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The Safety and Efficacy of Petrolatum

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HISTORY

Petroleum jelly (PJ) was invented by Robert Chesebrough, a chemist, who was first inspired to investigate the properties of petroleum "wax" during a visit to the oil fields of Titusville, Pennsylvania in 1859. Chesebrough noticed that oil workers were using the waxy substance that accumulated at the top of the oil drills to help heal their cuts and burns. He brought the substance back to his lab in Brooklyn, New York, developed a procedure to purify the material, and undertook an effort to identify its utility. In 1865, Chesebrough applied for his first patent describing a triple refining process that created the PJ, or petrolatum, that we know today (1). So ardent was his belief in his "wonder jelly" that Chesebrough traveled around New York selling the semisolid from a horse-drawn cart as he purportedly burned himself. He then slathered the jelly onto his fresh wounds in front of crowds that had gathered to see his demonstrations. It was not until 1872 that Chesebrough dubbed his product Vaseline® (Unilever, Trumbull, Connecticut), from the German name for water (wasser) and the Greek word for oil (oilon) (2). The main advantage of Vaseline PJ (VPJ) versus other vegetable-based oils that were in use at the time was its stability and resistance to oxidation and hydrolysis. VPJ won numerous awards, including the grand medal at the Philadelphia Exposition of 1876 and the silver medal at the Paris Exposition of 1878. By the late 1880s, the product was so successful that production could not keep up with demand, and shortages occurred in 1885 and again in 1891 (3). At that time, Vaseline and Epsom salts shared the number one spot as the most prescribed products in a survey of pharmacists. Chesebrough survived to the age of 96 and attributed his longevity to eating a spoonful of VPJ every day (4).

COMPOSITION

PJ is an odorless, colorless, translucent, and semisolid mixture of hydrocarbons with a melting point ~37°C. It is a purified derivative of petroleum, containing a liquid hydrocarbon fraction, paraffin wax, and a microcrystalline wax (5,6). Paraffin wax contains

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mostly straight-chain alkanes of 26 to 30 carbon atoms, while the microcrystalline wax contains isoalkanes and napthene-containing alkanes of 41 to 50 carbons. Petrolatum is a viscoelastic material (both fluid and elastic properties) owing to the presence of partly crystalline lamellar sheets that trap the liquid fraction (7). Paraffin oil can be comprised of hundreds of different species, and its composition and physical properties are largely dependent on processing (6). In fact, the safety and efficacy of petrolatum is highly dependent on the refinement process (8). VPJ is the original branded version of petrolatum, and it is refined to a very high standard that removes unwanted impurities.

SAFETY

VPJ has been safely used for almost 150 years and is widely used in both cosmetic and pharmaceutical preparations (7). Petrolatum is listed as an active ingredient in the Skin Protectant Monograph for over-the-counter drugs (9) and must meet specification set by the FDA and the European Pharmacopeia (10 and references therein). Petrolatum products that meet purity tests as published in the Code of Federal Regulations are permissible in food products (FDA regulation #21CFD172.880). Thus, petrolatum is safe if ingested only when it is refined to the appropriate standards. PJ is compatible with all skin types, is fragrance-free, is nonirritating (11), is hypoallergenic, and is noncomedogenic (12,13). Despite its occlusive properties and lipidic sensories, PJ can be used to moisturize acne-prone skin without exacerbating this condition (12). Allergic reactions to petrolatum are rare because the saturated hydrocarbons are not easily oxidized or metabolized, and it is frequently used as the vehicle in irritancy, allergenicity, photoallergy, and phototoxicity testing (14). There is no evidence of cumulative irritation potential. VPJ causes no adverse reactions in skin, not only due to its high standard of processing, but also because it remains in the stratum corneum. Numerous studies have shown that the hydrocarbons contained in petrolatum remain almost entirely in the stratum corneum, with few reaching the epidermis or dermis, even when applied on acetone-treated skin (15,16). A review of *in vitro* and *in vivo* penetration studies of petroleum derivatives used in cosmetics showed no evidence of systemic exposure from topically application (10). Polycyclic aromatic hydrocarbon levels in petrolatum are very low, as mandated by the FDA regulations cited previously. Numerous studies have failed to demonstrate any toxicity or carcinogenicity of PJ (8). Petrolatum is among the most highly tested materials in the world and has a long history, which confirms the safety of this material both for topical use and by ingestion.

UTILITY IN DERMATOLOGY

PJ helps promote skin health and healing in persons with compromised skin, including dry, cracked, and chapped skin (hands, heels, lips, angular chilitis, diaper rash); atopic dermatitis (AD); eczema; and certain medical conditions. It is endorsed as a post-procedure treatment for minor wound healing and is typically considered the first line of defense against ingress of certain microbes and from external insults. Once considered nonphysiologic, VPJ is not completely inert; in fact, compared to other skin treatments, it provides several additional benefits for skin. These include skin barrier recovery acceleration (15,17), preventing infections postoperatively, and stimulating the innate immune response (17).

XEROSIS

Xerosis or dry skin is characterized by perturbed barrier function, increased transepidermal water loss (TEWL), and retention of adherent squames, which leads to the flaky appearance of cosmetically dry skin. Dry skin is best treated by use of a combination of mild cleansers and moisturizers. Moisturizers typically contain a triad of humectants, emollients, and occlusives (13), and petrolatum is one of the most common and effective occlusive agents (18). PJ forms an occlusive layer on the skin, effectively slowing water loss as measured by TEWL by more than 50%, while certain other oils reduce TEWL by less than 20% (19). Water is instead retained in the skin, thus increasing hydration (20) as evidenced by changes in skin capacitance (21). Petrolatum is the gold standard topical agent for reducing TEWL (22,14). As PJ hydrates the skin, skin suppleness and softness is improved.

Unlike other occlusive or vapor-permeable products, petrolatum jelly penetrates the stratum corneum where it diffuses into the intercellular lipid domains (15). Penetration of many other oils is limited to the upper layers of the stratum corneum (23,19). A recent study by Choe et al. (24) also observed increased stratum corneum thickness (32% average) with PJ, it but argues that this may be due to changes in increased absorption of water by corneocytes. Importantly, PJ retards water loss *without* a decrease in the lipid biosynthetic rate (25,15). This potentially increases its efficacy by facilitating the skin's own barrier recovery. Many actives have been included into moisturizing creams, claiming to provide superior benefits. However, few studies have demonstrated a superior moisturizing effect over VPJ (26).

Cosmetic dry skin may result from environmental factors, such as low humidity and cold temperatures, as well as from intrinsic factors such as age. Skin aging is associated with a degradation in skin barrier function, hence senile xerosis and pruritis are common features in the elderly population (27,28). Routine application of an effective moisturizer, such as PJ or petrolatum-based moisturizers, is critically important in maintaining optimal skin condition. Moreover, epidermal dysfunction and a poor barrier have recently been found to contribute to an increase in age-associated systemic inflammation in mice, while daily rehydration lowered levels of circulating cytokines. Maintenance of a healthy skin barrier may extend well beyond the realm of dermal health alone (29,30).

AD AND ECZEMA

AD is a common inflammatory skin disease that manifests as dry, scaly, erythematous skin. Dysregulation of the innate and adaptive immune responses contributes to the pathophysiology of AD. However, barrier dysfunction is a key feature of the disease (31). Perhaps the strongest evidence to support this later point is the finding that loss-of-function mutations in the filaggrin gene are a major predisposing factor for developing AD (32). Disruption of the skin barrier integrity allows entry of irritants, microbes, and allergens into the compromised skin, and when set in the context of a dysregulated immune setting, this can lead to the development of allergy and asthma—the so-called "atopic march."

The need for routine moisturization is a well-established part of the skin care regimen for AD suffers (33). Maintenance of an adequate barrier may reduce the need for corticosteroids or calcineurin-inhibitors (34). Studies demonstrate that mild to moderate AD can be improved with a PJ-containing emollient cream (35,36). Norman (37) recommends use

of petrolatum under gloves to be worn at bedtime for treatment of eczematous hands. Paraffin-based containing emollients are recommended for the treatment of the severely dry skin found in ichthyosis (38).

AD patients experience a higher frequency of skin infections (39,40). Thus, preservation of the barrier is important to protect against further inflammation. Interestingly, patients with AD experience many more skin infections than those afflicted with psoriasis, despite the commonality of a perturbed barrier. It has been suggested that the decreased production of antimicrobial peptides (AMPs) in AD patients may explain the increased susceptibility to skin Infection (41). Surprisingly, PJ has been found to upregulate AMP production in the skin of both healthy patients and patients with AD (17). In the Czarnowicki study, petrolatum, applied under occlusion, significantly increased gene expression of AMPs (including members of the S100 family and cathelicidin) and cytokines (IL1b, Il6, Il8, TNFa), as compared with occlusion alone (17). Increases in AMP protein levels were observed in both subjects with AD and subjects without AD, although upregulation was higher in the subjects without AD. Epidermal differentiation was also assessed in the study. Petrolatum occlusion resulted in an increase in filaggrin and loricrin protein and improvement in the overall differentiation process as assessed by hematoxylin and eosin staining. Finally, decreases in T cell and dendritic cell counts were observed in the AD cohort. The authors hypothesized that the upregulation of the Th17 pathways that underlie the increase in AMP could be mediated by upregulation of the arylhydrocarbon receptor. However, very few polyaromatic hydrocarbons remain in VPJ after purification, and topical hydrocarbons do not penetrate intact or damaged skin (16,10). Overall, the study demonstrates that the benefits of PJ in AD may extend well beyond mere moisturization.

BABY SKIN

Infant skin (i.e., 3–12 months) has been shown to have different water handling properties versus adult skin, suggesting the barrier properties of infants are not identical to those of adults. Hydration and water content are higher in infants, as measured by Raman spectroscopy and conductance measurements (42). However, in this same study by Nikolovski et al., water-holding capacity was lower, as evidenced by lower levels of natural moisturizing factors and higher TEWL (42). Thus, protecting the delicate and maturing skin of infants is important. PJ is frequently recommended to prevent diaper dermatitis (43,44) and is a favorite for use in pediatric AD (36). Additionally, it is commonly used and recommended by midwives across Africa for skin protection properties before, during, and after birth, as it can be purchased at many local stores at prices typically lower than those of baby lotions (45,46).

AD is a common chronic inflammatory skin condition that typically begins in early childhood. Prevalence is at 20% in some countries and is increasing (47). Prophylactic use of daily moisturizers from birth is now widely recognized as a cost-effective means of reducing the risk of developing AD in high-risk infants (48–50). Petrolatum was deemed the most cost-effective preventative strategy when tested on newborns at high risk of developing AD (36). Routine use of moisturizers has been shown to reduce the severity of symptoms in children with mild to moderate AD (51,52). As with adults, the proposed mechanisms for the beneficial effect of emollients in children and infants are focused on barrier repair and decreased TEWL.

However, moisturization has also been shown to improve microbial diversity and reduce colonization in patients with AD. In one study, topical treatment with PJ-containing

ointment decreased TEWL, severity of dermatitis, and bacterial colonization of axillary skin in premature infants treated twice daily (53). Studies by Glatz et al. (54) showed that early daily use of a petroleum-based emollient led to a more beneficial skin microbiome in high-risk newborns. Microbial diversity increased and more closely mirrored non-AD sites in both adults and infants with AD after emollient treatment (55). Numerous studies have shown that moisturization is useful in prevention and treatment of AD in infants and children through improvement in barrier properties and through modulation of skin microbiome. However, petrolatum and petrolatum-containing products have an additional benefit in accelerating barrier recovery and stimulating the innate immune response.

WOUND HEALING

Although commonly used for minor wounds or burns, topical antibiotic dressings do not offer any advantages over PJ alone and may cause irritation due to cross-sensitization or allergic contact dermatitis. They also present a risk for antibiotic resistance (56–59).

Petrolatum is routinely used postoperatively as an alternative to antibiotic ointments to promote wound healing and prevent infections. In a large, randomized, controlled clinical study, no significant differences in infection rates and healing characteristics were found between petrolatum and bacitracin for skin healing post-procedurally (56). Bacitracin was shown to induce allergic contact dermatitis in up to 13% of patients, whereas allergic reactions to petrolatum are rare. Bacitracin has reportedly caused contact anaphylaxis in several cases, while there have been no documented cases for VPJ (60–63). Smack and colleagues concluded that "white petrolatum is an effective, safe wound care ointment for ambulatory surgery" and furthered stated that PJ is highly cost-effective compared to antibiotic ointments. PJ was the highest (69.4%) recommended emollient post-surgically by more than 850 members of the American College of Mohs Surgery (64). In a small comparative study of patients who had undergone Mohs surgery, the authors found that the surgical wounds treated with PJ resulted in significantly less erythema (12%) than did those treated with Aquaphor® (Beiersdorf Inc., Wilton, Connecticut) healing ointment (52%). This was presumably due to differences in formulation where other allergens may have been present (65). More recently, Saco and colleagues performed a meta-analysis and found no significant difference in postoperative wound infection rates between topical antibiotics and petrolatum/paraffin (66).

PJ is also indicated for treatment of partial thickness burns. In one clinical study, it was as effective as silver sulfadiazine as measured by time to reepithelialization and incidence of infection and contact dermatitis, and it was significantly better than silver sulfadiazine gauze dressing for wound adherence and ease of use (65,67). The authors concluded that PJ was a cost-effective alternative for minor superficial partial thickness burns. In patients with extensive burn wounds, application of a petrolatum-based moisture dressing for microskin autografting on granular tissue showed improvement in cosmetic appearance, with less blood loss, shorter surgical duration, and lower cost of surgery (68).

Treatment for toxic epidermal necrolysis wounds by gauze infused with PJ was found to be a good alternative for disease management, decreasing pain without impacting wound healing time as compared with more expensive treatments (69). Petrolatum was equally effective in prevention of postoperative auricular suppurative chondritis as gentamicin. Campbell et al. concluded it was cost-effective and potentially less irritating (58).

VPJ has been found useful in multiple skin-healing applications. PJ is considered a moisturizer with therapeutic attributes because it creates a highly occlusive, semipermeable barrier that allows for exchange of water and oxygen. This contrasts with the application of higher occlusion products, such as certain polymers, that likely impair barrier function (25,15). These examples establish petrolatum as a safe and effective wound care agent, with a similarly low infection rate and minimal risk for inducing allergies.

OTHER APPLICATIONS

PF is not just restricted to leave-on care applications. It has also been tested in cleansing formulations for mildness benefits. In a clinical trial involving subjects with moderate xerotic eczema, those using a petrolatum-delivering bodywash demonstrated enhanced clinical benefits over conventional cleansing systems (70). Furthermore, in a study involving subjects with moderately dry legs, use of a petrolatum-containing bodywash had positive benefits on stratum corneum health, such as hydration and biomarkers including improved cohesion as measured by tape stripping (71). Petrolatum has also been used as an emollient in hair care to coat the hair fibers, thus repelling water loss and maintaining style integrity. Additionally, pomades consisting of petrolatum are applied directly to the scalp, typically before harsher treatments—such as chemical hair straighteners—to mitigate irritation (72).

CONCLUSION

Petrolatum has been shown to be safe and effective for topical use and by ingestion. Its long history of use and extensive testing have demonstrated that it is nonirritating, is hypoallergenic, and has no systemic toxicity. Petrolatum is also highly efficacious in the treatment of barrier impairment and wound healing. Multiple studies have compared petrolatum's therapeutic potential to a wide assortment of other ointments, moisturizers, and oils, including those containing antibiotics or other drugs. In many of these comparisons, petrolatum was found to be comparable or superior to the other ointments and oils. Furthermore, petrolatum is highly cost-effective when compared to steroid-, calcineurin-, and antibiotic-containing ointments. Petrolatum may have some unique advantages compared with other moisturizers, because it has been shown to accelerate the skin's own barrier repair mechanisms and to stimulate aspects of the innate immune response, such as production of AMPs. Robert Chesebrough's description of PJ as a "wonder jelly" still rings true to this day.

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