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Eczema and the Role of Dermal Patches in its Management

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Abstract

Atopic eczema is a skin condition with dry, itchy patches and inflammatory symptoms. It occurs primarily due to allergic irritants in the environment and can develop genetically by damaging the skin barrier. This condition is particularly concerning for children aged 3 to 13. To treat atopic eczema effectively, dermal patches can be used, as they reduce the risk of side effects and provide a steady delivery of medication to the affected areas. This consistent delivery helps manage symptoms more efficiently and can be especially beneficial for children struggling with traditional treatments. Dermal patches tend to be less stressful than frequent oral medications or topical creams.

The patches should be easy to use and safe for regular applications. They offer a convenient solution for both parents and children, minimising the risk of medication accumulation in young, sensitive bodies. These patches deliver medication directly to the affected areas, providing relief over time. Additionally, they are often designed to be breathable and hypoallergenic to prevent further irritation. With the increasing focus on personalized medicine, dermal patches have the potential to become a widely used method for treating a variety of skin conditions, extending beyond just eczema. This innovative approach offers a unique and convenient alternative to traditional medication delivery methods.

Dermal patches specifically designed for children with eczema provide a practical solution for administering medication. These patches not only allow for precise and consistent dosing but also minimise the risk of side effects commonly associated with oral medications or topical treatments. This is particularly important for children, as parents often seek treatments that are both effective and easy for their children to use patches.

Keywords: Atopic Eczema, Hypoallergenic Irritation, Skin Barrier, Allergic Irritants, etc

Introduction

Eczema, also known as atopic dermatitis, is a chronic inflammatory disorder characterized by itching, redness, dryness, and recurrent flare-ups [1-2]. It affects both children and adults and is often [associated with allergic conditions such as asthma or allergic rhinitis.]{.mark} The disease significantly impacts the quality of life due to discomfort, cosmetic concerns, and the need for long-term management [15]. Conventional treatment options, such as topical corticosteroids, calcineurin inhibitors, and emollients, often face challenges, including poor patient compliance, skin irritation, and systemic side effects when used long-term [3].

In recent years, drug delivery innovations such as dermal patches have gained attention for the treatment of dermatological conditions, including eczema [6]. These patches provide localized and controlled drug release, minimize systemic exposure, and improve patient adherence compared to traditional ointments and creams [7].

One of the significant advantages of using dermal patches is the ability to maintain steady levels of medication in the bloodstream over an extended period [10]. This can lead to more effective symptom management and improved quality of life for those dealing with the Discomfort of eczema [11]. Additionally, because the patches can be easily applied, they promote adherence and reduce the likelihood of missed doses [12].

However, the development and implementation of dermal patches do come with challenges. One key issue is ensuring that the patches adhere properly to the skin throughout the duration of use [13]. Researchers and manufacturers must find innovative materials and designs that can address this challenge, especially considering children's active lifestyles.

Overall, the potential for innovation in dermal patch technology and its diverse applications creates exciting opportunities for

Future development in this area [14]. As research continues and new methodologies are explored, there is a strong possibility that dermal patches could significantly enhance the treatment for not only eczema but also other skin conditions [8].

Causes of Eczema

Eczema generally develops from a complex interplay between genetic, immunological, and environmental factors [2, 3, 4]:

Environmental Factors: Pollutants, allergens, weather changes, and stress are common factors that are responsible for eczema symptoms [4]. In India, the most common allergens detected are nickel sulphate and dichromate [21, 23]. In females, the nickel sulphate was most common, while in males, cobalt sulphate and paraphenylenediamine were most common.

Table 1: Cause of eczema in males and females

Allergens	Males (n)	Females (n)	N(%)
Nickle sulphate	3	17	20 (23.2)
Potassium dichromate	5	8	13 (15.1)
Balsam of Peru	4	8	12 (13.9)
Cobalt sulphate	12	0	12 (13.9)
Para phenylene diamine	12	0	12 (13.9)
Formaldehyde	7	4	11 (12.8)
Wool alcohol	4	4	8 (9.3)
Fragrance mix	0	5	5 (5.8)
Paraben mix	4	1	5 (5.8)
Benzocaine	4	0	4 (4.6)
Mercapto benzene thiazide	3	1	4 (4.6)
Nitrofurazone	0	4	4 (4.6)
Chlorocresol	1	3	4 (4.6)
Epoxy resins	0	3	3 (3.5)
Patches test negative	15	17	32 (37.1)

Skin Barrier Dysfunction: The outer layer of our skin acts like a strong shield, keeping moisture locked in and preventing harmful substances or microbes from entering [3]. In people with eczema, this protective barrier is weaker. As a result, water escapes from the skin more easily, causing dryness, and irritants or allergens can enter more freely [2]. Mutations in the filaggrin gene and alterations in epidermal proteins weaken the skin barrier, leading to excessive water loss and increased entry of allergens and irritants [3]. These irritants are responsible for developing eczema symptoms, which are dependent on the type of allergens or irritants [4].

Immune Dysregulation: The immune system becomes unusually reactive when the skin is exposed to common triggers such as dust, soaps, food allergens, or even stress [2]. The immune cells release inflammatory chemicals, which attract more immune cells to the skin, creating redness, swelling, and itching [3]. Persistent scratching further damages the skin, leading to a vicious cycle of irritation and inflammation, and becomes the reason for common eczema symptoms [15].

Genetics also plays a key role in the development of eczema. Many people with eczema have mutations in the filaggrin gene, which reduces the ability of the skin to maintain a strong, waterproof barrier [2]. This makes the skin more sensitive and allows allergens to penetrate deeper, fueling immune overreaction [3].

Environmental Triggers: Environmental triggers play a significant role in the worsening of eczema symptoms, such as Changes in weather, such as cold air, dry climates, or sudden shifts in temperature, which can strip the skin of moisture and make flare-ups more likely [4]. Everyday irritants like harsh soaps, detergents, perfumes, and cleaning products can also damage the already fragile skin barrier [5]. In addition, allergens such as dust mites, pollen, mould, and pet dander commonly activate the immune system, leading to itching and redness [4]. Pollution and cigarette smoke further add to skin irritation, while microbes like Staphylococcus aureus may worsen inflammation [5]. Even factors like emotional stress, sweating, and tight clothing can act as hidden triggers [15]. Together, these environmental influences interact with genetic and immune system changes, making eczema unpredictable and difficult to control [2, 4].

Pathophysiology of Eczema

The development of eczema begins with a fundamental disturbance in the skin's natural barrier [2, 3]. The stratum corneum, which normally functions as a protective shield against environmental aggressors, becomes weak and less capable of retaining moisture. This occurs because of structural protein defects, particularly in filaggrin, ceramides, and natural moisturizing factors [3]. The loss of these components leads to increased trans epidermal water loss, resulting in dry, fragile, and easily damaged skin [2]. This weakened barrier allows irritants, allergens, and microorganisms to penetrate more deeply, initiating the early stages of eczema [3].

Once the skin barrier is compromised, the immune system becomes overactive in response to even mild irritants [2]. Antigen-presenting cells in the skin, such as Langerhans cells, recognize foreign substances and activate T-helper (Th2 and Th22) immune responses [3]. These cells release inflammatory cytokines, including interleukin-4, interleukin-13, and interleukin-31, which cause redness, swelling, and intense itching [2]. The itching leads to scratching, which further damages the skin and releases more inflammatory mediators, forming a vicious cycle of irritation and immune activation [15].

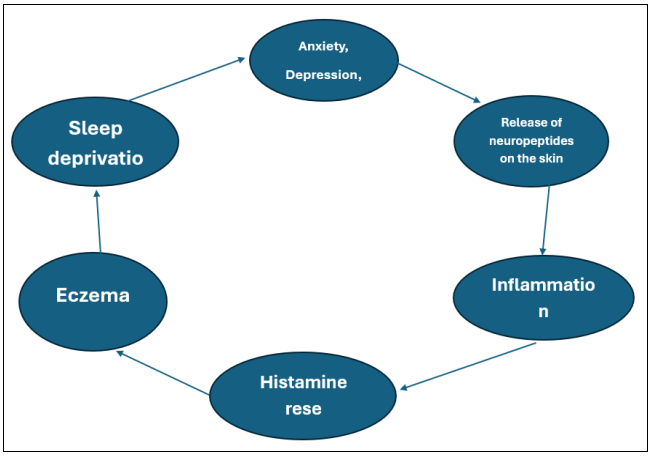

Fig 1: The psychometric cycle of eczema

As inflammation continues, the skin's natural microbiome also becomes imbalanced [3]. Beneficial bacteria such as

Staphylococcus epidermidis are reduced, while pathogenic strains like Staphylococcus aureus proliferate [2]. These microbes release toxins that worsen inflammation and further impair the barrier function [3]. The presence of bacteria and their byproducts trigger additional immune responses, causing oozing, crust formation, and worsening of eczema lesions, particularly in chronic cases [2].

With repeated inflammation and scratching, eczema can progress to a chronic phase characterized by thickened, leathery skin and changes in pigmentation [2]. Fibroblast activation in the dermis leads to increased collagen deposition, while continuous immune signaling sustains inflammation even in the absence of external triggers [3]. Over time, the skin loses its natural flexibility and appears lichenified, particularly in areas of constant friction such as the elbows, knees, and neck [2].

Eczema can affect various parts of the body differently [2]. Facial and neck regions are often more reactive due to thinner skin and greater exposure to allergens, while limbs may show scaling and thickening due to mechanical irritation [3]. In severe cases, systemic inflammation can develop, influencing the immune system beyond the skin and increasing susceptibility to allergies, asthma, or rhinitis---a condition collectively known as the "atopic march" [2].

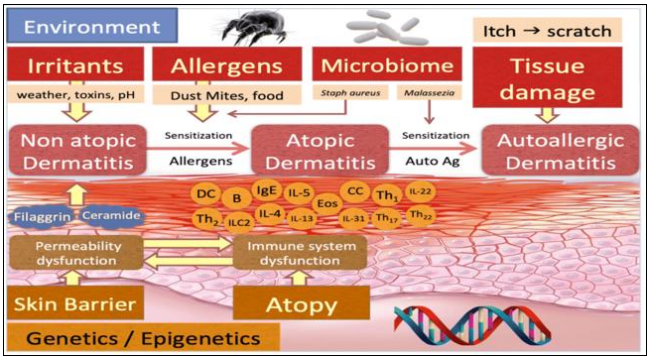

Fig 2: Various factors Causing eczema

Although genetic factors predispose an individual to eczema, environmental influences play a major role in triggering and worsening the disease [4]. Exposure to harsh detergents, cold weather, dust mites, synthetic fabrics, and air pollution can aggravate existing inflammation [5]. Emotional stress, diet, and lack of sleep may also modulate immune responses, leading to flare-ups [15]. Therefore, both intrinsic and extrinsic factors work together to determine the severity and pattern of eczema in each person [2, 4].

Overview of Transderml Drug Delivery System:

Dermal patches are medicated systems designed to deliver therapeutic agents directly to the skin for localized or controlled treatment [6]. They consist of a thin, flexible layer that adheres comfortably to the skin surface and allows gradual diffusion of the drug into the targeted area [7]. Unlike conventional creams or ointments, dermal patches maintain continuous contact with the skin, creating a controlled microenvironment that promotes better absorption, consistent dosing, and reduced application frequency [8].

Structurally, a typical dermal patch is composed of several layers: A backing layer that protects the patch and provides support; A drug-containing matrix or reservoir where the active ingredient is embedded; an adhesive layer that ensures skin contact and may also contain part of the drug; and a release liner that is removed before application [6]. Depending on the formulation, these patches can be designed for transdermal delivery (where the drug enters systemic circulation) or topical dermal delivery, where the drug remains within the skin layers to treat localized conditions like eczema, psoriasis, or dermatitis [7].

In eczema treatment, dermal patches play an important role by maintaining hydration, delivering anti-inflammatory or soothing agents, and protecting sensitive skin from external irritants [9]. Their occlusive nature helps reduce trans epidermal water loss and restores the skin barrier, while the controlled drug release ensures sustained therapeutic action with minimal irritation [10]. Because they are easy to apply, painless, and suitable for both children and adults, dermal patches are becoming an increasingly popular alternative to messy or short-acting topical formulations [11].

Overall, dermal patches represent an innovative approach to dermatological therapy, combining drug delivery and skin protection in a single, patient-friendly system [6, 12].

Development of Dermal Patches in Eczema

Dermal patches are an advanced transdermal drug delivery system designed to deliver therapeutic agents or API directly to the skin [6]. According to several studies on eczema, the development of dermal patches focuses on the following principles [7, 8, 9]:

Material Selection: Choosing the right material is one of the most important steps in the development of dermal patches for eczema [9]. The material must be biocompatible, non-toxic, flexible, and comfortable for long-term wear on sensitive skin. Polymers such as hydrogels, hydrocolloids, and biodegradable films are widely studied because they can provide moisture retention, oxygen permeability, and strong adhesion without irritating the skin [10].

Drug Incorporation: Drugs are carefully embedded within the patch matrix to ensure stability and effectiveness [7]. Commonly incorporated agents include corticosteroids, calcineurin inhibitors, antihistamines, and natural anti inflammatory compounds. The method of incorporation depends on the drug's solubility and stability, ensuring that the active substance remains effective throughout storage and use [8].

Controlled Release: A major advantage of dermal patches is their ability to deliver drugs in a controlled and sustained manner [6]. Instead of multiple daily applications, patches gradually release the medication over several hours or even days. This steady release helps maintain a consistent therapeutic effect, improves patient compliance, and reduces the risk of local or systemic side effects [10].

Moisturizing Effect: Besides drug delivery, modern dermal patches are often designed to enhance skin hydration [9]. Ingredients such as glycerin, hyaluronic acid, or natural oils can be included in the patch matrix, providing a moisturizing effect that supports skin barrier repair [10]. This dual action---drug delivery and hydration---offers better symptom control and reduces flare-ups in eczema patients [11].

Recent Advancement in Dermal Patches for Dermatological Conditions and Eczema Care

Microneedle-based Patches: Microneedle (MN) patches have rapidly advanced as a minimally invasive platform to bypass the outermost skin barrier and deliver drugs directly

into the epidermis and superficial dermis, improving bioavailability for anti-inflammatory and biologic agents [8]. Recent work highlights dissolving and hydrogel forming MNs that release corticosteroids, small molecules, or peptides in a controlled fashion while causing minimal pain --- a major advantage for pediatric eczema patients [12]. Studies also explore multifunctional MNs that combine drug delivery with photothermal or NIR-assisted activation to boost therapeutic effects [13].

Hydrogel and Bio adhesive Patch Systems: Hydrogel-based patches continue to gain attention for eczema because they retain moisture, are gentle on inflamed skin, and can act as reservoirs for sustained drug release [9]. Modern hydrogel formulations are tuned for bio adhesion and oxygen permeability, so they adhere securely to moving skin (e.g., joints) without maceration, while simultaneously supplying humectants (e.g., hyaluronic acid) that aid barrier repair [10]. Clinical-translation reviews highlight hydrogels' safety record and increasing use in topical dermatology [11].

Nanocarrier-Integrated Patches: Incorporating nanocarriers (liposomes, solid-lipid nanoparticles, polymeric nanoparticles, and nano emulsions) into patch matrices improves skin permeation of poorly soluble drugs and enables more predictable sustained-release profiles [7]. Recent preclinical reviews show nanocarrier-loaded patches can increase permeability several-fold compared to conventional formulations and allow lower drug doses with maintained efficacy --- attractive for reducing steroid exposure in chronic eczema [8].

Smart & Closed-Loop Patches (Sensing + Delivery): A new frontier is "smart" patches that combine sensing (e.g., hydration, pH, inflammatory biomarkers) with on-demand drug release [14]. Closed-loop systems have been reported to detect skin hydration or other signals and trigger microneedle or reservoir delivery only when needed, which could limit unnecessary exposure and tailor therapy to flare-ups [14]. Early prototypes and proof-of-concept studies indicate feasibility for atopic dermatitis management [14].

Multifunctional and Patient-Friendly Designs: Recent efforts emphasize combining therapeutic delivery with barrier repair: patches that carry both active anti-inflammatories and moisturizing agents (e.g., glycerin, hyaluronic acid), patches with itch-protective physical barriers to reduce scratching, and child-friendly thin, flexible designs that increase adherence [9]. Innovations such as osmotic-driven hollow MNs and improved adhesive chemistries address practical dosing and wear-time problems [10].

Translation, Challenges, and Outlook: While research is fast-moving, several translational challenges remain consistent manufacturing and dose uniformity (especially for dissolving MNs), long-term safety on inflamed/compromised skin, regulatory pathways, and robust clinical trials in eczema populations (including children) [11]. Nevertheless, converging advances in materials science, nanocarriers, and integrated sensing make dermal patches a highly promising direction for personalized, lower-burden eczema therapy in the coming years [12].

Table 2: Recent advancement in dermal patches

Year	Patch type / Material	Durg / Agent incorporated	Key advancement
2022	Hydrogen-based patch	Hyaluronic acid + corticosteroid	Better skin hydration and slow drug release
2022	Lipid nanoparticle patch	Natural anti-inflammatory extract	Improved drug penetration and stability
2023	Dissolving microneedle patch	Corticosteroid/peptide	Pain-free drug delivery with controlled release
2023	Bio adhesive hydrogen patch	Moisturizer + antihistamine	Long lasting adhesion and comfort on sensitive skin
2024	Smart hydration-responsive patch	Corticosteroid (with hydration sensor)	ON-demand drug release based on skin hydration
2024	Polymeric nanocarrier patch	Calcineurin inhibitor	Higher drug permeation with lower dose requirement
2025	Hollow micro needle patch	Anti-inflammatory+ moisturizer	Dual action: drug delivery and skin hydration

Limitations

1. Limited Drug Loading Capacity

Most patches are designed for thin and flexible applications, which restrict the amount of active drug that can be incorporated [7]. In eczema, where treatment often requires both anti-inflammatory drugs and moisturizers, this limitation reduces therapeutic effectiveness [8].

2. Variability in Drug Release

Although controlled release is a key advantage, maintaining consistent drug delivery over prolonged periods is still challenging [6]. Factors such as patch thickness, material degradation rate, and skin condition (hydrated vs. dry or inflamed) may cause unpredictable release kinetics, potentially leading to under- or over-dosing [10].

3. Adhesion and Skin Irritation

Adhesion to the skin is critical for patch performance [9]. However, in patients with eczema, the skin is already sensitive and prone to irritation [11]. Prolonged adhesion or use of strong adhesives can worsen inflammation, while weak adhesion reduces effectiveness [10].

4. Barrier Dysfunction in Eczema

Eczema is characterized by impaired skin barrier function, which can influence drug penetration [3]. In some cases, patches may not perform uniformly across affected and unaffected skin, leading to uneven absorption and reduced efficacy [7].

5. Manufacturing and Cost Challenges

Advanced systems, such as microneedle-based or hydrogel-integrated patches, involve complex manufacturing techniques [8]. High production costs and scalability issues may limit their availability, particularly in low-resource settings [9].

6. Patient Compliance and Practical Barriers

While patches are designed to improve convenience, patients with severe eczema often experience itching, sweating, and skin movement that can dislodge or damage patches [11]. Children, who represent a large portion of eczema patients, may also find it uncomfortable to keep patches on for extended periods [15].

7. Regulatory and Clinical Validation

Most of the advanced patch systems are still in preclinical or early clinical trial stages [12]. Large-scale clinical studies and

long-term safety evaluations are lacking, which slows regulatory approval and clinical adoption [13].

Conclusion

Eczema is a complex dermatological condition that arises from a combination of genetic susceptibility, skin barrier dysfunction, immune hyperreactivity, and environmental triggers [2, 3, 4]. Its chronic and recurrent nature makes long-term management challenging, especially when conventional topical formulations are associated with poor penetration, frequent dosing, and low patient compliance [15]. Dermal patches have emerged as a promising alternative, offering sustained and controlled drug release, skin hydration, and protection against irritants [6, 7]. Careful consideration of material selection, drug incorporation techniques, release mechanisms, and moisturizing components has led to the development of more patient friendly and effective systems [9, 10]. Recent advancements, such as hydrogel-based patches, microneedle arrays, nanocarrier integration, and smart sensor-based designs, highlight the growing innovation in this field and demonstrate strong potential for personalized therapy in eczema and other dermatological disorders [11, 12, 13, 14].

However, challenges remain, including limited drug loading, variability in release performance, adhesion difficulties, and high production costs [7, 8, 9]. Addressing these limitations through novel biomaterials, scalable manufacturing, and multifunctional designs will be crucial for successful clinical translation [10, 11]. Overall, dermal patches represent a significant step forward in modern dermatology, with the potential not only to improve symptom control and patient adherence but also to reshape the future of eczema management by combining therapeutic delivery with skin barrier restoration and environmental protection [6, 12].

Declaration of Interest

Author declares no conflict of interests.

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