimize systemic absorption and successfully lessen epidermal hyperplasia and scaling.
3. Polymeric nanoparticles and nanoemulsions have been shown in animal-based studies to improve the solubility of poorly water-soluble medications, improve dermal penetration, prolong the duration of drug action, and show potent anti-inflammatory effects. These findings ultimately lead to better therapeutic outcomes and disease management in lesions that resemble psoriasis.

2.2. Methodologies and Findings

Pre-clinical research on the use of nanotechnology in dermatology has mostly used animal models, especially rodent and murine models, to simulate inflammatory skin disorders such as psoriasis[12]. Numerous experimental techniques are used in these studies, such as topical application of formulations based on nanocarriers, measurement of drug penetration and retention in various skin layers, and evaluation of therapeutic outcomes through immunological, biochemical, and histopathological analyses. The results of these investigations consistently show that drug stability, solubility, and controlled release are much improved by nanocarriers, including liposomes, solid lipid nanoparticles, nanostructured lipid carriers, polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles. In addition, they have potent anti-inflammatory and antioxidant properties, enhance skin penetration, lower the production of inflammatory cytokines, and lessen epidermal hyperplasia as compared to traditional formulations[13]. All together, these approaches and findings demonstrate how nanotechnology may be able to get around the drawbacks of conventional treatments and provide safer, more effective, and more tailored therapy choices in pre-clinical models of psoriasis and other skin conditions.

2.3. Strengths and Weaknesses

In the pre-clinical treatment of skin conditions like psoriasis, drug delivery systems based on nanotechnology provide a number of benefits, including as better skin penetration, targeted distribution, increased bioavailability, controlled drug release, and less systemic toxicity. Studies conducted on animals have shown better anti-inflammatory, antioxidant, and lesion-healing properties than traditional therapies[14]. To guarantee consistent therapeutic results and future translational feasibility, these systems

must be addressed despite their drawbacks, which include complicated and expensive production, a lack of long-term safety data, possible immunogenicity, variability in drug loading and release, and regulatory issues[15].

- **Strengths:** Drug delivery methods based on nanotechnology have a number of important benefits for the pre-clinical treatment of skin conditions like psoriasis. The focused distribution of therapeutic medicines directly to afflicted regions is made possible by their enormous surface area and nanoscale size, which promote penetration through the epidermal barrier. By enhancing medication bioavailability, enabling regulated and prolonged release, and decreasing systemic absorption, this tailored action minimizes the toxicity and adverse effects linked to traditional therapies. Liposomes, solid lipid nanoparticles, nanostructured lipid carriers, polymeric nanoparticles, dendrimers, and metallic nanoparticles are examples of nanocarriers that improve the solubility and stability of medications that are not very soluble in water. Studies using animal models have regularly shown that they have better anti-inflammatory, antioxidant, and lesion-healing properties than conventional formulations, underscoring their significant therapeutic promise in dermatology[16].
- **Weaknesses:** Notwithstanding these benefits, there are still a number of restrictions and difficulties in the creation of dermatological therapies based on nanotechnology. Widespread use is limited by the complexity and expense of nanocarrier fabrication and large-scale manufacture. Pre-clinical models still have little long-term safety and toxicity data, especially for repeated or chronic exposure. The consistency of treatment results may also be impacted by problems including stability in physiological settings, possible immunogenic reactions, and variations in drug loading and release patterns. The road to clinical translation is made more difficult by regulatory obstacles and the lack of established procedures for formulation, characterisation, and pre-clinical assessment. To maximize the effectiveness, safety, and viability of nanotechnology-driven treatments for psoriasis and other skin conditions, these flaws must be addressed.

3. NANOCARRIER SYSTEMS IN PSORIASIS TREATMENT

Effective treatment of psoriasis, a chronic inflammatory skin condition marked by erythematous plaques, immune cell infiltration, and hyperproliferation of keratinocytes, is very difficult[17]. The need for more sophisticated treatment approaches is highlighted by the fact that conventional medications often have systemic adverse effects, low drug bioavailability, poor skin penetration, and short duration of action. A potential approach in this regard is the use of nanocarrier technologies, which minimize systemic exposure while providing targeted medicine delivery straight to the afflicted skin layers. These nanoscale carriers have been thoroughly studied in pre-clinical animal models of psoriasis[18]. These include liposomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles. By improving drug solubility and stability, facilitating regulated and sustained release, and enhancing therapeutic effectiveness, they help to overcome a number of traditional therapy restrictions. The many kinds of nanocarrier systems investigated for the treatment of psoriasis are thoroughly reviewed in this part, with an emphasis on their benefits, modes of action, and results from studies involving animals[19].

3.1. Liposomes and Niosomes

Niosomes are structurally similar vesicles made from non-ionic surfactants, whereas liposomes are spherical vesicles made of phospholipid bilayers that may encapsulate therapy materials that are both hydrophilic and lipophilic. Because of their high levels of biocompatibility and biodegradability, both nanocarrier systems considerably lower the possibility of toxicity in pre-clinical animal studies[20]. The therapeutic efficacy of encapsulated pharmaceuticals is improved by their unique vesicular shape, which also protects them from enzymatic breakdown and increases their stability. Liposomal and niosome-

based formulations significantly improve medication penetration through the stratum corneum, reaching deeper levels of the epidermis and dermis, according to pre-clinical research conducted on murine models of psoriasis[21]. By facilitating a more localized therapeutic impact, this tailored distribution reduces the likelihood of systemic absorption and adverse consequences. Comparing liposomal delivery of anti-inflammatory agents to traditional topical formulations, animal-based studies have demonstrated that the former can effectively reduce the expression of pro-inflammatory cytokines, decrease immune cell infiltration, and mitigate epidermal hyperplasia, leading to improved lesion healing and symptomatic relief. These results demonstrate how liposomes and niosomes may be used as sophisticated nanocarrier systems to enhance the results of pre-clinical therapy for psoriasis and other skin conditions[22].

3.2. Solid Lipid Nanoparticles (SLNs) and Nanostructured Lipid Carriers (NLCs)

In contrast to solid lipid nanoparticles (SLNs), which are made solely of solid lipids, nanostructured lipid carriers (NLCs) are made up of a precisely crafted mixture of liquid and solid lipids that create a stable nanoscale matrix that may include therapeutic molecules[23]. Because of their capacity to improve drug stability, shield active ingredients from enzymatic and chemical degradation, and enable regulated and sustained drug release over prolonged periods of time, SLNs and NLCs both provide significant benefits in pre-clinical dermatological research. The topical use of SLNs and NLCs allows for the extended retention of therapeutic substances in the epidermis and dermis, as shown by animal model studies, especially in rats with skin diseases similar to psoriasis. In comparison to traditional ointments or creams, this prolonged presence accelerates lesion healing, lessens epidermal hyperplasia and scaling, and strengthens the local anti-inflammatory benefits[24]. Additionally, these lipid-based carriers reduce systemic absorption and related adverse effects, which makes them a viable nanotechnology-based approach for pre-clinical targeted psoriasis therapy. The combined results of these investigations highlight the potential of NLCs and SLNs as safer and more efficient substitutes for conventional topical treatments in the treatment of long-term inflammatory skin conditions.

3.3. Polymeric Nanoparticles

Encapsulated medicinal drugs may be released in a regulated and sustained manner using polymeric nanoparticles, which are nanoscale carriers made from biodegradable and biocompatible polymers like PLGA (polylactic-co-glycolic acid). Pre-clinical research on psoriasis benefits greatly from these nanoparticles since they increase drug stability, extend the duration of therapeutic impact, and lessen the need for repeated administrations. Animal studies have shown that polymeric nanoparticles may efficiently transport anti-psoriatic medications to the afflicted skin layers, leading to improved localized drug concentration and therapeutic efficiency, especially in murine models of psoriasis[25]. In comparison to traditional formulations, studies have shown that therapy with polymeric nanoparticles dramatically decreases oxidative stress indicators, inflammatory cell infiltration, and epidermal hyperplasia in psoriatic lesions. In pre-clinical psoriasis care, they are a safe and efficient choice because of their biodegradable nature, which guarantees low toxicity and quick removal from the body. The aforementioned results underscore the promise of polymeric nanoparticles as sustained-release vehicles that may surmount the constraints of conventional treatments, providing encouraging pathways for sophisticated dermatological interventions in animal models.

3.4. Nanoemulsions and Micelles

Oil-in-water or water-in-oil systems may be dispersed at the nanoscale in nanoemulsions, and hydrophobic pharmaceuticals can be encapsulated and dissolved in micelles, which are self-assembling amphiphilic structures. Pre-clinical dermatological research has focused a lot of interest on both nanocarrier systems because of their capacity to improve the solubility, stability, and skin penetration of medicinal medicines. Studies on animals, especially in rodent models of psoriasis, have shown that

drug delivery via nanoemulsions and micelles allows active ingredients to penetrate deeper into the epidermis and dermis, resulting in more effective localized therapy[26]. Comparing these systems to traditional creams or ointments, it has been shown that they improve anti-inflammatory activity, lower oxidative stress, and hasten the healing of psoriatic disorders. Additionally, their amphiphilic character and tiny droplet size enhance medication absorption and retention within the epidermal layers, resulting in less systemic exposure and longer therapeutic benefits. All of these results highlight how prospective nanocarrier techniques for enhancing the safety and effectiveness of psoriasis therapies in pre-clinical animals may be achieved using nanoemulsions and micelles.

3.5. Dendrimers and Metallic Nanoparticles

Multiple surface functional groups on dendrimers, which are extremely branched, tree-like polymers, enable accurate encapsulation and targeted delivery of medicinal medicines. Because of their distinct physicochemical characteristics, such as inherent anti-inflammatory and antioxidant effects, metallic nanoparticles—like those of gold and silver—are attractive options for dermatological applications[27]. Dendrimer-based drug delivery devices may specifically target inflammatory psoriatic tissues, increasing drug stability, extending therapeutic activity, and boosting overall therapy success, according to pre-clinical animal research. In mouse models, metallic nanoparticles have also shown potent anti-inflammatory properties, decreased oxidative stress, and sped up the healing of psoriatic lesions. In addition to improving targeted drug delivery, these cutting-edge nanocarrier techniques provide further therapeutic advantages that traditional carriers are unable to give[28]. All things considered, results from studies conducted on animals indicate that dendrimers and metallic nanoparticles have a great deal of promise as cutting-edge psoriasis therapy options, providing both enhanced effectiveness and unique modes of action in pre-clinical settings.

4. MECHANISMS OF NANOCARRIER-MEDIATED DRUG DELIVERY IN PSORIASIS

In pre-clinical animal models intended to mimic human psoriasis-like conditions, nanocarrier-mediated drug delivery has shown promise as a means of overcoming the drawbacks of traditional psoriasis treatments[29]. Systemic toxicity, quick medication clearance, poor bioavailability, and restricted skin penetration are common problems with traditional topical and systemic therapies. By improving the delivery and effectiveness of therapeutic agents in animal-based studies, nanocarrier systems—such as liposomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles—offer creative solutions[30].

Targeted delivery and improved skin penetration are two important ways that nanocarriers increase therapeutic results. These nanoscale carriers are able to pass through the stratum corneum more efficiently than traditional formulations in psoriasis models in mice and rodents. For instance, liposomes, SLNs, and nanoemulsions build up in the dermis and epidermis and carry anti-inflammatory medications straight to psoriatic tissues that are inflamed. Improved treatment results in animal trials are the result of this tailored localization, which raises the medication concentration at the lesion site while reducing systemic absorption and any adverse effects[31].

Controlled and prolonged medication release is another crucial technique. A lot of nanocarriers are made to release encapsulated medications gradually over long periods of time. According to research on animals, polymeric nanoparticles, SLNs, and NLCs prolong the duration of therapeutic drug levels in psoriatic lesions, minimizing the need for repeated treatments and guaranteeing steady pharmacological activity[32]. In skin disorders similar to psoriasis, this prolonged release also aids in preserving anti-inflammatory properties and hastening lesion healing.

Lastly, oxidative and inflammatory pathways are modulated by nanocarrier systems. Pro-inflammatory cytokine production, oxidative stress indicators, and epidermal hyperplasia have all been shown to

decrease in pre-clinical animals when anti-inflammatory, antioxidant, or immunomodulatory drugs are delivered by nanocarriers. For example, in murine psoriasis models, metallic nanoparticles, dendrimers, and liposomal formulations have shown a significant increase in lesion clearance and decreased immune cell infiltration. These results suggest that in animal trials, nanocarriers actively affect the underlying pathophysiology of psoriatic lesions in addition to improving medication delivery.

The foundation for the future translation of nanotechnology-based therapies for psoriasis and related skin disorders is laid by comprehending these mechanisms in pre-clinical models, which offer vital insights into how nanocarrier-mediated systems enhance therapeutic efficacy, optimize local drug concentrations, and minimize side effects.

Table 1: Summary of Pre-Clinical Studies on Nanocarrier-Based Therapeutic Strategies for Psoriasis

Author(s) & Year	**Nanocarrier Type / Focus**	**Animal-Based Study / Model**	**Key Findings**	**Significance / Contribution**
Biswasroy et al., 2021[33]	Topical nanocarriers (general overview)	Murine psoriasis models	Nanocarrier formulations enhanced skin penetration, reduced inflammation, and improved lesion healing compared to conventional therapies	Provided a comprehensive overview of recent advancements in nanocarrier systems for pre-clinical psoriasis management
Ramanunny et al., 2021[34]	Topical nanocarriers for psoriasis	Rodent models	Highlighted the role of nanocarriers in improving drug solubility, targeted delivery, and controlled release, leading to better anti-psoriatic effects	Emphasized the necessity of nanocarrier-based delivery for effective pre-clinical treatment strategies
Zhang et al., 2022[35]	Advanced topical nanocarrier systems	Animal models (mice/rats)	Demonstrated enhanced therapeutic efficacy, reduced epidermal hyperplasia, and prolonged drug retention in psoriatic lesions using liposomes, SLNs, and NLCs	Offered insights into the design and optimization of next-generation nanocarrier systems for pre-clinical evaluation
Dadwal et al., 2018[36]	Novel topical nanocarriers	Murine models	Reviewed various nanocarriers including liposomes, polymeric nanoparticles, dendrimers; reported improved drug bioavailability, penetration, and anti-inflammatory effects	Provided an early comprehensive review of nanocarrier strategies for psoriasis management in animal studies

Husain et al., 2025[37]	Lipid nanocarriers (SLNs, NLCs, liposomes)	Pre-clinical animal studies	Lipid-based carriers improved targeted delivery, reduced oxidative stress, and enhanced lesion healing in psoriasis-like skin models	Highlighted the therapeutic potential of lipid nanocarriers and their advantages over conventional topical treatments in animal models

5. DISCUSSION

The review's results are critically examined and interpreted in the discussion section, which also highlights the implications of nanotechnology-based therapies for psoriasis pre-clinical care. In contrast to traditional treatments, this section examines how different nanocarrier systems—such as liposomes, niosomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles—improve drug delivery, therapeutic efficacy, and safety by synthesizing data from animal-based studies[38]. The conversation also examines the molecular insights provided by these investigations, including enhanced skin penetration, prolonged drug release, and oxidative and inflammatory pathway regulation, all of which enhance pre-clinical results. Furthermore, this part assesses the importance of these results in light of developing dermatological treatments, points out the shortcomings of the present research, and suggests important gaps that need further study. The talk offers a thorough grasp of the function of nanocarriers in enhancing the results of psoriasis therapy by bridging the gap between possible translational tactics and experimental data from animal models via an integrated viewpoint.

5.1. Interpretation and Analysis of Findings

The reviewed literature shows that in pre-clinical animal models of psoriasis, drug delivery methods based on nanocarriers greatly improve treatment results. Superior medication penetration and targeted delivery to inflammatory epidermal and dermal layers were shown by liposomes and niosomes, which resulted in decreased cytokine production, decreased immune cell infiltration, and enhanced lesion healing. Comparably, regulated and sustained drug release was offered by lipid-based carriers like SLNs and NLCs, guaranteeing extended local therapeutic concentrations and reducing systemic exposure[39]. In models of murine psoriasis, polymeric nanoparticles and nanoemulsions improved the solubility and retention of medications that were not very water soluble, increasing their bioavailability and anti-inflammatory properties. Lesion healing was further accelerated by dendrimers and metallic nanoparticles, which not only made targeted administration easier but also demonstrated inherent anti-inflammatory and antioxidant properties. Together, our results show that nanocarrier systems provide better pre-clinical treatment outcomes by successfully overcoming the drawbacks of traditional treatments, such as inadequate skin penetration, brief drug retention, and systemic toxicity.

5.2. Implications and Significance

The results of research conducted on animals highlight how nanotechnology has the potential to transform the treatment of psoriasis and more general dermatological treatments. Nanocarriers improve therapeutic effectiveness while lowering systemic adverse effects by facilitating targeted medication delivery and controlled release, which is especially important in chronic inflammatory disorders like psoriasis[40]. Given their capacity to alter oxidative stress and inflammatory pathways, nanocarriers may provide two advantages: symptomatic alleviation and underlying disease change. Additionally, a solid basis for creating topical medicines that are safer, more effective, and more patient-friendly is provided by the successful use of these systems in pre-clinical models. This might lessen the need for systemic

medications, which have greater toxicity concerns. These ramifications demonstrate how nanotechnology may be used to improve dermatological treatment paradigms.

5.3. Gaps and Future Research Directions

Even with encouraging preclinical findings, there are still a number of research gaps. Nanocarriers' long-term safety, immunogenicity, and consequences of chronic exposure are still not well understood, and the majority of research is restricted to short-term assessments in rodent models. Finding the safest and most efficient method for treating psoriasis is challenging due to the lack of comparative research comparing various nanocarriers under controlled circumstances. Additional difficulties in converting pre-clinical results into clinical applications include scale-up, repeatability, and regulatory compliance. In order to fill these gaps, future research should concentrate on long-term studies, combinatorial or multifunctional nanocarrier systems, dosage form optimization for increased effectiveness and retention, and the creation of standardized pre-clinical assessment methodologies. Further investigation into other animal models that replicate distinct facets of the pathophysiology of psoriasis may confirm the translational potential of these cutting-edge nanocarrier systems.

6. CONCLUSION

The study concludes by highlighting the substantial potential of drug delivery systems based on nanotechnology in the treatment of psoriasis and other chronic inflammatory skin conditions based on the pre-clinical data given. Liposomes, niosomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles are among the nanocarriers that have been shown in animal-based studies to improve therapeutic outcomes by improving skin penetration, extending drug retention, enabling controlled and sustained release, and lowering systemic toxicity when compared to conventional therapies. In rodent and mouse models, these technologies not only enable targeted delivery to inflammatory psoriatic tissues but also alter underlying oxidative and inflammatory pathways, which reduces cytokine expression, speeds up lesion repair, and lessens epidermal hyperplasia. The review notes that despite these encouraging findings, there are still issues that need to be resolved to guarantee repeatable and clinically applicable results. These issues include the intricacy of nanocarrier synthesis, possible immunogenicity, fluctuating drug loading, and a lack of long-term safety monitoring. All things considered, the results demonstrate that nanotechnology provides a revolutionary method for pre-clinical psoriasis treatment, offering safer, more efficient, and patient-focused treatment approaches. They also establish a solid basis for further research that aims to close the gap between animal simulations and clinical applications in human dermatology.

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