Research Review™
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The Skin and Oil-based Skin Care

About the Expert

Dr Susan Simpkin
MBChB; FRACP

Dr Susan Simpkin is a Dermatologist practicing at the Skin Centre in Tauranga. She graduated from Auckland Medical School in 2006. Susan trained in Dermatology in Waikato and Auckland City Hospital before she completed her advanced training in Dermatology in the UK based in Lincoln.

Susan has a special interest in inflammatory skin diseases such as eczema and psoriasis and skin cancer diagnosis.

The purpose of this review is to raise awareness of the benefits of topical oils in maintaining skin health and appearance, with a focus on mineral oil (paraffinum liquidum) and plant oils. The biology of the skin and the role of oils in skin care products that are used for skin moisturisation and improving the appearance of scars and stretch marks is also outlined. The intended audience for this educational resource is general practitioners, general practice nurses, pharmacists, and midwives.

Background

As the largest organ in the human body the skin serves many biological functions, some of which are essential for survival. Functions attributable to the skin include:[1,2]

- Protecting the body from environmental insults.
- Restricting water loss from the body.
- Contributing to metabolic processes.
- Thermoregulation.
- Participating in immunological processes.
- Sensory perception.

The importance of these biological functions in overall human wellbeing emphasises the need to maintain the integrity and inherent health of the skin. A key factor in sustaining skin health is preservation of skin barrier function. For example, impaired skin barrier function plays a role in the pathology of dry skin (xerosis) and eczema (dermatitis).[3,4]

Skin barrier structure and function

Skin barrier function resides primarily with the outermost layer of the epidermis, the stratum corneum (SC). The primary role of the SC is to prevent the entry of harmful substances and pathogens into the skin and underlying tissues at the same time as preventing the exit of water from the skin and tissues.[3,5,6]

The competency of the skin's barrier function is dependent on the unique structure and composition of the SC.[3,6] The SC is composed of protein-rich corneocytes surrounded by a continuous phase of lipids. Corneocytes are fully differentiated keratinocytes (skin cells), which are tightly parcelled into bundles.[2,3,7] To maintain their hydration, the corneocytes produce natural moisturising factor (NMF), which is a mixture of moisture-absorbing (hygroscopic) compounds.[7,8] The continuous lipid phase is a mixture of water-repelling (hydrophobic) ceramides, cholesterol, and free fatty acids, which form an intercellular lipid matrix.[2,3] The structure of the SC has been likened to a brick wall, with the corneocytes being the bricks and the intercellular lipid matrix serving as the cement.[2]

A lack of moisture can undermine the structural integrity and functionality of the SC.[9,10] The retention of water in the SC is dependent on two major factors:

1. The presence of water-absorbing NMF within the corneocytes to keep them hydrated and tightly packed; and
2. The intercellular hydrophobic lipid matrix forming a barrier to trans-epidermal water loss (TEWL).

A film of natural oil (sebum) covering the skin surface also helps to maintain the water-binding capacity of the SC and hence maintain the structural integrity and functionality of the SC.[2] Secreted by sebaceous glands, sebum is a sticky liquid that is a mixture of hydrophobic lipids, including free fatty acids, wax esters, triglycerides, and squalene.

Risk factors for dry skin

Certain individual and environmental factors can modify the water content of the SC leading to compromised SC structure and function and dry skin.[6,10] Risk factors for dry skin include:[11-13]

- Age >40 years.
- Systemic diseases, e.g. diabetes mellitus, kidney disease, hypothyroidism.
- Skin diseases, e.g. atopic dermatitis.
- Climate, e.g. cold with low humidity or dry heating.
- Occupations requiring frequent cleansing of the skin, e.g. nurses, hair stylists.
- Use of harsh cleansing products
- Long hot showers.
- Swimming often in chlorinated pools.
- Some medications, e.g. statins, retinoids, diuretics.

Skin cleansing and dry skin

Effective skin cleansing requires water and a surfactant as water alone does not remove oil-based impurities. Surfactants have the ability to solubilize fats and oils, which can then be washed away.[14,15] Traditional soaps, the alkali salts of fatty acids, are the oldest surfactants while synthetic surfactants have subsequently been developed.[16]

With repeated use, however, soaps and some synthetic surfactants (labelled 'harsh' surfactants) can damage skin proteins and solubilise skin lipids,[14,16] leading to after-wash SC barrier damage, skin dryness, and irritation. In addition, over-washing may also result in the removal of the sebum surface oil film,[15] potentially contributing to increased TEWL and skin dryness and irritation.

Traditional soaps (e.g. sodium stearate), anionic synthetic surfactants (e.g. sodium laureth sulphate), and cationic synthetic surfactants (e.g. benzalkonium chloride) are generally accepted as having the highest potential to irritate human skin.[14] Non-ionic synthetic surfactants (e.g. polyethylene glycols) are considered to have the lowest skin irritation potential.

Role of oils in skin health

As the skin is composed of both hydrophilic (e.g. water) and hydrophobic components (e.g. lipids), the maintenance of healthy skin requires both sufficient moisture and appropriate amounts and types of lipids.[2,3,17] Reduced levels of ceramides, cholesterol, and free fatty acids in the intercellular matrix lead to reduced skin moisture.

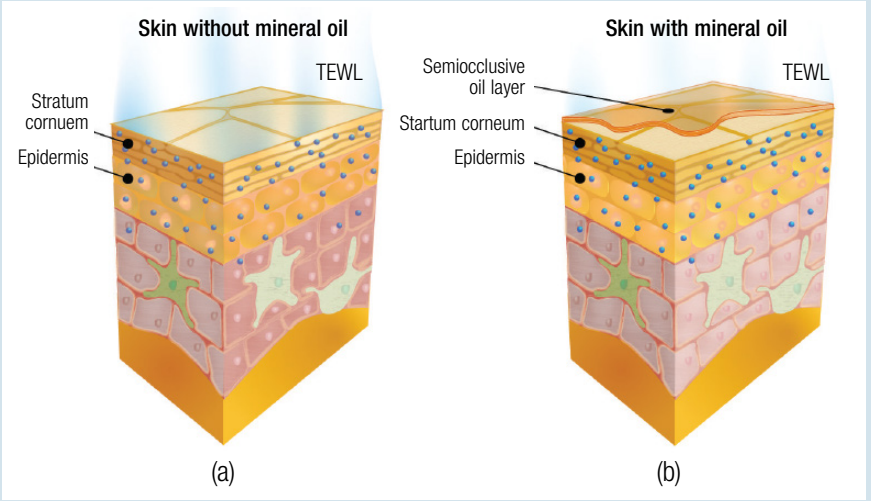

Figure 1. Depiction of skin moisture retention following the application of mineral oil.[6] Compared with skin without mineral oil (a), the application of mineral oil creates a semi-occlusive layer on the skin surface that results in lower trans-epidermal water loss (TEWL) from the stratum corneum (b).

Based on the premise that lipids in the SC help to prevent excessive TEWL,[2,5] the topical application of oils has the potential to enhance the barrier effect by adding quantitatively to the intercellular lipid matrix. Indeed, mineral oil and plant oils have been shown to penetrate into the upper layers of the SC.[18,19] However, for both mineral oil and plant oils, the most important mechanism resulting in SC moisturisation is reduction of TEWL via the formation of a thin semi-occlusive layer on the skin surface (**Figure 1**), i.e. the trapping of water in the SC by occlusion.[18-20] This is similar to one of the functions of sebum, which is to help maintain moisturisation of the SC.[2]

The occlusive effect of an oil is primarily dependent on alkyl chain length and distribution and substantivity.[21] Similar-length straight alkyl chains align to form a barrier that prevents the passage of other molecules and poor vertical and lateral diffusion of an oil leads to high substantivity.

Mineral oil and plant oils

The physical, chemical, and biological characteristics of mineral oil and plant oils are summarised in **Table 1**.[20]

The main differences between the two types of oil are:

1. Plant oils vary in their chemical composition, e.g. in the ratio of linoleic to oleic acid, and in their molecular chemistry, e.g. the presence of unsaturated aromatic groups.
2. Plant oils may have biological activity, depending the component compounds.[5,6,20]

In contrast, mineral oil is composed of mainly saturated straight chain hydrocarbons and is chemically stable and biologically inert.

The chains of saturated hydrocarbons contained in mineral oil are flexible and can incorporate themselves into the SC lipid matrix without affecting its organisation.[5] The effect of unsaturated hydrocarbons, such as those contained in free fatty acids of plant oils, varies depending on the number and position of their unsaturated bonds. For example, a destabilising effect on the SC has been reported with oleic acid (one unsaturated bond) whereas linoleic acid (two unsaturated bonds) appears to have a stabilising effect.[22-24] It has been proposed that the free oleic to linoleic acid ratio can be used as an indicator of whether a specific plant oil is suitable for skin care.[22] Currently, however, this ratio is not well established and may vary considerably for any particular plant oil, depending on the source, region, harvest time, and storage conditions.[5]

The benefits of mineral oil manifest mainly at the skin surface where its application leads to emolliency and moisturisation via occlusivity.[5,20] As a smaller and more chemically diverse class of chemicals, plant oils typically offer less occlusivity but some have biological effects that may be useful in specific applications. Mineral oil has high occlusivity due to a combination of the uniform alignment of its straight alkyl chains and its relatively high substantivity (it shows only some lateral diffusion and almost no skin penetration).[21] The occlusivity of plant oils is generalised as being 'medium' due to their variable chemical properties (**Table 1**).

Mineral oil is derived from fossilised animal material (plankton and algae) via refining and purification steps. Pharmaceutical grade mineral oil is the most refined and purified fraction of mineral oil and has approved uses as an ingredient in food, cosmetics, and pharmaceutical products.[5,20] Although mineral oil and vegetable oils are both derived from nature, the chemical process required in the production of mineral oil means that it does meet the definition of 'natural' in the context of cosmetic products.[20]

As an ingredient in skin care products, mineral oil is non-toxic and generally considered safe.[20] Long-term animal studies have demonstrated that topical exposure to mineral oil does not lead to adverse local or systemic health effects.[25,26] These observations are at least partially attributable to mineral oil not penetrating into the epidermis; the penetrability of plant oils is likely to vary due to variation in their (generally smaller) chemical structures relative to mineral oil.[20] In a series of human studies, no allergic, phototoxic, or photo-allergic responses occurred with repeated topical exposure to skin care products containing pharmaceutical-grade mineral oil.[5] The lack of allergic/atopic responses is attributable to mineral oil being biologically inert, suggesting that it can be used on atopic and allergic skin.[18,20] Contrastingly, because plant oils are not highly stable and some possess biological activity there is a risk of adverse skin reactions in the form of contact allergies.[27-29]

The findings of early animal studies suggested that mineral oil was mildly comedogenic, which fuelled the popular perception that mineral oils block skin pores leading to acne.[5,20] However, subsequent human model studies using advanced measuring methods have demonstrated that mineral oil is not comedogenic.[18,19,30] It has since been proposed that animal models are more prone to comedogenicity than human models, which may help to account for the early animal study findings.[20]

Specific characteristics of mineral oil may be advantageous in terms of maintaining the integrity of oil-based skin care products and reducing the risk of product contamination. Mineral oil is not readily metabolised by microbes because it consists of biologically-inert saturated hydrocarbons and being hydrophobic, leading to the absence of moisture, mineral oil does not support bacterial growth.[5,20] In contrast, many plant oils are unstable and degrade via hydrolysis and oxidation potentially leading to microbial growth and product

PRACTICE TIPS 1: PREVENTION OF DRY SKIN

- Take short (5–10min) baths or showers with warm (not hot) water.
- Use gentle cleansers that are alcohol-free and sodium laureth sulphate-free.
- Use water-dispersible oils in the shower or bath.
- With a towel gently pat (rather than rub) the skin, leaving it damp.

	Mineral oil	Plant oils*
Origin	• Animal (fossil plankton and algae)	• Plant
Production volume	• High	• Low to medium
Production cost	• Low	• Medium to high
Chemical stability	• Inert	• May be sensitive to oxidation and light
Biological activity	• Moisturisation	• Variable, depending on active ingredients
Toxicology	• Non-toxic, generally regarded as safe (GRAS)	• Variable, depending on active ingredients
Occlusivity	• High, due to alignment of straight alkyl chains	• Medium, due to chemical diversity
Emolliency	• High	• Variable
Comedogenicity	• Not, based on experimental findings	• Rarely
Moisturising	• Medium	• Variable, mainly medium
Substantivity	• Medium	• Variable, from low to high
Penetrability	• Low, due to molecular size of the alkyl chains	• Variable, due to smaller chemical structures vs mineral oil

Table 1. Comparison of mineral oil and plant oils in terms of certain production factors and physical, chemical, and biological characteristics related to their topical use.[20] *Given the considerable diversity of this group, this refers to the 'average' plant oil or alternatively a range is provided.

spoilage.[6] In addition, plant oil degradation products can contribute to sensitisation and contact allergies.[31-33]

There are different reasons for using mineral oil and plant oils.[20] Plant oils are generally used in skin care products in relatively small amounts to obtain a direct biological effect whereas mineral oil is used in a higher concentration for its emolliency and for its occlusivity, which facilitates skin moisturisation.

Oil-based skin care: Definitions

- Emolliency: Degree to which an oil makes the skin feel soft and smooth.
- Moisturisation: Degree to which an oil increases the moisture content of the skin.
- Comedogenicity: Tendency of an oil to block pores and cause acne.
- Substantivity: Degree to which an oil remains on the skin.
- Penetrability: Extent to which an oil penetrates the skin.
- Occlusivity: Degree to which an oil provides a semi-occlusive barrier.

Role of oils in cleansers

Surfactants are used in skin cleansers for the purpose of solubilizing and aiding the removal of excess sebum and skin oils.[16,34,35] However, surfactants also have a propensity to damage skin protein structures and solubilise natural lipids, especially fatty acids, leading to after-wash skin dryness, SC barrier damage, and irritation.

In addition to the use of less harsh non-ionic surfactants, the incorporation of 'mildness enhancers' and moisturising agents, such as physiologically-relevant lipids, occlusives, or humectants (substances that reduce moisture loss) into skin cleansers is a commonly employed means of minimising adverse interactions between surfactants and skin proteins and lipids thereby limiting skin damage.[16,34,35] Furthermore, these agents also replenish natural skin lipids lost during washing and facilitate skin hydration.

In a recent *in vivo* animal study, plant oil (sunflower seed oil) was more effective than mineral oil in reducing surfactant (sodium lauryl ether sulphate)-induced skin irritation.[36] This finding was attributed to the stronger interaction of the polar plant oil (versus the non-polar mineral oil) with skin proteins, which protected them from surfactant binding.

Appearance benefits of oils - scars and striae

Scars are formed as a result of fibrous tissue replacing normal skin following injury.[37,38] They are usually classified as atrophic (sunken) or hypertrophic/keloid (raised). Striae (stretch marks), which exhibit histological changes similar to scar formation, are generally considered to be a form of scarring.[39,40]

Impaired SC barrier function, including increased TEWL, is a characteristic of scarred skin.[21] Striae may possess similar SC characteristics to scars since striae development and anatomy appear to be similar to that of scar formation. Hence, approaches that improve skin barrier properties may improve the appearance of scars and striae.

Occlusive therapy is used to treat and prevent scar formation. Studies using *in vivo* hypertrophic scar models suggest that the mechanism of occlusive therapy involves reduced dermal fibrosis via hydration of epidermal keratinocytes and a combination of keratinocyte pro-fibrotic signal inhibition and anti-fibrotic signal stimulation.[41,42] These observations are supported by *in vitro* evidence that it is the direct effect of hydration through occlusion rather than the occlusive agent *per se* that modulates the effects of keratinocytes and fibroblasts in the reduction of hypertrophic scarring.[43]

Topical silicone-based products are commonly regarded as first-line agents in the management of scars.[44,45] In addition to a large number of clinical studies showing that silicone gel improves scar thickness and colour,[46] there is limited preliminary clinical evidence that a variety of other topical preparations have the potential to improve the signs and symptoms and cosmetic appearance of scars and striae.[47-50] Notwithstanding possible biological effects of the specific agents themselves, it is likely that the improvements demonstrated are also attributable to the occlusive and moisturisation effects of the products.[21,45]

One of the clinical studies of a non-silicone product was an evaluation of a vitamin A and antioxidant oil-based moisturiser, which contains pharmaceutical-grade mineral oil.[49] In the 12-week study, the oil formulation was associated with a statistically significant improvement from week 4 onwards in the appearance of striae in healthy Caucasian women (n=20) compared with a normal moisturising routine as demonstrated by subjective and objective assessment (**Figure 2**). There were no adverse reactions to the oil formulation or the women's normal products.

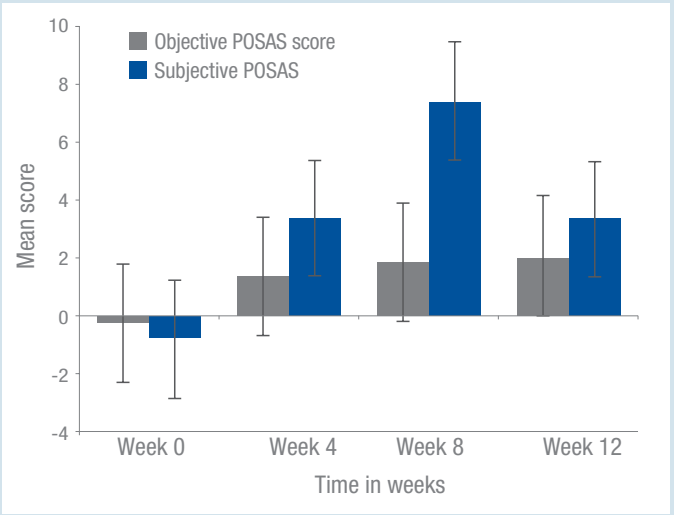

Figure 2. Mean improvement (versus a normal moisturising routine) in the appearance scores of striae treated with vitamin A and antioxidant oil-based moisturiser (Bio-Oil™) in 20 women according to objective (i.e. expert) and subjective (i.e. self) assessments using the Patient and Observer Scar Assessment Scale (POSAS).[49]

PRACTICE TIPS 2: USE OF OIL-BASED SKIN CARE PRODUCTS

- Apply to warm damp skin as soon as possible (≥3–5 mins) after showering or bathing
- Apply liberally and in downward strokes, in the direction of hairs.
- Use more frequently during winter or in low humidity environments.
- Pay particular attention to high-risk areas, i.e. lower limbs, hands, and feet.

EXPERT'S CONCLUDING COMMENTS

Plant oils are in vogue with our patients and well marketed in the beauty industry as anti-ageing moisturising natural products. Natural oils such as coconut oil, argan oil, and peppermint oil are used by many of our patients suffering from skin conditions who are seeking an alternative to emollients they have found ineffective for their dry skin or pruritus. There is a popular opinion to avoid 'chemicals' (anything considered unnatural) and fear of harmful substances on the skin. Plant oils may be tolerated without significant adverse effect; however, we should be mindful of the risk of allergic contact dermatitis, comedogenic potential, and cost to the patient. Mineral oils being less biologically active and more chemically stable have a lower risk of allergic contact dermatitis than their plant-based counterparts.

TAKE-HOME MESSAGES

- Mineral oil and plant oils are used in personal skin care products to provide occlusivity and emolliency.
- Occlusion reduces TEWL and promotes retention of moisture, which benefits SC function leading to improvements in overall skin condition.
- Pharmaceutical-grade mineral oil is biologically inert, chemically stable, and non-comedogenic.
- The properties of plant oils are more variable than those of mineral oil and their use in oil-based skin care is generally more selective.
- The occlusivity of mineral oil is higher than that of plant oils.
- Improvements in the appearance of scars and striae with oil-based skin care has been attributed to the occlusive and hydrating properties of topical oils.
- Randomised controlled trials are needed to evaluate oil-based skin care for scars and striae.

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