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A REVIEW ON INVESTIGATION OF TOPICAL NANO FORMULATION OF APRIMILAST FOR PSORISIS THERAPY

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ABSTRACT

Psoriasis (PSO) is a chronic autoimmune skin condition characterized by the rapid and excessive growth of skin cells, which leads to the formation of thick, red, and scaly patches on the surface of the skin. These patches can be itchy and painful, and they may cause discomfort for patients affected by this condition. Therapies for psoriasis aim to alleviate symptoms, reduce inflammation, and slow down the excessive skin cell growth. Conventional topical treatment options are non-specific, have low efficacy and are associated with adverse effects, which is why researchers are investigating different delivery mechanisms. A novel approach to drug delivery using nanoparticles (NPs) shows promise in reducing toxicity and improving therapeutic efficacy. The unique properties of NPs, such as their small size and large surface area, make them attractive for targeted drug delivery, enhanced drug stability, and controlled release. In the context of PSO, NPs can be designed to deliver active ingredients with anti-inflammatory effect, immunosuppressants, or other therapeutic compounds directly to affected skin areas. These novel formulations offer improved access to the epidermis and facilitate better absorption, thus enhancing the therapeutic efficacy of conventional anti-psoriatic drugs. NPs increase the surface-to-volume ratio, resulting in enhanced penetration through the skin, including intracellular, intercellular, and trans-appendage routes. The present review aims to discuss the latest approaches for the topical therapy of PSO using NPs. Apremilast is a selective phosphodiesterase 4 inhibitor administered orally in the treatment of moderate-to-severe plaque psoriasis and active psoriatic arthritis. It is classified as class IV drug as per BCS classification so it indicates low solubility and lower permeability through the skin. Therefore, the objective of the research is to improve permeability of Apremilast through the skin and improve solubility by using oil and surfactant by formulating Nanoemulsion.

Keywords: Psorisis, Nanoparticles, Immunosuppresants.

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INTRODUCTION

Psoriasis is considered a chronic, inflammatory autoimmune disorder of the skin affecting 2-5% of the world's population and is characterized by inflamed reddish erythematous plaques [1]. There are several therapeutic drugs available for the treatment of psoriasis. Despite this, none of them is entirely safe and effective in treating the condition without jeopardizing patient compliance. Traditional topical therapies have significant drawbacks, including inadequate drug penetration, higher dose frequency, severe toxicity, and poor patient compliance [2]. Phototherapy and systemic drugs employed in psoriasis therapy have many side effects such as hepatotoxicity, nephrotoxicity, skin cancer and high blood pressure. These complications limit the usage of currently available psoriasis treatments [3]. Thus, there is a need to look out for alternative moiety or advanced delivery systems which overcome the limitations of the current therapeutic regimens for psoriasis. Apremilast (APM) is a type 4 phosphodiesterase inhibitor authorized to treat psoriasis and psoriatic arthritis worldwide. It has low solubility and permeability and is hence categorized as a BCS class IV drug [4]. Currently, apremilast is marketed only as an oral tablet under the brand name Otezla® in strengths of 10, 20, and 30 mg, respectively. However, side effects such as nausea, diarrhoea, upper respiratory illness, weight loss, depression, and suicidal impulses may lead to failure to adhere to the medication and unnecessary discontinuation of therapy. Therefore, it is necessary to develop an alternative formulation of apremilast that can overcome the limitation of the oral formulation [5]. The topical application of apremilast directly to the affected skin will avoid the problems associated with oral administration, and also, dose reduction is possible since the first-pass metabolism can be bypassed. However, due to apremilast's poor aqueous solubility, permeability and modest lipophilicity, it is not easy to deliver it to across the scaly psoriasis lesions through conventional topical formulations [6,7]. The use of topical Nano formulations, especially lipid nanocarriers, can overcome the limitations mentioned above and permeate psoriatic horny layers and retain the drug in the skin layers [8]. Hence the current work attempts to prepare topical Nano formulations of apremilast to improve the permeability of the drug across the keratinized psoriatic skin lesions, prolong the drug release and achieve patient compliance.

Anatomy of the Skin

The skin is the largest organ in the human body, and it serves several essential functions: it helps protect the body from the external environment, acts as the first line of defense against the entry of chemicals and microorganisms, as well as a barrier to the loss of fluids and salts, and it aids in the regulation of body temperature. The structure and thickness of human skin vary considerably, although it is generally around 1.5 mm thick [9]. Briefly, the skin comprises three-layer: epidermis, dermis (reticular and papillary), and subcutaneous layer, also known as hypodermis. The epidermis is divided into four layers, from the deepest to the superficial layer: Stratum Basale, Stratum spinosum, Stratum granulosum, and Stratum corneum.

The deepest layer consists of dividing keratinocytes that push the cells outward. As the cells travel outward, they lose their nuclei and produce lipids in the inter cellular gaps, and by the time they reach the outermost surface, the cells are dead and form a layer of laminated and loosely connected keratinocytes. Other cells found in the Stratum Basale include melanocytes, Merkel cells, and Langerhans cells. The dermis is composed of cellular components such as fibroblasts, hair follicles, sebaceous glands, apocrine glands, eccrine glands, blood arteries, and acellular components like fibers and ground substances. There are two lymphatic plexuses around the blood vessels of the dermis' top and lower layers, namely superficial lymphatic plexus and big lymphatic vessels. The Subcutaneous tissue comprises connective tissue, fats, blood vessels, and nerves.

Overall, the epidermis protects the underlying layers by acting as a barrier to pathogens. The dermis supports and nourishes the epidermis, while the subcutaneous layer stores fat, regulates body temperature, and serves as a shock absorber [10,11]

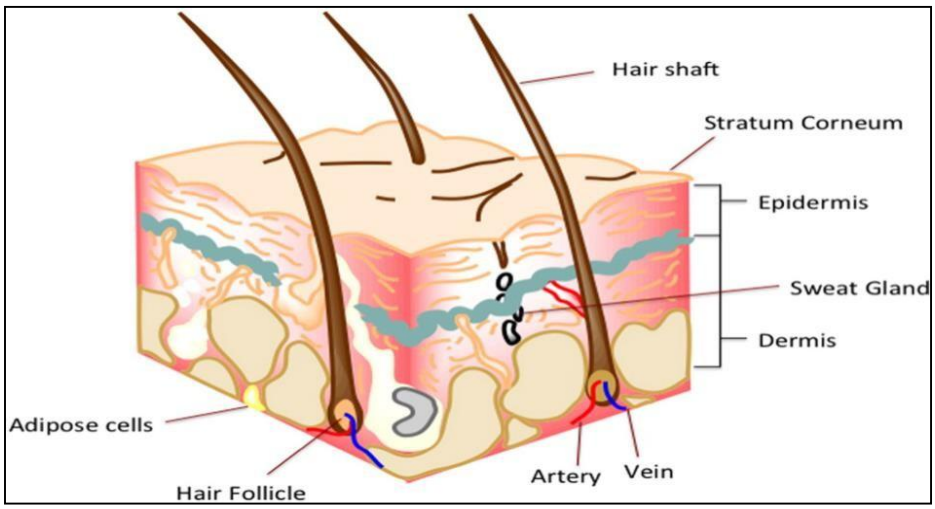

Figure 1. Structure of the skin [12]

Overview of Psoriasis

Psoriasis is a chronic immune-mediated inflammatory disorder of the skin that affects 2-5% of the global population. It is characterized by highly inflamed red erythematous plaques supported by silvery scales [12].

In contrast to normal skin, Psoriatic skin comprises scaly patches due to the high epidermal proliferation, partial cornification, and the retention of nuclei in stratum corneum cells. Hyperplasia of the epidermis with considerable keratinocyte differentiation, Enhanced angiogenesis, and the presence of inflammatory infiltrates are histopathological features seen in psoriatic skin [13,14].

Although the specific causes of the disease remain unknown, it might be associated with many factors such as asedentary life style, family history, cigarette use, alcohol intake, stress and metabolic disorders [15]. Patients with psoriasis face physical stigmatization, which exacerbates the psychological issues in their social, occupational, and emotional lives. Furthermore, these

manifestations may lead to depression and suicidal tendencies.

Psoriasis can affect any body area, including the knees, scalp, groin, elbows, palms,or the entire body. Based on the scales visible on the skin, psoriasis can be divided into different types.

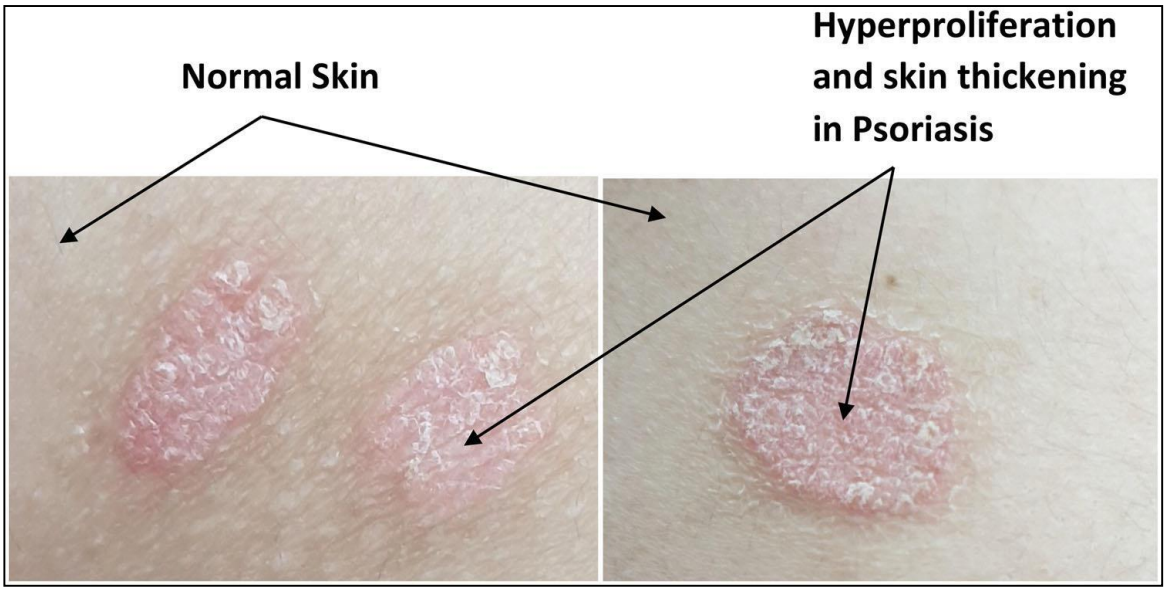

Figure 2. Appearance of psoriatic skin when compared to normal skin [8]

Plaque Psoriasis

The most common psoriasis, plaque psoriasis or psoriasis vulgaris, is characterized by reddish lesions partially covered with dry silvery-white scales. The affected body areas are the elbows, knees, scalp, and lower back. Infections, skin abrasion, drugs, sunburn, strain, smoking, and drinking are common causes of this type of psoriasis [16].

Guttate psoriasis

Guttate psoriasis is distinguished by tiny red dots that cover a large skin area. The red patches here are thinner than the plaques in plaque soriasis. Guttate psoriasis starts in childhood, but it can progress to plaque psoriasis if left untreated for too long [17].

Pustular psoriasis

The presence of pustules on red, irritated skin is characteristic of pustular psoriasis. The pustules are not contagious but can cause fever, fast heart rate, lack of appetite, chills, and flu-like symptoms. It occurs in less than 5% of populations having psoriasis.

Scalp psoriasis

Scalp psoriasis is another prevalent type of psoriasis that causes itching and discomfort in individuals. This type of psoriasis impacts the patients' quality of life in terms of self-esteem and social presence. About 80% of patients affected by psoriasis will have involvement of scalp. Psoriasis of the scalp is marked by red, thicker plaques with a silver-white scale that might be restricted to the hairline or expand over the forehead, ears, and posterior neck [18].

Psoriatic arthritis

Psoriatic arthritis is an inflammatory musculoskeletal disease related to cutaneous psoriasis affecting

men and women between 40 and 50. It is characterized by painful joints along with other salient features of psoriasis. Peripheral and axial joints, entheses, skin, and nails are among the organ systems that are impacted by the disease [19].

Nail Psoriasis

Psoriasis of the nails is a painful and debilitating disorder that can impair the function of the fingers and toes and limit everyday activities. Half of the skin psoriatic and 70% of psoriatic arthritic patients develop psoriasis in the nail apparatus. Pitting, dystrophy, onycholysis, leukonychia, splinter haemorrhages involving the distal part of the nail plate, and subungual hyperkeratosis are all typical features of nail psoriasis [20,21].

Pathophysiology of Psoriasis

The fundamental pathogenic reasons for psoriasis are outlined into three key points. Firstly, the hyper proliferation of the keratinocytes is the primary underlying cause for psoriasis. Keratinocytes normally mature and shed off every 35-40 days, but with psoriasis, keratinocytes mature and migrate to the epidermis within a week, and instead of shedding off, they accumulate on the epidermis, resulting in non-evident lesions [22,23].

The second line of pathogenesis is angiogenesis, which causes the expansion of intercellular spaces and the dilatation of blood vessels, leading to the production of pro-inflammatory cytokines, the third line of pathogenesis. Interleukins, Endothelin, IFN-!, TNF-α, and VEGF (vascular endothelial growth factor) are examples of pro-inflammatory mediators. They are considered to activate T-cells, most likely in response to an unknown antigen, resulting in an immune response memorized by memory cells, resulting in a cross-reaction when exposed to an antigen [24].

Molecular events that occur during the pathogenesis of psoriasis are as follows. Initially, unidentified autoantigen binds to the major histocompatibility complex (MHC) of skin's antigen-presenting cells (APCs). Following autoantigen recognition, APCs such as Langerhans cells in the skin migrate to regional lymph nodes, where they reversibly bond with naïve Tlymphocytes due to the interaction of surface molecules present on both cells [24]. The MHC of APCs then presents the antigen to a T-lymphocyte receptor, which initiates T-cell activation. A cell-cell interaction known as co-stimulation is the next signal for T-lymphocyte activation [24].

Activated T lymphocytes undergo clonal selection after co-stimulation, resulting in the development of antigen-recognizing T lymphocytes and memory T cells. The activated T lymphocytes migrate to inflamed skin after entering the vascular system. When these activated T cells arrive at the inflamed site, they release T- helper type-1 (TH1) cytokines such as tumour necrosis factor-alpha (TNFA), interleukin-1 (IL-1) and gamma interferon (INFG)[25,26].

These cytokines have an essential role in the phenotypic manifestation of psoriasis, including inflammation and epidermal hyper-proliferation. Besides that, they also influence the release of

cytokines from other cells responsible for lesions seen in psoriatic skin.

Current therapeutic regimens for psoriasis and their limitations

In general, four basic approaches are involved in psoriasis according to the disease's type and severity, including topical therapy, Systemic therapy, Phototherapy, and biological therapy.

Topical therapy

Topical therapy remains the first-line treatment for psoriasis, with around 80% of the psoriasis patients relying on it. The topical formulations used in the treatment include creams, ointments, gels and shampoo. Topical therapy plays a vital role in reducing keratinocyte hyperproliferation and inflammation in the skin [27,28].

A wide range of topical agents is used for psoriasis, which is discussed below.

a) Coal tar

Coaltar has been used to treat psoriasis since ancient times, particularly for scalp psoriasis, although its use has waned in recent decades compared to other topical agents. The cosmetically unpleasant nature of coaltar, along with its pungent smell and staining nature, have limited its utility. Due to the carcinogenic concerns, coal tar is banned in Canada and the European Union [18,29].

b) Dithranol

Dithranol is one of the oldest therapeutic regimes for plaque psoriasis. It is also used to treat scalp plaques and in psoriasis Vulgaris. Dithranol induces apoptosis of the keratinocytes and inhibiting its proliferation. Despite its benefits, dithranolis associated with limited solubility and stability, toxicity, discolouration, and skin irritation; therefore, it may not be robust enough for skin penetration [28].

c) Retinoids

Vitamin A compounds or their derivatives are known as retinoids. Topicalretinoids are used for the treatment of plaque-type psoriasis. Tazarotene cream and gel at a concentration of 0.1% or 0.05% is the only FDA-approved topical retinoid for psoriasis [28]. Tazoretine act by binding to retinoic acid receptors and retinoid-X- receptors present on the cell lines of keratinocytes and alter the gene expression resulting in inhibition of keratinocyte proliferation. However, topical application of keratinocytes can cause localized toxicity and skin irritation [30,31].

d) Calcineurin inhibitors

Calcineurin inhibitors are used in the treatment of patients having mild to moderate psoriasis. They act by binding to an intracellular protein called immunophilin, following which these protein complexes bind to an intracellular molecule called calcineurin resulting in the inactivation of T cells and prevention of psoriasis. Tacrolimus and pimecrolimus are the two most often utilized calcineurin inhibitors. They are available as 0.03 % tacrolimus ointment and 1 % pimecrolimus cream in the market [28,32].

e) Vitamin D analogues

Topical vitaminD3 analogues to the psoriatic remain the corner stone of therapy in mild to moderate

psoriasis. They bind to vitamin D receptors and regulate the genes involved in cell proliferation, differentiation, and inflammation, thus modulating the immune response. The four main calcineurin inhibitors currently used for psoriasis are Calcipotriol, maxacalcitol, tacalcitol, and calcitriol [34].

Local irritation is one of the prominent side effects associated with calcineurin inhibitors. Some instances of burning sensations on the applied lesions and mild dermatitis have also been reported [35].

Corticosteroids

Corticosteroids remain the most widely used topical therapy for psoriasis. These drugs exert their anti-inflammatory effect by decreasing the expression of inflammatory mediators such as leukotrienes and prostaglandins and inhibiting cytokines production [35].

The topical corticosteroids employed in treating psoriasis include clobetasol, betamethasone, mometasone, and halobetasol. The effect of corticosteroids is superior compared to other agents used in psoriases- such as calcineurin inhibitors, retinoids and Vitamin D analogues. However, long term use of corticosteroids leads to side effects such as perioral dermatitis, striae, hypertrichosis, and infections [36].

Phototherapy

Since the 1920s, photo-based therapy has been used to treat psoriasis, and it is now a standard treatment for moderate to severe psoriasis. Phototherapy uses ultraviolet radiation for the treatment of psoriasis. Four main types of phototherapies are employed in psoriasis include Ultraviolet A plus a psoralen (PUVA), ultraviolet B (UVB), excimer/laser and ultraviolet A[37]. Phototherapy works by bringing about alteration in cytokine expression, promoting cutaneous immunosuppression, and triggering lymphocyte apoptosis [38].

Despite the good therapeutic effect, phototherapy still continues to be unpopular among psoriasis patients due to the possibility of carcinogenicity. Moreover, the therapy is not suitable for patients suffering from photosensitive disorders.

Systemic Therapy

Systemic therapy is typically utilized in moderate to severe instances of psoriasis, especially when topical treatment and phototherapy have failed to improve the condition. The drugs employed in systematic therapy circulate throughout the body, and patients undergoing systemic therapy are advised to take liver function tests, and blood tests since most of the drugs used here are toxic [39]. There are two most frequently used oral drugs for systemic treatment in psoriasis they are

a) Methotrexate

Methotrexate is an oral drug that is used for all kinds of psoriasis. It induces apoptosis of the proliferating keratinocytes and thus normalizes the psoriatic condition [40]. However, its continuous

use leads to hepatotoxicity, Pulmonary toxicity, myelosuppression, immunosuppression, and increased risk of cardiovascular disease events [41].

b) Cyclosporine

Cyclosporine has been one of the most successful psoriasis treatments till date. It is a calceurin inhibitor and works by inhibiting the activation of an important cytoplasmic enzyme i.e calceneurin phosphatase responsible for the activation T cells. When cyclosporine is used to for the long-term treatment of psoriasis, three major risks arise i.e. hypertension, kidney damage.

Biological therapies

According to the American Academy of Dermatology (AAD), biologic drugs are definedas"engineeredmonoclonalantibodiesandfusionproteinsthatexerttheir therapeutic activities by inhibiting specific cytokines or cytokine receptors crucial to psoriatic inflammation," according to the American Academy of Dermatology (AAD) and the National Psoriasis Foundation [45]. Biologics are larger molecules and have more specificity compared to drugs used fort opical and system icapplication. Biologics used for psoriasis therapy comprises Cytokines, RNA, monoclonal antibodies, kinase inhibitors, fusion proteins, and antisense oligonucleotide [46,47]. There are now 11 different FDA-approved biologic agents for adult psoriasis therapy, divided into cytokine groups (TNF, IL-12, IL-23, IL-17A) [48]. Biologics are primarily developed through genetically modifying livecells or specific cells. However, these methods are complex, time-consuming, costly and require unique technologies involving bioengineering and biotechnology for their production. Moreover, biological treatments are costly or require high investment [46].

Current treatment regimens employed in the treatment of psoriasis have their limitations in terms of efficacy and safety. None of the available treatments can provide the desired bioavailability and targeting effect. Therefore, there is a need to look out for an ideal drug and delivery system to manage psoriasis.

Apremilast is a selective phosphodiesterase inhibitor (PDE4) approved by the USFDA in 2014 to treat moderate to severe psoriasis. Since apremilast does not interfere with immune suppression, unlike other antipsoriatic drugs,it is expected that apremilast revolutionize psoriasis treatment [49].

This drug induces an intracellular accumulation of cyclic adenosine monophosphate (cAMP), which alters the signaling pathways of innate (monocytes) and adaptive (Tcells) immune cells, as well as non-immunecells (keratinocytes), resulting in reduced production of pro inflammatory cytokines such as tumour necrosis factor (TNF)-α, Interferon (IFN)-γ and interleukin (IL)-23.

Celgene Corporation presently manufactures and markets an oral Tablet formulation of apremilast under the trade name Otezla® in three strengths of 10, 20, and 30 mg. It is the only formulation of apremilast existing in the market [50].

However, when administered orally, apremilast causes various side effects such as headache, nausea,

diarrhoea, upper respiratory tract infection, and nasopharyngitis. Therefore, there is a need to explore an alternative route of administration to overcome the constraints of the oral formulation [51–53].

Recent research has found elevated expression of mRNA and protein levels of PDE4 and its isoform in the dermis of psoriasis patients. In such as scenario, the delivery of apremilast via the topical route will be ideal. It is expected that topical delivery of apremilast will reduce systemic adverse events and improve patient compliance. Moreover, topicaldeliveryenables theapplicationof thedrugdirectly to the affected area of the skin [51].

Apremilast belongs to class IV as per Biopharmaceutical Classification System (BCS), having low solubility and permeability [54]. The epidermis and dermis are rich in water; therefore, the delivery of apremilast to these layers is difficult due to its hydrophobic nature, whereas the moderate lipophilicity of apremilast (logP1.8) may create a challenge to permeate the stratum corneum. Moreover, the topical delivery of apremilast using conventional dosage forms like creams, gels, and ointment require high doses of the drug, which eads to skin irritation.

Nanotechnology-based carriers, especially lipid nanocarriers like nanoemulsions, liposomes, solid lipid nanoparticles and nanostructured lipid carriers, can overcome these problems concerning topical delivery. These nanocarriers, especially lipid nanocarriers, can directly contact the stratum corneum and permeate the horny psoriatic layers. They can also be retained in the skin layers for a prolonged period hence ideal for treating dermatological diseases such as psoriasis [54,55].

It is considering the limitations concerning the physicochemical properties of apremilast, the shortcoming of oral administration, the challenge involving conventional topical dosage forms, and the advantages of topical nanocarriers. The current investigation attempts to prepare topical nanoformulations of apremilast to treat psoriasis. It is expected that the developed nanoformulations will be able to permeate and retain the drug to deeper layers of the psoriatic skin and come out as an effective alternative to the existing apremilast formulations.

CONCLUSION

Psoriasis remains a chronic, immune-mediated skin disorder with complex pathophysiology and significant limitations in existing therapeutic regimens. Conventional topical, systemic, phototherapy, and biologic treatments are often associated with safety concerns, poor penetration, or systemic adverse effects, thereby reducing patient compliance. Apremilast, a selective PDE4 inhibitor, has shown promise in psoriasis therapy but its oral administration is restricted by adverse events, low solubility, and limited permeability as a BCS Class IV drug.

Topical nanoformulations, particularly lipid-based nanocarriers such as nanoemulsions, liposomes, and solid lipid nanoparticles, provide an advanced strategy to overcome these challenges. These systems can enhance drug solubility, improve skin permeability, prolong drug retention within psoriatic lesions, and reduce systemic toxicity by bypassing first-pass metabolism. Therefore, the

development of apremilast-loaded nanoformulations represents a rational and innovative approach for effective psoriasis management. Such systems not only offer improved therapeutic efficacy but also hold the potential to enhance patient safety, compliance, and quality of life, making them a promising alternative to conventional apremilast formulations.

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