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Coated Textiles in the Treatment of Atopic Dermatitis

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Abstract

Atopic dermatitis (AD) is a chronic inflammatory skin disease with increasing prevalence over the last few decades. Various factors are known to aggravate the disease. In particular, wool and synthetic fabrics with harsh textile fibres, aggressive detergents and climatic factors may exacerbate AD. Cutaneous superinfection, particularly with *Staphylococcus aureus*, is also recognized as an important factor in the elicitation and maintenance of skin inflammation and acute exacerbations of AD. The severity of AD correlates with *S. aureus* colonization of the skin. Beside the treatment of AD patients with creams and emollients, new developments in the textile industry may have therapeutic implications. Silk or silver-coated textiles show antimicrobial properties that can significantly reduce the burden of *S. aureus*, leading to a positive effect on AD. Silver products have been used as wound dressing, whereby silver has antiseptic properties, and drug resistance is hardly found. Padycare® textiles consist of micromesh material containing woven silver filaments with a total silver content of 20%. In vitro studies of these silver-coated textiles demonstrated a significant decrease in *S. aureus* and *Pseudomonas aeruginosa* as well as *Candida albicans*. Silk has been increasingly implemented in medical treatment of AD thanks to its unique smoothness that reduces irritation. Silk can be coated with antimicrobials (Dermasilk®). The combination of the smoothness of silk with an antimicrobial finish appears to make an ideal textile for patients suffering from AD.

Atopic Dermatitis and the Role of *Staphylococcus aureus*

Cutaneous superinfection, particularly with *Staphylococcus aureus*, is recognized as an important factor in the elicitation and the maintenance of skin inflammation and acute exacerbations of atopic dermatitis (AD) [1–9]. Hauser

et al. [10] showed that, in comparison to healthy individuals, AD patients have significantly more *S. aureus* colonization, even in non-lesional skin. Moreover, in lesional skin of AD patients, *S. aureus* colonization is 100–1,000 times higher than in non-lesional skin [10], and the degree of colonization is associated with disease severity [11].

Knowledge of the pathophysiological role of *S. aureus* in AD has increased during recent years. The organism produces a variety of immunomodulatory toxins with superantigen properties such as the well-characterized staphylococcal enterotoxins A–E and the toxic shock syndrome toxin 1 [12]. In addition, *S. aureus* produces enzymes that directly exhibit cytotoxic properties, e.g. haemolysins and exfoliative toxins. *S. aureus* also produces elaborate defence mechanisms against the majority of currently used antimicrobial drugs [13, 14].

The immune response of AD patients to *S. aureus* is characterized by (1) a selective hyporesponsiveness to purified *S. aureus* cell walls when measured by delayed-type hypersensitivity in skin, (2) the induction of IgE antibodies against soluble and membrane-bound antigens of *S. aureus* in patients with high serum IgE titres and (3) regional lymphadenopathy that is not correlated with impetiginization but rather high total IgE and *S. aureus* cell-wall-specific IgE [15].

Although there is controversy about topical glucocorticoid and antibiotic combination therapy with regard to their potential diametrical pharmacological properties, antibiotics as well as antiseptic substances with antistaphylococcal activity are successfully used for the treatment of AD. Indeed, the reduction of the *S. aureus* burden adds to the anti-inflammatory effect of topical corticosteroids and emollients [16–18].

Atopic Dermatitis and the Role of Textiles

New developments in the textile industry may have secondary implications on medicine and may open new avenues in certain treatment traditions. For example, special silk or silver-coated textiles show antimicrobial properties (table 1). In addition to the absorbing and air-permeable natural substances such as cotton and wool, new materials have been developed. These new fabrics typically transmit humidity across the material and thereby help to keep the skin dry. This property may be beneficial in preventing fungal infections [19]. Likewise, textiles with antimicrobial coatings may be further means to prevent such infections. For instance, the admixture of chitosan to cotton fibres can be used to manufacture fabrics with antimicrobial properties.

Knittel et al. [20] published a report that describes new methods to modify the surface of textiles used near the skin. These modifications can readily be added to the conventional procedures of textile finishing, e.g. by using cyclodextrins or

Table 1. Silver-coated textile in comparison with silk fabric in the treatment of AD

Textile	Silver	Silk
Examples	Padycare®	Dermasilk®
Mode of action	Silver ions seem to cause a detachment of the cytoplasmic membrane from the bacterial cell wall; the existence of elements of silver and sulphur in the electron-dense granules and cytoplasm suggest the antibacterial mechanism of silver by loss of the ability of DNA replication and protein inactivation after Ag^+ treatment	Silk properties thanks to an exclusive water-resistant treatment with Aegis ADM 5772/5, a durable antimicrobial finish for textile products that prevents odour and the survival of bacteria including *S. aureus*; it is based on the compound alkoxysilane quaternary ammonium → antibacterial (anti-germ)
Advantages	Broad-spectrum antibiotics, not yet associated with drug resistance (almost)	Allows the skin to breathe, high capacity to absorb sweat
Side-effects	–	–
Effects	Highly significant decrease in *S. aureus* colonization shown already after 2 days in children with AD	Dressing can be easily produced and sterilized, and also enhances collagen synthesis, reduces oedema and scarring due to inflammatory responses and promotes epithelialization

linear carbohydrate biopolymers that can be covalently attached to the textile, in order to allow frequent use and washing. Also Sander and Elsner [19] described the effect of antimicrobial textiles based on the admixture or treatment of the textile fibres with bactericidal chemicals or the subsequent applying of active substances. Textiles that have this antimicrobial finish prevent the bacterial metabolism of sweat components and can therefore prevent odour formation [20].

The defect of the skin barrier is assumed to play an important role in the pathogenesis of AD [21], as protection of the skin against exposure to irritants is reduced. Patients with AD often complain of itching when wearing woollen clothes. The itching is likely to be caused by the rather spiky nature of the wool fibres. Due to this phenomenon, parents of children suffering from AD are often advised to use cotton clothes for their children. However, recent studies have suggested that cotton may also irritate the skin of children affected by AD [22, 23].

Cotton is made up of many short fibres (1–3 cm) with flattened and irregular sections. Absorption and transfer of humidity occur by extension and contraction of the single fibres producing a movement that may irritate the skin. Novel textile materials can diminish this type of physical movement and thereby disrupt the itch-and-scratch cycles.

Silver

Since ancient times silver has been highly regarded as a versatile healing tool. In ancient Greece, Rome, Phoenicia and Macedonia, silver was used extensively to control infections and spoilage. Hippocrates taught that silver healed wounds and controlled disease. The popularity of medicinal silver especially arose throughout the mediaeval Middle East where it was widely used and esteemed for blood purification, heart conditions and to control halitosis. Paracelsus (approx. 1520) extensively used silver medicinally, and, following him, silver nitrate was successfully applied in the treatment of chorea and syphilis. In the 1800s, the antibacterial properties of silver were further described and clinically demonstrated. More recently, silver products have been investigated with special regard to wound-healing properties [24], whereby silver appears to have two key advantages: it is a broad-spectrum antibiotic [25], and drug resistance is hardly found [26]. Silver-coated materials are also routinely used in surgery (external fixation), urology (catheter) or odontology [27–29]. For the topical therapy of venous legs, Wunderlich and Orfanos [30] showed that a consistent therapy performed with dry wound dressings containing silver is superior to the conventional treatment without silver-containing dressings.

The antibacterial mechanism of action of silver is not yet fully understood, but silver ions seem to cause a detachment of the cytoplasmic membrane from the bacterial cell wall [31]. The existence of elements of silver and sulphur in the electron-dense granules and in the cytoplasm suggests that the antibacterial mechanism of silver may be impaired DNA replication and protein activation [31].

Padycare® textiles consist of micromesh material containing woven silver filaments with a total silver content of 20%. In vitro studies of these silver-coated textiles demonstrated a significant decrease in bacteria (*S. aureus* and *Pseudomonas aeruginosa*) as well as *Candida albicans* [24].

Gauger et al. [32] compared treatment with silver-coated textiles on one arm to that of cotton on the other arm for 7 days followed by 7 days without treatment in 15 patients with generalized or localized AD. This open-label controlled side-to-side comparative trial demonstrated a highly significant decrease in *S. aureus* colonization on the side covered by the silver-coated textile already after 2 days which lasted until the end of the treatment. Even 7 days after cessation, the *S. aureus* burden remained lower when compared to baseline. In addition, significantly lower numbers of *S. aureus* were observed on the surface of the silver-coated textile as compared to that of cotton. As the results of this study showed that clinical improvement was paralleled by reduced *S. aureus* colonization, this may point towards a crucial role of antiseptic therapy in the treatment of AD. These findings are in accordance with earlier studies implying that antibiotic or antiseptic therapy facilitates a faster clearance of AD [16, 33].

Another interesting finding of the study of Gauger et al. [32] was that the reduction of staphylococcal colonization was long lasting, with reduced bacterial burden more than 7 days after wearing the antimicrobial clothes. This is in contrast to the effects seen by the antistaphylococcal dye gentian violet where cessation of therapy resulted in immediate re-colonization by *S. aureus* [16]. This suggests that intermittent, e.g. overnight, wearing of silver-coated textiles might be sufficient to sustain impairment of *S. aureus* growth.

Finally, the toxicological side-effects of silver-coated textiles appear to be limited to systemic absorption through dermal wounds [34]. However, further studies on silver absorption in patients wearing silver-coated textiles need to be performed.

Silk

Silk in its natural state consists of a single thread secreted by the silkworm and is made up of a double filament of protein material (fibroin) glued together with sericin, an allergenic and gummy substance that is normally extracted during the processing of the silk threads [35, 36]. Silk is comprised of perfectly smooth fibres that do not cause mechanical irritation of the skin. The structure of silk fibres is quite similar to that of human hair (97% proteins, 3% fat and waxy substances), thus allowing its use in surgery and also directly on scalded skin. Each silk thread is made up of many filaments more than 800 m long which are highly resistant to mechanical and thermal forces. Silk helps to maintain the body temperature, by reducing the excessive sweating and moisture loss that can worsen xerosis. Whereas silk allergy among workers in the silk industry is widely recognized, allergic reactions of consumers on a large scale have been only rarely described [37, 38], as the final silk fabrics are mostly non-allergenic [39].

A study performed by Sugihara et al. [40] in Japan examined the effects of a silk film on full-thickness skin wounds. They found that wounds dressed with sterilized silk film healed 7 days faster than those covered with traditional dressing. The silk films also enhanced collagen synthesis, reduced oedema and scarring due to inflammatory responses and promoted epithelialization. Moreover, silk has been used as suture thread for many years especially in dermatological and ophthalmic surgery [41].

The type of silk fabric generally used for clothes is not particularly useful in the care and dressing of children with AD, as such silk reduces transpiration and may cause discomfort when in direct contact with the skin. However, a new type of silk fabric made of transpiring and slightly elastic woven silk is now commercially available (Microair Dermasilk®) and may be used for the skin

care of children with AD. Woven silk allows the skin to breathe and the sensation is not skin irritating. It also has a high capacity to absorb sweat and serous exudates (up to 30% of its weight without becoming damp). The latter is important in maintaining the water balance of the skin through its emollient and soothing action. The use of sericin-free silk products would appear to alleviate the symptoms of AD in children and as such may represent a useful tool in the management of AD.

The Dermasilk also has antibacterial properties thanks to an exclusive water-resistant treatment with Aegis ADM 5772/5, a durable antimicrobial finish for textile products that prevents scent and the survival of bacteria including *S. aureus* [42]. It is based on the compound alkoxysilane quaternary ammonium. These Aegis antibacterial treatments are already utilized in the USA in many commercial products.

A study performed by Ricci et al. [43] examined the clinical effectiveness of a silk fabric in the treatment of AD. The study included 46 children aged between 4 months and 10 years with a mean age of 2 years. All children were affected by AD in accordance with the Hanifin and Rajka inclusion criteria [44]. Thirty-one children received products made of silk (Microair Dermasilk), a pure form of silk consisting exclusively of fibroin without sericin. Fifteen children in the control group received cotton clothing. No pharmacological treatment with steroids or antibiotics was permitted in either group. In addition, the local score of an area covered by the silk clothes was compared with the local score of an uncovered area in the same child. All patients were evaluated prior to and 7 days after the treatment start. At the end of the study, a significant decrease in AD severity was observed in the children wearing the silk clothes. At the same time, the improvement in the mean local score of the covered area was significantly greater than that of the uncovered area. While silk showed a statistically significant improvement of the skin, cotton showed no significant improvement; unpublished results from our group showed similar results. These data suggest that such special silk clothes may be useful in the management of AD in children.

Conclusion

The skin of children affected by AD is very sensitive and may worsen after exposure to various irritant factors. Such factors may include rough textile fibres, such as those in wool. Therefore cotton clothes have been recommended for children with AD. Also, a recent study demonstrated beneficial effects of softened fabrics on atopic skin [45], including a significantly faster recovery of irritated skin in contact with softened rather than unsoftened fabrics. Therefore,

silk has been increasingly implemented in the medical treatment of AD thanks to its unique smoothness that reduces irritation.

The severity of AD correlates with *S. aureus* colonization of the skin. Silver-coated textiles induce a highly significant reduction of the *S. aureus* burden already within 2 days and show a positive clinical effect. These findings are in accordance with earlier studies implying that antibiotic or antiseptic therapy contributes to a faster clearance of AD [33].

Therefore, the combination of the smoothness of silk fabrics with an antimicrobial finish appears to make an ideal textile for patients suffering from AD.

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