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[54] **COMPOSITIONS AND METHODS FOR TOPICAL APPLICATION OF THERAPEUTIC AGENTS**

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[57] **ABSTRACT**

The present invention generally relates to pharmaceutical compositions that enable control of drug delivery properties and the development of optimal drug delivery strategies customized for particular drugs and particular diseases. The composition includes a dissolved pharmaceutical that has the capacity to permeate the stratum corneum layer of the epidermis and become available systemically, and a pharmaceutical in a microparticulate state that does not readily cross the stratum corneum of the epidermis. The dissolved and microparticulate pharmaceuticals may be the same or different pharmaceuticals. Methods for the preparation and use of the compositions are also provided. In a preferred embodiment, the invention finds particular use in a formulation for the topical application of dapsone for the treatment of acne. In another preferred embodiment, the invention finds particular use for the treatment of herpes lesions.

10 Claims, No Drawings

COMPOSITIONS AND METHODS FOR TOPICAL APPLICATION OF THERAPEUTIC AGENTS

FIELD OF THE INVENTION

The present invention relates to novel dermatological compositions that exhibit readily optimized solubility and systemic drug delivery properties for applying drugs and therapeutic agents to the skin of humans and animals and methods for their preparation and use.

BACKGROUND OF THE INVENTION

While the skin has long been considered the preferred route of administration for cosmetic applications and dermatological therapies, the introduction of transdermal nitroglycerin patches initiated use of the skin as a route for administering systemic drug therapy. Three types of known product applications which employ the barrier properties of the skin for drug delivery include cosmetic, topical, and transdermal applications. The optimal delivery strategy for administering pharmaceuticals via the skin varies among individual pharmaceuticals and among different disease states.

Cosmetic applications are limited to negligible drug penetration past the stratum corneum. Thus, any carrier that minimizes penetration or that aids excipient retention within or onto the stratum corneum would be of tremendous advantage. For transdermal applications, steady state drug delivery is preferred. Steady state delivery requires the use of rate-controlling membranes that slow systemic breakthrough of highly permeable drugs such as nitroglycerin. This type of control can be achieved by using matrix type patches that modify delivery rates by using polymer adhesives and solvents. For topical delivery, minimal systemic breakthrough is always preferred. In order to adequately dose the viable epidermis and dermis, however, large amounts of drug must cross the intact skin barrier, i.e. the stratum corneum, or the lesional delivery barrier, i.e. scab, plaque, etc.

Some dermatological conditions, such as acne, require multiple delivery strategies because they have multiple delivery requirements. Acne is chronic pilosebaceous unit inflammation associated with the face and trunk usually occurring in adolescence due to complex interactions of androgens and bacteria. For the adolescent, circulating androgen results in significantly increased sebum production. The sebaceous glands dramatically enlarge and excrete more sebum than the immature pilosebaceous canals can accommodate. Simultaneously, anaerobic bacteria (*Propionibacterium acnes*) that feed upon the sebum, converting triglycerides to fatty acids, dramatically increase in number due to an increase in volume of the nutrition source. The increase in constricted immature ducts and bacterial waste products results in plugged follicles and typical acne inflammation. Acne severity for a particular anatomical location parallels the number of sebaceous glands per unit of skin.

Acne, which is often treated with antibiotics, is one condition where a highly specialized topical drug delivery is needed. Ideally, a topical antimicrobial would be primarily delivered into the pilosebaceous unit, with only minimal active crossing of the skin barrier. Intact stratum corneum lines the upper third of the pilosebaceous unit, and it is into this upper third of the hair follicle that the sebaceous duct secretes sebum. Thus, a need exists for an acne treatment that maximizes antimicrobial drug levels in the upper third of the pilosebaceous unit.

Additionally, when an anti-inflammatory agent is used to treat acne, it is important to increase the level of drug that will cross the intact stratum corneum lining the upper third of the pilosebaceous unit. By definition, inflammation is the response of the viable epidermis to irritants and sensitizers. In order to reduce the amount of inflammation, the active pharmaceutical must penetrate past the stratum corneum and interfere with the cascade of inflammatory events. Ideally, delivery of an anti-inflammatory for acne requires that steady-state levels be sustained. To date, the ideal delivery system that provides antimicrobial agents above the stratum corneum while providing anti-inflammatory agents below the stratum corneum has not been implemented.

Other dermatological conditions, such as herpes lesions, require multiple delivery strategies because the barrier properties of the lesion dramatically change in the course of the disease. Starting with the prodrome and progressing through the formation of vesicles, the lesion has an intact stratum corneum delivery barrier, and thus, maximum penetration of the drug is necessary. While in place, the stratum corneum delays penetration to the target tissue and sustains the time that the dissolved active drug resides in the target tissue. During this stage of the lesion, microparticulate drug will not significantly cross the intact stratum corneum, and thus, has no real effect in treatment of the lesion. Once the herpes lesion vesicles rupture, the stratum corneum is no longer in place, and the dissolved drug rapidly sweeps past the target tissue, providing minimal or insignificant benefit. However, from the time that the vesicle ruptures and through to the complete formation of the scab, the microparticulate drug is deposited directly at the target area, where it can slowly be released for sustained and significant therapeutic benefit. Thus, in order to adequately dose the viable epidermis from the prodrome through the time of scab formation in a herpes lesion, two distinctly different drug delivery strategies must be implemented.

While the dermatological conditions of acne and herpes lesions serve as conceptual examples of how therapeutic approaches can require dramatically different drug delivery profiles, all skin diseases are best treated by a particular drug delivery strategy tailored specifically to the pharmaceutical and the particular disease. Some diseases are best treated using pulsed or spiked delivery in which high levels of drug are delivered in a short period of time. This type of treatment saturates receptor sites and provides maximum microbial or viral replication inhibition, thus providing optimal therapy for certain diseases. Conversely, a cosmetic, topical, or transdermal product that provides steady state active pharmaceutical delivery while minimizing excipient delivery provides the preferred skin delivery profile for other diseases. Thus, a carrier system that can be adjusted to optimize the delivery profile for the pharmacology of the active drug and the nature of the disease state is needed to advance the effectiveness of pharmaceutical products applied to the skin.

SUMMARY OF THE INVENTION

The present invention concerns a pharmaceutical carrier system comprising a dermatological composition that is a semi-solid aqueous gel, wherein a pharmaceutical is dissolved in the gel such that the pharmaceutical has the capacity to cross the stratum corneum layer of the epidermis and become available systemically, and wherein the composition also contains pharmaceutical in a microparticulate state that does not readily cross the stratum corneum of the epidermis. The ratio of microparticulate pharmaceutical to dissolved pharmaceutical is adjustable, but is preferably five or less. The microparticulate pharmaceutical and the dis-

solved pharmaceutical may be the same drug, or they may be different drugs.

Methods for preparing the compositions of the present invention are also shown. In addition, methods for treating dermatological conditions that include topically applying the dermatological compositions of the invention are shown. More particularly, the invention concerns methods for treating dermatological conditions or diseases such as acne, herpes lesions, and dermatitis. Antimicrobial agents having anti-inflammatory properties such as dapsone are used to treat acne. Antiviral agents or antiviral agents in combination with local anesthetics are used to treat herpes lesions, and anti-inflammatory agents are used to treat dermatitis.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention comprises compositions for application to the skin that can form microparticulate drug precipitates in adjustable ratios of microparticulate drug to dissolved drug, methods for the formation of said compositions, and methods for treatment of skin conditions using said compositions. The advantages of the present invention are appreciated in the treatment of skin conditions or diseases by using cosmetics or topical pharmaceuticals, and in the systemic treatment of illness by using transdermal pharmaceuticals. The present invention is particularly effective in the treatment of acne with antimicrobial actives known to possess anti-inflammatory properties such as dapsone. The invention also finds particular use in the treatment of herpes lesions and dermatitis.

In one embodiment, the present invention is directed to a novel pharmaceutical carrier system comprising a dermatological composition that is a semisolid aqueous gel, wherein the composition exhibits an optimal balance between a dissolved pharmaceutical that is available to cross through the stratum corneum to become systemically available, and a microparticulate pharmaceutical that is retained in or above the stratum corneum to serve as a reservoir or to provide drug action in the supracorneum zone. The microparticulate pharmaceutical and the dissolved pharmaceutical may be the same or different drugs. The microparticulate pharmaceutical may comprise a crystalline precipitant or an amorphous precipitant.

Optimal balance is accomplished by having a semisolid gel carrier system in which microparticulate pharmaceutical precipitates are formed in reproducible ratios with respect to the dissolved pharmaceutical. For the composition to have a wide range of applicability, the microparticulate to dissolved pharmaceutical ratio preferably should be no greater than five, at therapeutic levels of applied active pharmaceutical.

A composition having a microparticulate to dissolved pharmaceutical ratio of less than two may provide the greatest amount of pharmaceutical available for immediate partition out of the stratum corneum and into the viable epidermis. This should provide minimum reservoir capacity, but may not maintain sustained delivery or provide maximum activity in the supracorneum zone. A composition having a microparticulate to dissolved pharmaceutical ratio of two or greater may have a reduced amount of drug available for immediate partition out of the stratum corneum and into the viable epidermis. This provides maximum reservoir capacity, and maintains sustained delivery, providing maximum activity in the supracorneum zone. For the present invention, the ratio for microparticulate drug to dissolved drug should be no greater than 50, preferably no greater than 10, and most preferably no greater than 5. Drug

delivery from the microparticulate/dissolved pharmaceutical formulation may be optimized to provide higher levels of drug to the supracorneum zone, while maintaining the level of drug partitioning out of the stratum corneum and into the viable epidermis, despite 10-fold increases in the amount of pharmaceutical applied to the skin.

The compositions of the present invention comprise semi-solid and gel-like vehicles that include a polymer thickener, water, preservatives, active surfactants or emulsifiers, antioxidants, sunscreens, and a solvent or mixed solvent system. The solvent or mixed solvent system is important to the formation of the microparticulate to dissolved pharmaceutical ratio. The formation of the microparticulate, however, should not interfere with the ability of the polymer thickener or preservative systems to perform their functions.

Polymer thickeners that may be used include those known to one skilled in the art, such as hydrophilic and hydroalcoholic gelling agents frequently used in the cosmetic and pharmaceutical industries. Preferably, the hydrophilic or hydroalcoholic gelling agent comprises "CARBOPOL®" (B. F. Goodrich, Cleveland, Ohio), "HYPAN®" (Kingston Technologies, Dayton, N.J.), "NATROSOL®" (Aqualon, Wilmington, Del.), "KLUCEL®" (Aqualon, Wilmington, Del.), or "STABILEZE®" (ISP Technologies, Wayne, N.J.). Preferably, the gelling agent comprises between about 0.2% to about 4% by weight of the composition. More particularly, the preferred compositional weight percent range for "CARBOPOL®" is between about 0.5% to about 2%, while the preferred weight percent range for "NATROSOL®" and "KLUCEL®" is between about 0.5% to about 4%. The preferred compositional weight percent range for both "HYPAN®" and "STABILEZE®" is between about 0.5% to about 4%.

"CARBOPOL®" is one of numerous cross-linked acrylic acid polymers that are given the general adopted name carbomer. These polymers dissolve in water and form a clear or slightly hazy gel upon neutralization with a caustic material such as sodium hydroxide, potassium hydroxide, triethanolamine, or other amine bases. "KLUCEL®" is a cellulose polymer that is dispersed in water and forms a uniform gel upon complete hydration. Other preferred gelling polymers include hydroxyethylcellulose, cellulose gum, MVE/MA decadiene crosspolymer, PVM/MA copolymer, or a combination thereof.

Preservatives may also be used in this invention and preferably comprise about 0.05% to 0.5% by weight of the total composition. The use of preservatives assures that if the product is microbially contaminated, the formulation will prevent or diminish microorganism growth. Some preservatives useful in this invention include methylparaben, propylparaben, butylparaben, chloroxylenol, sodium benzoate, DMDM Hydantoin, 3-Iodo-2-Propylbutyl carbamate, potassium sorbate, chlorhexidine digluconate, or a combination thereof.

Titanium dioxide may be used as a sunscreen to serve as prophylaxis against photosensitization. Alternative sunscreens include methyl cinnamate. Moreover, BHA may be used as an antioxidant, as well as to protect ethoxydiglycol and/or dapsone from discoloration due to oxidation. An alternate antioxidant is BHT.

Pharmaceuticals for use in all embodiments of the invention include antimicrobial agents, anti-inflammatory agents, antiviral agents, local anesthetic agents, corticosteroids, destructive therapy agents, antifungals, and antiandrogens. In the treatment of acne, active pharmaceuticals that may be used include antimicrobial agents, especially those having

anti-inflammatory properties such as dapsone, erythromycin, minocycline, tetracycline, clindamycin, and other antimicrobials. The preferred weight percentages for the antimicrobials are 0.5% to 10%. In the topical treatment of herpes lesions, active pharmaceuticals that may be used include antiviral or local anesthetic agents. A concentration of about 1.0% to 10% by weight is preferred for nucleoside analogues such as acyclovir, famciclovir, penciclovir, valacyclovir, and ganciclovir.

Local anesthetics include tetracaine, tetracaine hydrochloride, lidocaine, lidocaine hydrochloride, dyclonine, dyclonine hydrochloride, dimethisoquin hydrochloride, dibucaine, dibucaine hydrochloride, butambenpicrate, and pramoxine hydrochloride. A preferred concentration for local anesthetics is about 0.025% to 5% by weight of the total composition. Anesthetics such as benzocaine may also be used at a preferred concentration of about 2% to 25% by weight.

Corticosteroids that may be used include betamethasone dipropionate, fluocinolone acetonide, betamethasone valerate, triamcinolone acetonide, clobetasol propionate, desoximetasone, diflorasone diacetate, amcinonide, flurandrenolide, hydrocortisone valerate, hydrocortisone butyrate, and desonide are recommended at concentrations of about 0.01% to 1.0% by weight. Preferred concentrations for corticosteroids such as hydrocortisone or methylprednisolone acetate are from about 0.2% to about 5.0% by weight.

Destructive therapy agents such as salicylic acid or lactic acid may also be used. A concentration of about 2% to about 40% by weight is preferred. Cantharidin is preferably utilized in a concentration of about 5% to about 30% by weight. Typical antifungals that may be used in this invention and their preferred weight concentrations include: oxiconazole nitrate (0.1% to 5.0%), ciclopirox olamine (0.1% to 5.0%), ketoconazole (0.1% to 5.0%), miconazole nitrate (0.1% to 5.0%), and butoconazole nitrate (0.1% to 5.0%). For the topical treatment of seborrheic dermatitis, hirsutism, acne, and alopecia, the active pharmaceutical may include an antiandrogen such as flutamide or finasteride in preferred weight percentages of about 0.5% to 10%.

Typically, treatments using a combination of drugs include antibiotics in combination with local anesthetics such as polymyxin B sulfate and neomycin sulfate in combination with tetracaine for topical antibiotic gels to provide prophylaxis against infection and relief of pain. Another example is the use of minoxidil in combination with a corticosteroid such as betamethasone dipropionate for the treatment of alopecia areata. The combination of an anti-inflammatory such as cortisone with an antifungal such as ketoconazole for the treatment of tinea infections is also an example.

In one embodiment, the invention comprises a dermatological composition having about 0.5% to 4.0% carbomer and about 0.5% to 10% of a pharmaceutical that exists in both a dissolved state and a microparticulate state. The dissolved pharmaceutical has the capacity to cross the stratum corneum, whereas the microparticulate pharmaceutical does not. Addition of an amine base, potassium hydroxide solution, or sodium hydroxide solution completes the formation of the gel. More particularly, the pharmaceutical may include dapsone, an antimicrobial agent having anti-inflammatory properties. A preferred ratio of microparticulate to dissolved dapsone is five or less.

In another embodiment, the invention comprises about 1% carbomer, about 80–90% water, about 10%

ethoxydiglycol, about 0.2% methylparaben, about 0.3% to 3.0% dapsone including both microparticulate dapsone and dissolved dapsone, and about 2% caustic material. More particularly, the carbomer may include “CARBOPOL® 980” and the caustic material may include sodium hydroxide solution.

In a preferred embodiment, the composition comprises dapsone and ethoxydiglycol, which allows for an optimized ratio of microparticulate drug to dissolved drug. This ratio determines the amount of drug delivered, compared to the amount of drug retained in or above the stratum corneum to function in the supracorneum domain. The system of dapsone and ethoxydiglycol may include purified water combined with “CARBOPOL®” gelling polymer, methylparaben, propylparaben, titanium dioxide, BHA, and a caustic material to neutralize the “CARBOPOL®.”

Another preferred embodiment of this invention relates to a composition for the treatment of herpes lesions comprising a semisolid aqueous gel; a first pharmaceutical in the gel, partially in a microparticulate form and partially in a dissolved form, where optimized delivery for early state lesions is provided when the pharmaceutical is dissolved and optimized delivery for later state lesions is provided when the pharmaceutical is in a microparticulate form; and a second pharmaceutical dissolved in the gel which provides benefit throughout lesion progression. In a preferred embodiment, the composition comprises acyclovir and 1-methyl-2-pyrrolidone, which allows for an optimized ratio of microparticulate drug to dissolved drug for the treatment of herpes lesions. Acyclovir may be present in dissolved and microparticulate forms. The ratio determines the amount of drug delivered up to the point of lesion vesicle formation, as compared to the amount of drug available to be deposited into the lesion once the vesicles rupture. The drug delivery system of acyclovir and 1-methyl-2-pyrrolidone may include purified water combined with KLUCEL® hydroxypropyl cellulose gelling polymer, methylparaben, and propylparaben.

In another preferred embodiment, a combination drug system of acyclovir and tetracaine HCl may be formulated with 1-methyl-2-pyrrolidone to provide both antiviral and local anesthetic activity. Tetracaine HCl is a local anesthetic that alters membrane function and blocks pain. In a preferred embodiment, acyclovir comprises 5% by weight of the composition. The system of acyclovir, tetracaine HCl, and 1-methyl-2-pyrrolidone can include purified water, sodium lauryl sulfate, KLUCEL® hydroxypropyl cellulose gelling polymer, methylparaben, and propylparaben. The combination of a local anesthetic with sodium lauryl sulfate has been shown to be an effective therapy for herpes lesions. The combination of the nucleoside analogue acyclovir with the anesthetic/late stage antiviral combination tetracaine HCl and sodium lauryl sulfate should provide complete topical therapy for herpes lesions.

The relative percentages for each of the reagents used in the present invention may vary depending upon the desired strength of the target formulation, gel viscosity, and the desired ratio of microparticulate to dissolved pharmaceutical. Unless otherwise designated, all reagents listed above are commonly known by one of ordinary skill in the art and are commercially available from pharmaceutical or cosmetic excipient suppliers.

The present invention also provides methods for preparing the dermatological compositions described above. In a general form, the method for producing a dermatological gel composition having dissolved drug and microparticulate

drug precipitates comprises the steps of completely dissolving a pharmaceutical in a solvent or solvent mixture; adding and adequately dispersing a polymeric thickener in water; and combining the dissolved pharmaceutical with the dispersed polymeric thickener. Alternatively, water may be slowly added to the dissolved pharmaceutical, followed by the addition of a polymeric thickener. Ethoxydiglycol and 1-methyl-2-pyrrolidone are preferred solvents for use in this invention.

In one preferred embodiment, the method for preparing a dermatological composition having dissolved and microparticulate pharmaceutical comprises the steps of forming a homogenous dispersion by stirring purified water vigorously enough to form a vortex and sifting gel polymer into the vortex formed in the water while continuing to stir; forming a pharmaceutical component by dissolving methyl paraben and propylparaben in ethoxydiglycol by mixing to form a solution, and mixing an active pharmaceutical with the solution until the pharmaceutical dissolved; mixing the pharmaceutical component with the homogenous dispersion to form a microparticulate pharmaceutical dispersion; and adding a caustic material. The active pharmaceutical may comprise any of the types mentioned above. In a preferred embodiment, the active pharmaceutical comprises dapsone. In another preferred embodiment, the active pharmaceutical comprises acyclovir or acyclovir in combination with tetracaine or tetracaine HCl.

The order in which reagents are combined may be important, depending on the particular reagents necessary for the target mixture. For example, after a pharmaceutical such as dapsone is dissolved in a solvent such as ethoxydiglycol, water may be slowly added to the dapsone in the ethoxydiglycol solution, or the dapsone in ethoxydiglycol solution may be added to the water with mixing. Adding the dapsone in ethoxydiglycol solution to water may result in less polydispersity in the size of the microparticulates than adding water to the dapsone in ethoxydiglycol solutions.

The carbomer is generally dispersed in the water component of the formulation, while the remaining ingredients will be dissolved or dispersed in whichever of the two components are best for dissolving or dispersing the ingredient. For example, it is suggested to dissolve methylparaben, propylparaben, and BHA in ethoxydiglycol. After the ethoxydiglycol component and water component are combined, neutralizer is added to formulate the gel.

Finally, in another embodiment of the invention, methods for the treatment of dermatological conditions by topical application of the compositions of this invention are shown. These methods are useful in the treatment of diseases such as acne, herpes lesions, seborrhea dermatitis, hirsutism, and alopecia. In a preferred embodiment, a method for the treatment of dermatological conditions comprises applying topically a gel composition comprising a dissolved pharmaceutical that has the capacity to cross the stratum corneum of the epidermis and become systemically available, and a microparticulate pharmaceutical that has only minimal capacity to cross the stratum corneum in its microparticulate state. In one embodiment, the dissolved pharmaceutical and microparticulate pharmaceutical comprise about 1.0% to 10% antiviral agent. In another embodiment, the dissolved pharmaceutical and microparticulate pharmaceutical comprise about 0.5% to 10% antiandrogen.

In a preferred embodiment, a method for the treatment of acne comprises applying topically a gel composition that comprises a dissolved anti-inflammatory pharmaceutical

and a microparticulate antimicrobial pharmaceutical, wherein the dissolved anti-inflammatory pharmaceutical crosses the stratum corneum of the epidermis and is absorbed into the lower two-thirds of the pilosebaceous unit, while the microparticulate antimicrobial pharmaceutical is primarily delivered into the upper third of the pilosebaceous unit, crossing the stratum corneum of the epidermis only minimally. Preferably, the dissolved pharmaceutical and microparticulate pharmaceutical comprise dapsone.

In another preferred embodiment, a method for the treatment of herpes lesions comprises applying topically a semisolid gel composition that comprises a semisolid aqueous gel; a first pharmaceutical in the gel, which exists in a partially microparticulate form and a partially dissolved form, providing for optimized delivery for early state lesions when dissolved and optimized delivery for later state lesions when present as a microparticulate; and a second pharmaceutical dissolved in the gel, providing benefit throughout progression of the lesion. Preferably, the first pharmaceutical comprises a nucleoside analogue, and the second pharmaceutical comprises a local anesthetic. In a preferred embodiment, the nucleoside analogue comprises acyclovir, penciclovir, famciclovir, valacyclovir, or ganciclovir, and the local anesthetic comprises tetracaine, dyclonine, dibucaine, or a salt thereof, such as tetracaine HCl, dyclonine HCl, or dibucaine HCl. More preferably, acyclovir comprises 5% by weight of the composition, and tetracaine HCl comprises 2–5% by weight.

The following examples are provided to enable those of ordinary skill in the art to make and use the methods and compositions of the invention. These examples are not intended to limit the scope of what the inventors regard as their invention. Additional advantages and modifications will be readily apparent to those skilled in the art.

Examples 1 through 6 describe methods for the preparation of compositions of the invention that include microparticulate crystalline dapsone, dissolved dapsone, and combinations of the two. The examples offer illustrations of methods that can be used to control the ratio of dissolved to microparticulate pharmaceuticals in the final product. Since microparticulate pharmaceuticals are retained above the stratum corneum having negligible penetration and dissolved pharmaceuticals penetrate the stratum corneum, controlling the ratios between the two epidermal areas is important in developing a composition having an optimal delivery route for administering pharmaceuticals via the skin.

Example 7 describes a method for the preparation of compositions of this invention using two different pharmaceuticals in combination, resulting in one pharmaceutical dissolved in the composition and the other present in a microparticulate state, such that two epidermal areas may be treated with two different drugs. Example 8 provides a method for preparing a composition having a pharmaceutical partially in a microparticulate state and partially dissolved, combined with a different dissolved pharmaceutical. Examples 9–11 provide evaluations of the compositions and methods described herein.

EXAMPLE 1

The following example provides a method for producing a topical therapeutic is agent in which the pharmaceutical component is a combination of dissolved and microcrystalline dapsone. Because of the nature of the microcrystalline dapsone in the final product of Example 1, microcrystalline dapsone will be retained in or above the stratum corneum and will therefore serve as a reservoir or provide drug action

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