The impact of emollients on phototherapy: A review

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When treating psoriasis, various topical emollients exist that can affect the penetration of ultraviolet radiation in phototherapy. Compared with normal-appearing skin with a reflectance of 4% to 5%, psoriatic skin has higher reflectance as a result of its increased air-to-corneocyte interfaces. Studies have tested the effect of emollients on light penetration by assessing psoriatic plaque clearance, differences in minimal erythema dose, and physical properties of the emollient (eg, monochromatic protection factor and absorbance). Psoriatic plaque clearance was found to improve with serous (thin liquid)-based emollients (eg, Vaseline oil [Unilever, Blackfriars, London, UK], mineral oil, and glycerol), whereas clearance decreased with salicylic acid and viscous-based emollients (eg, petrolatum). Emollients with high ultraviolet absorbance properties increased minimal erythema dose, and those with low absorbance properties decreased minimal erythema dose. Interestingly, when a liquid emollient with a refractive index close to that of normal-appearing skin was applied, there was a net increase in light absorption, or a reduction in reflection that exceeded the emollient's innate ability to absorb light. (J Am Acad Dermatol 2013;68:817-24.)

Key words: broadband; emollient; Goeckerman; mineral oil; narrowband; phototherapy; psoriasis; refractive index; skin optics; ultraviolet; Vaseline.

Phototherapy is one of the oldest therapeutic modalities for generalized psoriasis, yet it remains today one of the safest and most effective treatment options for generalized psoriasis. Unlike biologics and oral immunosuppressants, phototherapy lacks serious systemic risks such as nephrotoxicity, hepatotoxicity, tuberculosis, and malignancy. Phototherapy works by reducing epidermal hyperproliferation, reducing angiogenesis, and acting as an immunosuppressor. Ultraviolet (UV) radiation reaches the proliferative compartment of the skin, where it temporarily decreases synthesis of DNA, RNA, and proteins, in turn leading to normalization of cell differentiation and cell kinetics.[1-3] UV light affects the cutaneous immune system and changes the cytokine pattern of the dermis and epidermis by reducing the number of Langerhans cells, therefore decreasing the ability of dendritic cells to present antigens.[3-5]

As compared with normal-appearing skin, psoriatic plaques pose more obstacles to penetration of UV radiation. Psoriatic plaques have a thicker and generally deeper proliferative compartment at the bottom of the epidermis.[6] There is also an increased thickness of stratum corneum. The study by Nielsen et al[7] showed that the protein keratin, one of the main components of the stratum corneum, absorbs a proportion of UV radiation. As such, psoriatic plaques, with a thicker stratum corneum, might prevent an adequate amount of therapeutic radiation from reaching the proliferative compartment.

In addition, psoriatic plaques often have increased scales with multiple air-corneocyte interfaces, which can increase the reflectance of optic radiations and prevent complete penetration of the therapeutic UV rays.[8,9] In normal-appearing skin,

Abbreviations used:

MED:	minimal erythema dose
MPF:	monochromatic protection factor
nD:	refractive index
SPF:	sun-protection factor
UV:	ultraviolet

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only a small fraction of an incident radiation (usually about 4%-7%) will be reflected as a result of refractive index (nD) mismatch of air (nD = 1.0) to stratum corneum (nD = 1.55).[8,10] Thick, micaceous scales characteristic of psoriatic plaques can dramatically refract incident radiation, causing it to scatter and significantly impede light penetration.[8]

Ultimately, the success of phototherapy depends on achieving adequate penetration of UV radiation into the deeper portions of the epidermis.[11] It is thought that emollients can improve the efficacy of phototherapy by reducing the reflectance and scattering of light as it transmits through psoriatic plaques.[12] However, some emollients can have the contrary effect, diminishing UV penetration.

Multiple studies have examined the effects of topical agents on UV penetration. In this review, we take these studies a step further, evaluating the properties of the emollients and determining the most effective emollients to enhance UV penetration.

CAPSULE SUMMARY

- Light therapy is known to be a highly effective treatment option for psoriasis. There are conflicting thoughts, however, regarding an emollient's ability to increase ultraviolet penetration when combined with light therapy.
- Our review analyzes the findings in multiple articles, including assessing psoriatic plaque clearance, differences in minimal erythema dose, and physical properties of the emollient (eg, monochromatic protection factor and absorbance) and their affect on plaque clearance.
- Our article will improve patient care by providing a better understanding of emollients when combined with phototherapy. It will guide the physician to choose the most effective emollient to increase psoriatic plaque clearance.

METHODS

Studies on the use of emollients in phototherapy were identified in PubMed's MEDLINE databases from January 1966 to November 2010 using the key search terms "emollient," "phototherapy," "photooptics of skin," and "psoriasis." Search terms were also used in combinations. Reference lists of relevant publications were manually searched for additional relevant studies. The search was limited to articles published in the English language or with English-language abstracts.

RESULTS

Several aspects of emollients were considered to determine their effectiveness when combined with light therapy. These different methods are discussed below.

Effects of emollients on transmission

Several studies analyzed how emollients affect the penetration of the UV light. Leroy et al[13] performed an in vitro study measuring UV transmission before and 3 minutes after applying Vaseline oil onto 10 epidermal specimens. Vaseline oil and Vaseline petrolatum are both primarily petrolatum but Vaseline oil is in the highly refined liquid form whereas Vaseline petroleum is in the semisolid form. The study found that penetration of UV rays through the specimens with Vaseline oil had a 2- to 3-fold increase in transmission.[13] Hoffmann et al[14] similarly showed that Vaseline can enhance UV transmission. In addition, Farr et al[15] carried out an in vivo study demonstrating that the application of the lipophilic liquid, glycerin, increased transmission of light through psoriatic plaques by roughly 2-fold by decreasing its backscatter.

Effects of emollients on minimal erythema dose

Some studies demonstrate that certain emollients have no effect on minimal erythema dose (MED), suggesting that the emollients do not block UV penetration.[16-18] Behrens-Williams et al[16] used *unguentum emulsificans* (cetylstearyl alcohol, paraffin. subliq, Vaseline. alb.) in 4 aqueous dilutions on nonpsoriatic skin and demonstrated no significant difference in MED.[16] Similarly, Lebwohl et al[18] found that mineral oil and clear liquid emollient (Theraplex clear lotion, The Theraplex Company, LLC, Memphis, TN) did not significantly affect UV transmission or erythemogenicity of UVB.

Studies using crude coal tar,[18] salicylic acid,[11,18-20] petrolatum,[18,19,21] and sunflower oil[22] have demonstrated increased MED after topical application, indicating that UV radiation may be partially blocked.[18,19,23,24]

The thickness of the application of the individual emollient can affect whether there is a difference in the MED. For instance, Lebwohl et al[18] demonstrated that petrolatum and white emollient cream (Eucerin, Beiersdorf, Inc, Wilton, CT) when applied as thin layer (0.4 mL/24 cm^2 of skin) had a negligible effect on MED. However, when applied as a thick layer (0.8 mL/24 cm^2 of skin), petrolatum and white emollient cream increased the MED.[18] Lebwohl et al[17] also observed that a thin layer of calcipotriene ointment did not change the erythemogenicity of UVB or the minimal dose of UVA required for immediate

pigment darkening; whereas a thick application of calcipotriene ointment increased MEDs for UVB and increased the minimal dose of UVA required for immediate pigment darkening.[17]

Fetil et al[24] found that 0.005% calcipotriol, 0.05% clobetasol-17-proprionate, and 0.1% tretinoin increased MEDs, regardless of whether applied thinly (0.1 mL/25 cm^2 of skin) or thickly (0.3 mL/25 cm^2 of skin). This suggests that certain emollients and medicated agents appear to have significant photoprotective properties and may reduce the effectiveness of phototherapy.[23]

Effects of emollients on psoriasis plaque clearance

Several studies have shown more effective clearing of psoriatic plaques when emollients are applied in conjunction with phototherapy.[10,12,25-27] For example, increased plaque clearance was demonstrated with Vaseline oil,[25] calcipotriol,[26] mineral oil,[10] and decubal (an oil-in-water emollient containing cethanol, glycerol, isopropyl myristate, adeps lanae, Span60, Twee 60, silicone, and fluid AK200-300).[27]

To be more specific, Penven et al[25] recruited 15 patients with chronic plaque-type psoriasis and found 49% clearance of plaques pretreated with Vaseline oil, as compared with only 17% clearance of untreated plaques. Similarly, Jain et al[10] applied mineral oil before narrowband UVB therapy to half of the body of children with widespread, symmetric psoriasis involving more than 20% body surface area. The cumulative dose necessary to achieve plaque clearance was significantly lower on the side of the body pretreated with mineral oil. Berne et al[27] found significantly increased rate of clearance using decubal before UVB therapy on half of the 127 symmetric pairs of plaques tested.

Other emollients such as salicylic acid[19,20] and coconut oil[28] have either had no effect on plaque clearance or decreased plaque clearance. Kristensen and Kristensen[20] showed that salicylic acid blocks UVB penetration with the photoprotective effect lasting over 12 hours, and concluded that this effect might be a result of the fact that salicylic acid is closely related chemically to para-aminobenzoic acid, a key ingredient in sunscreens. George et al[28] used coconut oil to pretreat 29 patients with chronic plaque psoriasis undergoing either psoralen plus UVA or narrowband UVB therapy. The study found that pretreatment of plaques with coconut oil showed no significant effect when used before narrowband UVB and decreased plaque clearance in the group that received psoralen plus UVA.[28]

Basic properties of an emollient

Considering that studies vary in regard to the effect that emollients have on UV transmission, it becomes critically important to investigate the characteristics of the emollient. Studies comparing the properties of emollients test how the emollient affects UV absorbance, and the monochromatic protection factor (MPF). MPF is the inverse of the transmittance of light at a given wavelength that is used in the calculation of sun-protection factor (SPF)[23]:

$$\mathrm{MPF} = \frac{\text{Transmitted UV radiation WITHOUT emollient applied}}{\text{Transmitted UV radiation WITH emollient applied}}$$

$$\mathrm{SPF} = \frac{\int A(\lambda)E(\lambda)d\lambda}{\int A(\lambda)E(\lambda)/\mathrm{MPF}(\lambda)d\lambda'}$$

When treating psoriatic plaques with phototherapy, pretreatment with an emollient should decrease the spectral remittance (ie, diffuse reflection) of UV radiation as it transmits through the plaques and should, therefore, improve psoriasis clearance.[1] Hudson-Peacock et al[23] defined an ideal emollient (or, one that causes no effect on UV transmission) to have MPF of less than 1.2. Emollients with MPF of higher than 1.2 have UV-blocking properties and reduce transmittance by at least 17%, thereby diminishing the effects of phototherapy.[6,23]

Otman et al[6] analyzed the UV-blocking properties of 30 emollients listed in British National Formulary used in phototherapy and calculated the MPF for each (Table I). Of the emollients tested, 13 of 30 had an MPF less than 1.2 in the UVA range and 7 of 30 had an MPF less than 1.2 in the UVB range.[6] Emollients with MPF less than 1.2 in both the UVB and UVA wavelengths included Aveeno cream (Johnson & Johnson, New Brunswick, NJ), Calmurid cream (Galderma, Cranbury, NJ), Dermol 500 lotion (Dermal Laboratories, Hertfordshire, UK), Doublebase cream

Table I. Monochromatic protection factor value of various emollients listed in British National Formulary

Name	In vitro SPF	Mean UVB protection factor	Mean UVA protection factor	PUVA protection factor
Aqueous cream	2.01*	2.04*	1.36*	1.41*
Aveeno cream	1.02	1.01	0.98	1.00
Balneum Plus	1.28*	1.27*	1.20*	1.21*
Calmurid cream	1.19	1.18	1.14	1.15
Cetraben emollient cream	1.42*	1.39*	1.23*	1.31*
Dermol 500 lotion	1.08	1.10	1.03	1.03
Diprobase cream	1.54*	1.51*	1.36*	1.38*
Doublebase cream	1.09	1.10	1.07	1.07
Drapolene cream	1.47*	1.48*	1.30*	1.32*
E45 cream	1.29*	1.28*	1.19	1.20*
Emulsiderm emollient	1.17	1.16	1.10	1.11
Emulsifying ointment	1.07	1.05	0.96	1.01
Epaderm ointment	1.45*	1.41*	1.06	1.10
Eucerin cream 10%	1.46*	1.43*	1.32*	1.35*
Eucerin cream 5%	1.31*	1.30*	1.22*	1.23*
Eucerin lotion 10%	1.31*	1.31*	1.21*	1.23*
Exorex moisturizing cream	2.14*	1.97*	1.46*	1.53*
Hydromol cream	1.59*	1.58*	1.35*	1.36*
Hydrous ointment	1.33*	1.32*	1.30*	1.37*
Johnson & Johnson baby cream	1.52*	1.51*	1.35*	1.38*
Kamillosan ointment	1.86*	1.83*	1.31*	1.41*
Keri lotion	1.35*	1.34*	1.19	1.20*
LactiCare lotion	1.49*	1.50*	1.25*	1.28*
Liquid and white soft paraffin ointment	1.34*	1.28*	1.02	1.09
Neutrogena cream	1.59*	1.62*	1.26*	1.25*
Nutraplus cream	1.20*	1.20*	1.10	1.12
Oilatum cream	1.22*	1.20*	1.14	1.21
Oilatum gel	0.90	0.89	0.88	0.89
Unguentum M cream	1.47*	1.40*	1.26*	1.27*
Yellow soft paraffin ointment	2.34*	2.30*	1.28*	1.39*

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PUVA, Psoralen plus ultraviolet A; *SPF*, sun-protection factor; *UV*, ultraviolet.
*Values ≥ 1.2.[6]

(Dermal Laboratories, Hertfordshire, UK), Emulsiderm emollient (Dermal Laboratories Limited, Hertfordshire, UK), emulsifying ointment, and Oilatum gel (Stiefel, Research Triangle Park, NC) (with Oilatum gel having the lowest MPF value).[6]

Unfortunately, however, many emollients studied absorb the UV radiation necessary to treat psoriatic plaques (Table II).[6,11,21] Schleider et al[21] applied various emollients to the normal-appearing skin of 3 subjects and calculated the absorbance of these emollients (Figs 1 and 2).[21] The study found that Vaseline petroleum jelly, petrolatum, and hydrophilic ointment had the most UV-blocking effects, whereas liquid emollients such as Alpha Keri bath oil (Bristol-Myers Squibb, New York, NY), mineral oil, and Johnson's baby oil (Johnson & Johnson, New Brunswick, NJ) had minimal effects. No differences were observed when Planter's peanut oil (Kraft Foods, Northfield, IL) or Mazola corn oil (ACH Food Companies, Cordova, TN) were applied.[21]

Kornreich et al[11] measured the absorptive properties of topical agents from 260 to 400 nm. Substantial UV absorption was found in salicylic acid—containing preparations, tar-based products, calcipotriene, tretinoin, and anthralin. Topical steroid preparations and ammonium lactate had low absorbance in UVB and UVA ranges.[11]

DISCUSSION

Psoriatic plaques, unlike normal-appearing skin, have multiple air-corneocyte interfaces, rather than a single continuous air-tissue interface, which creates a nonhomogeneous skin surface. The air-corneocyte interfaces prevent UV penetration because of increased reflectance and light scattering. The application of topical emollients to psoriatic plaques helps change the optics of skin, matching the UV refractive index of the psoriatic plaque to that of normal stratum corneum (nD = 1.55).[8] In theory, patients

Table II. Studies evaluating therapeutic effect of emollients before phototherapy

Authors	Study type	No. of patients	Skin tested	UV	Emollient	Effective*
Otman et al[6]	In vitro	N/A	N/A	Measured SPF	30 Emollients listed in BNF	N/A
Jain et al[10]	In vivo	20 Children	Psoriatic	Narrowband UVB	Mineral oil	Yes
Kornreich et al[11]	Ex vivo	N/A	N/A	Measured absorbance in entire spectrum	21 Topicals	No
Leroy et al[13]	In vitro	10 Specimens	Normal appearing	2500-W Xenon arc lamp	Vaseline oil	Yes
Hoffmann et al[14]	Ex vivo	20 Skin samples	Normal appearing	280- to 390-nm UV	Vaseline	Yes
Farr et al[15]	In vivo	10 Plaques	Psoriatic	900-W Xenon arc lamp	Glycerin	Yes
Behrens-Williams et al[16]	In vivo	10	Normal appearing	Broadband UVB	*Unguentum emulsificans*	Yes
Hecker and Lebwohl[26]	In vivo	20	Psoriatic	Broadband UVB	Calcipotriene Mineral oil	Yes
Lebwohl et al[17]	In vivo	10	Psoriatic	Broadband UVB PUVA	0.005% Calcipotriol	Varied
Lebwohl et al[18]	In vivo	20	Normal appearing	Broadband UVB	5% CCT	No
					6% Salicylic acid	No
					Mineral oil	Yes
					Clear liquid emollient	Yes
					Cream emollient	No
					Petrolatum	No
Fetil et al[19]	In vivo	35	Normal appearing	Broadband UVB	White petrolatum 20% Salicylic acid	No
Hudson-Peacock et al[23]	In vitro	N/A	N/A	Measured MPF and EPF	All emollients in BNF	N/A
Fetil et al[24]	In vivo	20	Normal appearing	Broadband UVB	0.005% Calcipotriol	No
					0.05% Clobetasol-17-proprioneate	No
					0.1% Tretinoin	No
Kristensen and Kristensen[20]	In vitro double blind	38		Broadband UVB	2% Salicylic acid	No
Schleider et al[21]	In vitro	3	Normal appearing	280- to 350-nm UV	Planter's peanut oil	Yes
					Mazola corn oil	Yes
					Alpha Keri bath oil	Yes
					Mineral oil	Yes
					Johnson's baby oil	Yes
					Vaseline petroleum	No
					Petrolatum	No
					Hydrophilic ointment	No
Sutton[22]	In vivo	N/A	Normal appearing	Entire spectrum	Sunflower oil	No
Penven et al[25]	In vivo	15	Psoriatic	UVB TL01	Vaseline oil	Yes
Berne et al[27]	In vivo	43	Psoriatic	Broadband UVB	Decubal	Yes
George et al[28]	Single blind	14		PUVA	Coconut oil	No
George et al[28]	Single blind	15		UVB TL01	Coconut oil	No

BNF, British National Formulary; *CCT*, crude coal tar; *EPF*, eye protection factor; *MPF*, monochromatic protection factor; *N/A*, nonapplicable; *PUVA*, psoralen plus ultraviolet A; *SPF*, sun-protection factor; *UBV TL01*, narrow band wavelength emission at 311 to 312 nanometers within the UVB range 280 to 320 nanometers; *UV*, ultraviolet.
*In respect to increasing plaque clearance or increasing UV light penetration.

will require fewer treatment sessions and less cumulative exposure to UV radiation.

The aim of applying emollients to psoriatic plaques is to increase UV penetration and decrease UV reflectance. One technique of achieving this outcome is refractive index matching, or matching of the refractive index of the emollient to that of normal stratum corneum (nD = 1.55). This helps to limit the changes in the refractive index within the psoriatic plaques as light passes from one optic boundary to another and decreases the reflectance to that of normal-appearing skin (which is about 4%-7%).[6,8] In

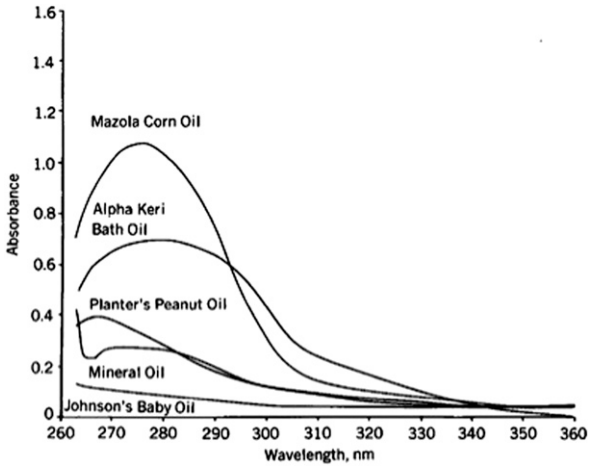

Fig 1. Absorption spectra of emollients: corn oil, bath oil, peanut oil, mineral oil, and baby oil. Reprinted with permission from Schleider et al.[21] Copyright © 1979 American Medical Association. All rights reserved.

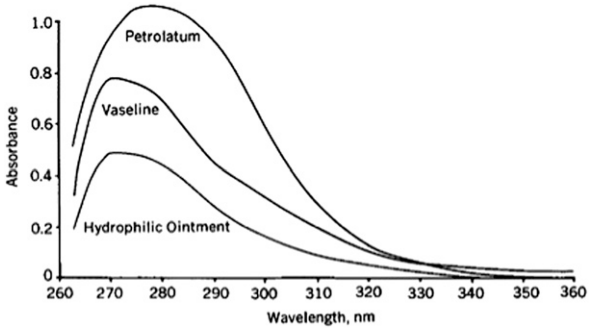

Fig 2. Absorption spectra of emollients: petrolatum, Vaseline, and hydrophilic ointment. Reprinted with permission from Schleider et al.[21] Copyright © 1979 American Medical Association. All rights reserved.

other words, refractive index matching is the idea that using clear lipophilic liquids will reduce the fraction of incident radiation that is re-emitted from the skin, and thus maximize the penetration of optical wavelengths into the psoriatic plaque.[8,29] Besides refractive index matching, other methods of altering the surface of the psoriatic plaque (eg, scale removal) have been suggested to increase UV penetration.[1]

When the refractive indexes of multiples emollients were compared, those emollients demonstrating a therapeutic effect also had a refractive index closest to that of the stratum corneum (Table III). Specifically, mineral oil, Vaseline oil, and glycerol, all of which increased UV transmission,[10,13-15,17,25-27] have a refractive index near that of normal stratum corneum. In contrast, petrolatum, salicylic acid, coconut oil, and sunflower oil, all of which decreased UV transmission,[11,18-22] have a refractive index farthest from that of normal stratum corneum.

Table III. Refractive indexes of various emollients in published literature

	Refractive index (nD)	Enhances phototherapy
Calcipotriene	1.579	Yes
Stratum corneum	1.55	N/A
Mineral oil	1.48	Yes
Glycerol	1.472	Yes
Vaseline oil	1.466	Yes
Oleic acid	1.466	Yes
Sunflower oil	1.465	No
Petrolatum	1.459	No
Coconut oil	1.448	No
Salicylic acid	1.384	No
Acetic acid	1.372	No
Air	1.00	N/A

N/A, Nonapplicable

When UV radiation is not reflected from the skin surface, it can either be absorbed or scattered.[8] Scattered radiations are re-emitted from the skin, decreasing the amount of radiation that penetrates through the skin tissue. Scattering is increased if the refractive index of the medium (ie, the skin tissue or psoriatic plaque) is not homogeneous.

On comparison of the various emollients used in phototherapy, liquid-based topical agents appeared to be more effective than thick petrolatum-based compounds. For instance, when Vaseline oil or liquid was applied before phototherapy, therapeutic benefits were generally observed.[14,25] However, when Vaseline was applied in a thicker consistency, such as Vaseline petroleum, a decrease in UV penetration was seen.[21] This difference is likely a result of the ability of liquids to seep between corneocytes and create a more homogenous skin surface inhibiting much of the refraction and scattering of UV light.

In addition to reducing the change in refractive index, an effective emollient should not block or absorb UV rays. Emollients such as mineral oil, Planter's peanut oil, and Johnson's baby oil have been shown to have very low absorbance of UV radiations and are, therefore, good emollients to use before phototherapy.[21] However, emollients such as petrolatum and Vaseline petrolatum jelly are not suggested, because these emollients have the highest absorbance of UV radiation.

Schleider et al[21] studied the balance of an emollient's UV absorbance properties and its ability to decrease reflectance and found a net benefit in using an emollient in combination with phototherapy if the amount of radiation that is prevented from being reflected by the emollient exceeds the amount of radiation absorbed by the emollient. These 2 factors should be considered with each emollient to give

Table IV. Comparing monochromatic protection factor and refractive index matching when evaluating physical properties of an emollient

MPF	Refractive index
$\text{MPF} = \frac{\text{Transmitted UV radiation WITHOUT emollient applied}}{\text{Transmitted UV radiation WITH emollient applied}}$	→ Normal stratum corneum: (nD = 1.55)
→ Effective emollient: MPF <1.2	→ Refractive index mismatch at optical boundaries increases reflectance as light goes from one optical medium into another and reduces UV penetration
→ MPF >1.2 are likely blocking UV radiation and preventing them from penetrating	→ Refractive index matching maximizes optic wavelength penetration by decreasing reflectance to that of normal-appearing skin (4%-7%) when selecting emollient with refractive index closest to that of normal-appearing skin
→ Maximizes optic wavelength penetration by selecting emollient with low ability to block UV radiations	

MPF, Monochromatic protection factor; *UV*, ultraviolet.

patients maximal benefit in treating psoriatic plaques.

In theory, emollients that increase UV penetration and enhance psoriatic plaque clearance should shorten treatment sessions, leading to less cumulative exposure to the surrounding skin to UV radiation, fewer chances of burning, and decreased risk of skin damage. Ultimately, we recommend the use of a few select emollients such as Vaseline oil, mineral oil, and glycerol, as they were all found to be phototherapy enhancing. Most other emollients are photoprotective, absorb too much UV radiation, and consequently decrease the therapeutic effect of light therapy.

CONCLUSION

After thoroughly reviewing the most recent and relevant studies on the emollients used in phototherapy, we conclude that although most emollients appear to have a negative effect on phototherapy, some emollients may provide therapeutic benefits (Table IV). Emollients may be a useful adjuvant to phototherapy only if the appropriate emollient is selected. When selecting an effective emollient to enhance phototherapy, the qualities that should be considered are the following:

1) The refractive index of the emollient should match that of the skin (nD = 1.55) as closely as possible to have the lowest fraction of incident radiation re-emitted from the skin.

2) The emollient should be liquid based and capable of seeping between the corneocytes to create a homogenous interface for incident radiation and decrease UV light refraction and scattering.

3) The emollient should have low absorptive properties to prevent the light rays from being absorbed.

4) The emollient should have MPF less than 1.2 to prevent UV light blocking.

5) The emollient should be applied at least 5 minutes before UV radiation to allow adequate time for maximal saturation through the stratum corneum.

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