Acta Derm Venereol 2015; 95: 659–663

INVESTIGATIVE REPORT

Acid-coated Textiles (pH 5.5–6.5) – a New Therapeutic Strategy for Atopic Eczema?

Teresa JAEGER[1–3], Markus ROTHMAIER[4], Holger ZANDER[5], Johannes RING[1,2], Jan GUTERMUTH[3,6#] and Mark D. ANLIKER[1#]

[1]Dermatology/Allergy, Cantonal Hospital of St. Gallen, St. Gallen, Switzerland, [2]Department of Dermatology and Allergy Biederstein, Technische Universität München, [3]Center of Allergy and Environment (ZAUM), Technische Universität München and Helmholtz Center, Munich, Germany, [4]Empa, Swiss Federal Laboratories for Materials Testing and Research, St. Gallen, [5]Weba, Weberei Appenzell AG, Appenzell, Switzerland and [6]Department of Dermatology, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel (VUB), Brussels, Belgium

[#]These authors contributed equally to the study

Increased transepidermal water loss (TEWL) and decreased skin capacitance are characteristic features of the disturbed epidermal barrier in atopic eczema (AE). The "acid mantle", which is a slightly acidic film on the surface of the skin has led to the development of acidic emollients for skin care. In this context, the effect of citric acid-coated textiles on atopic skin has not been examined to date. A textile carrier composed of cellulose fibres was coated with a citric acid surface layer by esterification, ensuring a constant pH of 5.5–6.5. Twenty patients with AE or atopic diathesis were enrolled in the study. In a double-blind, half-side experiment, patients had to wear these textiles for 12 h a day for 14 days. On day 0 (baseline), 7 and 14, tolerability (erythema, pruritus, eczema, wearing comfort) and efficacy on skin barrier were assessed by TEWL skin hydration (corneometry/capacitance), pH and clinical scoring of eczema (SCORAD). Citric acid-coated textiles were well tolerated and improved eczema and objective parameters of skin physiology, including barrier function and a reduced skin surface pH, with potential lower pathogenic microbial colonisation. ***Key words: atopic eczema; acid-coated textiles; transepidermal water loss (TEWL); skin capacitance.***

Accepted Jun 18, 2014; Epub ahead of print Jun 23, 2014

Acta Derm Venereol 2015; 95: 659–653.

Teresa Jaeger, MD, Department of Dermatology and Allergy Biederstein, Technische Universität München, Biedersteiner Str. 29, DE-80802 Munich, Germany. E-mail: Teresa.Jaeger@lrz.tu-muenchen.de

Atopic eczema (AE) is a chronic, relapsing, pruritic inflammatory skin disease caused by an interaction of genetic background and environmental factors. Risk genes for the development of AE are associated with skin barrier defects due to filaggrin mutations, changes in the epidermal ceramide profile or tight junctions defects (1–4), and with immune genes, such as IL-4 and IL-4 receptor genes (5, 6). Skin barrier defects decrease skin hydration (capacitance) and increase transepidermal water loss (TEWL) (7, 8). Moreover, due to the impaired skin barrier and elevated pH, *Staphylococcus aureus* colonises AE skin to a high extent and aggravates AE by secretion of *S. aureus* superantigen that polyclonally activates T cells (9). Therefore, the basic therapy of AE is geared towards restoring skin barrier and reducing *S. aureus* colonisation. Improvement of AE together with *S. aureus* reduction has already been reported for silver-coated textiles (10, 11). Already 80 years ago, Schade & Marchionini (12) developed the concept of the "acid mantle", which is created when sweat and sebum combine and act as a barrier to bacteria, viruses and other potential skin contaminants. This concept has led to the development of acidic emollients for skin care. Lactic acid and various amino acids containing emollients improve healing of AE lesions (13). Moreover gloves with low pH were shown to improve hand eczema (14). *In vitro* studies demonstrated an antibacterial effect of citric acid-coated textiles (pH 5.5–6.5) against gram-positive and gram-negative bacteria (e.g. *S. aureus*, *Pseudomonas aeruginosa*) (1).

Aim of this pilot study was to evaluate the tolerability of a new citric acid-coated fabric and its impact on skin physiology, barrier function and eczema in patients with AE or atopic diathesis.

MATERIAL AND METHODS

Patient characteristics

Twenty patients (6 males and 14 females) were included in the study with an age range of 20–64 years (mean age 36.85 ± 13.04).

Inclusion criteria were a history of AE or atopic diathesis (indicated by a Diepgen-Score > 7) (mean value: 16.85 ± 5.03). Seven patients had active AE with inflammatory skin lesions. Prior to the study only emollient therapy was used.

The study was approved by the Ethics Committee of the Cantonal Hospital of St. Gallen (Switzerland) and the Swiss Agency for Therapeutic Products (Bern, Switzerland). This study was conducted according to the Declaration of Helsinki principles. All participants gave their written informed consent.

Determination of disease severity

Clinical severity of AE was assessed by the SCORAD index (severity scoring of AD, European Task Force on Atopic Dermatitis, 1993). Skin dryness was evaluated by qualitative characteristics (none, little, moderate, intense, very intense).

© 2015 The Authors. doi: 10.2340/00015555-1916
Journal Compilation © 2015 Acta Dermato-Venereologica. ISSN 0001-5555

In addition, the Diepgen-Score was calculated for defining atopic diathesis. Here, 19 atopic features (e.g. xerosis cutis, dermographism, pruritus) are assessed with 1–3 points (15).

Study design

Twenty patients with a history of AE or atopic diathesis were enrolled in the study. In a double-blind half-side experiment, patients wore textiles that were coated on one half with citric acid for 12 h a day for 2 consecutive weeks. On day 0 (baseline) and on days 7 and 14 tolerability (erythema, pruritus, wearing comfort) and efficacy (TEWL, skin capacitance, pH-value, SCORAD) were recorded (Fig. 1).

Acidification of textiles

Citric acid is an alpha hydroxy acid and it is reported to function in cosmetics as a pH adjuster, chelating agent or fragrance ingredient. Products containing alpha hydroxyl acids are marketed for a variety of purposes, such as smoothing fine lines and surface wrinkles, improving skin texture and tone, unblocking and cleansing pores. The effect on the skin depends on type and concentration of the alpha hydroxyl acids and other ingredients in the product. Safety of citric acid and alkyl citrate esters as used in cosmetics has been approved (16).

In this study a textile carrier of cellulose fibres was coated with citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid) by esterification via a natriumhypo-phosphitmonohydrate catalyser. Saturating of the textile was done with a solution of citric acid followed by drying at 150°C. Treated textiles had a pH value of about 3.98 ± 0.5. The pH value was stabile at 5.5–6.5 over up to 20 washes. There was no difference between the textile side with or without citric acid concerning appearance or smell.

Analysis of textile tolerability

The tolerability of the textiles was evaluated by qualitative characteristics using a questionnaire: (*i*) wearing comfort: very well, well, moderate, little; (*ii*) pruritus: none, little, moderate, intense, very intense; (*iii*) erythema: none, little, moderate, intense, very intense; and (*iv*) eczema: none, little, moderate, intense, very intense.

Analysis of efficacy

After an acclimatisation period of 15 to 30 min, measurement of TEWL, skin capacitance and pH value were performed at room temperature (22–25°C) and a relative humidity of 25–60%. Skin capacitance was measured using a corneometer (Courage and Khazaka electronic GmbH, Cologne, Germany). TEWL was determined using a vapometer (Delfin Technologies, Kuopio, Finland). Skin pH was analyzed using a pH meter (Courage and Khazaka electronic GmbH, Cologne, Germany).

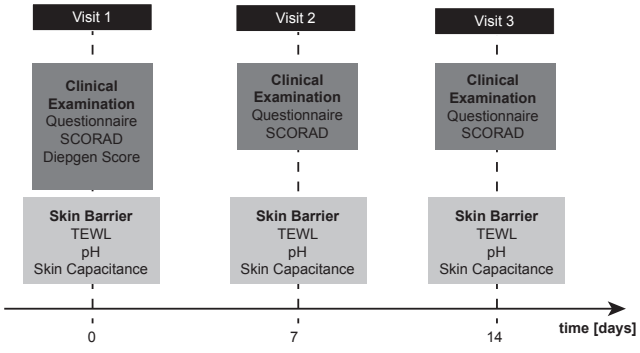

Fig. 1. Study protocol.

All measurements were taken in accordance with the manufacturer's instructions and at 3 separate sites on days 0/7/14: 1) forearm, 10 cm distal to the antecubital flexure, 2) upper arm, 10 cm distal to the antecubital flexure, and 3) upper back, 10 cm distal to the caput humeri.

Statistics

Statistical analyses were performed using SPSS 18.0 and Excel 2000. Data were expressed as mean, standard deviation, confidence interval. Student's *t*-test was used to compare the treated and non-treated site. *p*-values < 0.05 were considered significant.

RESULTS

Acid coating did not impair wearing comfort of cotton textiles

No differences were observed for wearing comfort of the acid-modified site vs. the untreated site of the cotton textile (Fig. 2). All except one patient referred the wearing comfort as very well or well. Moreover, there was no evidence for erythema, itch or eczema exacerbations.

Decrease of TEWL on acid-coated site after 7 and 14 days of textile exposure

TEWL was reduced on the citric acid-treated site compared to textile control after 7 days (statistically significant on the forearm compared to the untreated site; same trend on the other locations) (Fig. 3). On day 14 the TEWL was again lower on the treated site (Table I), but the overall conditions (very high outside temperature) had not been optimal resulting in an general higher level of TEWL value on day 14 compared to day 7 (due to increased perspiration). As expected in patients with active eczema lesions a higher TEWL was observed on both days 7 and 14 compared to patients with unaffected skin (Table I).

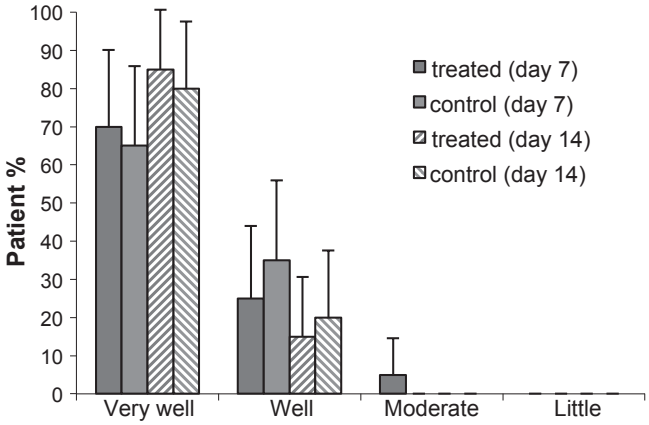

Fig. 2. Tolerability. Acid coating did not impair wearing comfort of cotton textiles. Textiles with esterificated citric acid are well-tolerated concerning pruritus, erythema, eczema and wearing comfort (CI 95%).

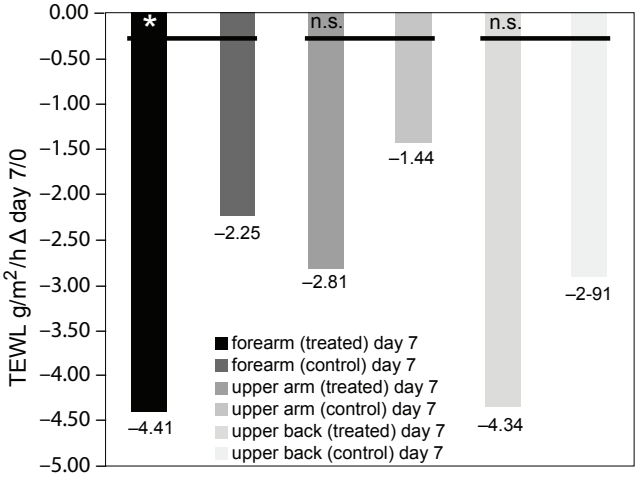

Fig. 3. Acid coated textiles reduced TEWL (Δ day 7/day 0) ($n=20$). The TEWL was reduced on the treated site compared to textile control after 7 days, statistically significant on the forearm (t-test; *significant $p<0.05$). n.s.: non-significant.

Improved skin capacitance in patients with unaffected skin

The water capacitance was higher in patients with unaffected skin, which was in accordance with previous literature (17). Due to climatic conditions with high outside temperature, the overall conditions for determination of skin capacitance had not been optimal. For this reason, acid-coated textiles did not affect skin capacitance essential (Table I).

Skin pH value showed a trend to a more acidic skin milieu after 14 days

The pH value of the skin increased slightly after one week (more pronounced in the non-treated skin than in the treated skin) (Table I). After 2 weeks a more acidic skin milieu was determined (more pronounced in the treated skin) (Table I), although the data did not reach statistic significance.

Table I. *TEWL values (g/m²/h), capacitance and pH value. TEWL was lower on the treated site. As expected in patients with active eczema lesions, a higher TEWL was observed on both days 7 and 14, compared to patients with unaffected skin. Improved skin capacitance in patients with unaffected skin. After 2 weeks a more acidic skin milieu was determined (more in the treated skin)*

	Forearm		Upper arm		Upper back	
	Treated Mean ± SD	Control Mean ± SD	Treated Mean ± SD	Control Mean ± SD	Treated Mean ± SD	Control Mean ± SD
TEWL (g/m²/h) day 0						
Active atopic eczema ($n=7$)	14.08 ± 7.42	13.4 ± 6.9	14.88 ± 8.18	13.28 ± 8.34	15.94 ± 11.97	13.03 ± 6.27
Unaffected skin ($n=13$)	16.85 ± 10.21	14.89 ± 9.15	15.13 ± 8.62	13.99 ± 8.33	18.26 ± 11.53	15.88 ± 9.38
Total ($n=20$)	15.88 ± 9.22	14.36 ± 8.27	15.04 ± 8.25	13.74 ± 8.12	17.45 ± 11.43	14.88 ± 8.36
TEWL (g/m²/h) day 7						
Active atopic eczema ($n=7$)	15.87 ± 7.26	16.70 ± 7.66	17.31 ± 8.74	17.97 ± 11.55	18.91 ± 10.37	16.25 ± 7.66
Unaffected skin ($n=13$)	9.11 ± 3.9	9.64 ± 2.73	9.49 ± 2.73	9.24 ± 3.29	9.99 ± 2.68	9.67 ± 2.36
Total ($n=20$)	11.48 ± 6.10	12.11 ± 5.93	12.23 ± 6.57	12.30 ± 8.20	13.11 ± 7.59	11.97 ± 5.70
TEWL (g/m²/h) day 14						
Active atopic eczema ($n=7$)	20.13 ± 12.39	22.74 ± 12.89	19.07 ± 11.34	20.26 ± 11.59	24.17 ± 16.03	22.66 ± 15.24
Unaffected skin ($n=13$)	17.43 ± 24.65	16.74 ± 18.91	19.58 ± 27.12	19.96 ± 21.14	21.54 ± 27.98	22.40 ± 28.71
Total ($n=20$)	18.37 ± 20.83	20.06 ± 18.02	19.40 ± 22.48	22.49 ± 24.37	22.46 ± 24.02	20.47 ± 19.32
Capacitance day 0						
Active atopic eczema ($n=7$)	62.43 ± 20.26	63.81 ± 19.57	62.95 ± 16.15	64.62 ± 19.37	75.14 ± 16.80	74.91 ± 20.88
Unaffected skin ($n=13$)	86.18 ± 14.39	85.95 ± 15.09	84.80 ± 13.16	83.02 ± 15.85	94.33 ± 11.46	96.62 ± 12.36
Total ($n=20$)	77.87 ± 19.89	78.20 ± 19.55	77.15 ± 17.49	76.59 ± 18.51	87.62 ± 16.13	89.02 ± 18.63
Capacitance day 7						
Active atopic eczema ($n=7$)	60.24 ± 21.01	48.19 ± 17.48	63.66 ± 18.57	64.76 ± 14.85	74.14 ± 20.27	75.29 ± 20.82
Unaffected skin ($n=13$)	72.82 ± 9.22	66.95 ± 8.89	71.07 ± 8.11	69.05 ± 7.85	84.20 ± 8.83	84.62 ± 6.60
Total ($n=20$)	68.42 ± 15.12	63.88 ± 12.50	68.48 ± 12.79	67.55 ± 10.63	81.03 ± 14.09	81.35 ± 13.61
Capacitance day 14						
Active atopic eczema ($n=7$)	72.95 ± 16.26	74.10 ± 15.37	77.76 ± 13.02	70.00 ± 19.91	85.48 ± 19.08	80.89 ± 15.40
Unaffected skin $n=13$)	75.26 ± 11.65	73.10 ± 14.49	76.85 ± 15.58	75.21 ± 15.44	92.05 ± 14.06	91.61 ± 13.40
Total ($n=20$)	74.45 ± 13.06	73.45 ± 14.40	77.17 ± 14.63	73.38 ± 16.79	89.75 ± 15.82	87.86 ± 14.69
pH value day 0						
Active atopic eczema ($n=7$)	5.55 ± 0.8	5.56 ± 0.83	5.51 ± 0.75	5.60 ± 0.83	5.64 ± 0.72	5.75 ± 0.81
Unaffected skin ($n=13$)	5.10 ± 0.64	5.04 ± 0.63	5.15 ± 0.67	5.13 ± 0.64	5.08 ± 0.58	5.09 ± 0.59
Total ($n=20$)	5.26 ± 0.72	5.22 ± 0.73	5.27 ± 0.71	5.30 ± 0.72	5.28 ± 0.69	5.32 ± 0.73
pH value day 7						
Active atopic eczema ($n=7$)	5.58 ± 0.72	5.60 ± 0.77	5.52 ± 0.72	5.57 ± 0.82	5.52 ± 0.76	5.64 ± 0.68
Unaffected skin ($n=13$)	5.27 ± 0.56	5.37 ± 0.64	5.34 ± 0.59	5.56 ± 0.61	5.23 ± 0.59	5.46 ± 0.57
Total ($n=20$)	5.38 ± 0.62	5.45 ± 0.68	5.42 ± 0.63	5.56 ± 0.67	5.33 ± 0.65	5.53 ± 0.60
pH value day 14						
Active atopic eczema ($n=7$)	4.97 ± 0.65	5.06 ± 0.75	5.09 ± 0.71	5.23 ± 0.83	5.23 ± 0.84	5.22 ± 0.79
Unaffected skin ($n=13$)	5.03 ± 0.71	5.12 ± 0.71	5.1 ± 0.71	5.25 ± 0.71	5.17 ± 0.66	5.28 ± 0.61
Total ($n=20$)	5.01 ± 0.67	5.10 ± 0.71	5.1 ± 0.69	5.25 ± 0.73	5.13 ± 0.71	5.26 ± 0.66

In the skin of active AE on day 0 and day 7 (treated and non-treated skin) the pH value was more alkalic compared to the unaffected skin. On day 14 the pH value in active AE was similar to the pH in unaffected skin (except on the treated upper back) (Table I).

SCORAD sub-parameters improved after 14 days

During the two-week course the SCORAD sub-parameters, skin dryness, pruritus and insomnia, as well as erythema and excoriations in active lesions were improved (Table II).

DISCUSSION

Textiles bearing esterificated citric acid were well tolerated and an improvement of objective and subjective symptoms of AE (skin dryness, pruritus, insomnia) with a decrease of the SCORAD was noted. Skin physiology measurements showed a decrease of TEWL after 7 days (significant) and 14 days (trend) on the citric acid treated site. An improved skin capacitance was observed in unaffected skin.

Over the last years, other new developments in the textile industry have shown therapeutic potential, such as silver-loaded cellulose fabric with incorporated seaweed or pure silver coated textiles. Both approaches improved TEWL, SCORAD and the patient's subjective perceptions (10, 11, 17). Also, chitosan impregnated cotton fabric or anion textile may be an addition or even an alternative to medical treatments in milder cases of AE (16, 18). Besides lactic acid and different amino acids improve healing of AE lesions (12). Moreover gloves with low pH were shown to improve hand eczema, with reduced irritation- and dryness scores (13). Already in 1928, Schade & Marchionini (12) defined the "acid mantle" of the skin and they demonstrated a reduction of *S. aureus* on the skin in acid milieu (pH 5 compared with pH 7) (11, 19).

Table II. *SCORAD. During the two-week course the SCORAD sub-parameters, skin dryness, pruritus and insomnia as well as in active lesions erythema and excoriation were improved. In patient no. 8 (unaffected skin) the SCORAD was 64.9 due to a pruritus and insomnia score of 10*

SCORAD	Day 0	Day 7	Day 14
Active eczema			
Patient no. 1	28.9	24.6	17.2
Patient no. 2	76.4	73.4	54.5
Patient no. 3	31.1	26.1	25.0
Patient no. 4	36.0	30.0	22.3
Patient no. 5	52.3	34.0	18.3
Patient no. 6	47.2	29.6	29.6
Patient no. 7	46.2	28.7	28.2
Unaffected skin			
Patient no. 8	64.9	58.9	43.4
Patient no. 9	9.0	5.5	0.0
Patient no. 10	19.5	12.0	4.5
Patient no. 11	4.5	0.0	0.0
Patient no. 12	3.5	3.5	3.5
Patient no. 13	7.0	7.0	7.0
Patient no. 14	21.0	11.0	3.5
Patient no. 15	3.5	3.5	0.0
Patient no. 16	6.5	5.5	0.0
Patient no. 17	6.5	6.5	6.5
Patient no. 18	8.5	7.5	3.0
Patient no. 19	1.4	0.0	0.0
Patient no. 20	3.5	3.5	3.5

In this study, the skin pH value showed a trend to an acid skin milieu after the two-week course of wearing a citric acid-coated shirt. In patients with active eczema lesions a higher skin pH value was detected, which was also observed on the non-treated site. The higher pH value and presumably more pronounced colonisation by *S. aureus* could be caused by missing of acidic filaggrin breakdown products like urocanic acid and pyrrolidone carboxylic acid in AE patients (20). Staphylococcal exotoxins are strong inducers of cytokines as for example IL-22 and can contribute to acute and chronic inflammation associated with AE (21). A positive correlation between higher pH value and the severity of the disease in our data is therefore in accordance with previous studies (22, 23). The low pH value of this fabric might therefore impact on the growth conditions for *S. aureus* and inhibit its expression of virulence factors, which promote inflammation (20).

The limitations of this pilot study include the number of patients and the climatic conditions with high outside temperature during the second week. Future studies should assess a longer protocol of 6 weeks, considering the duration of epidermal differentiation and an evaluation of the SCORAD in side difference. Moreover, the impact of citric-acid coating on skin colonisation with *S. aureus* should be examined in a further collective.

Taking hallmarks of AE pathogenesis, like genetic factors (e.g. filaggrin mutation), epidermal barrier impairment (water loss), high pH of the skin, bacterial colonisation (*S. aureus*) and inflammation we were looking at different factors influencing each other to a certain degree and probably leading to further aggravation or improvement of AE.

In summary, citric acid coated textiles are well tolerated, reduce itch, improve sleep and augment skin barrier. The lower skin pH might reduce microbial colonisation of atopic skin. Taken together, this citric acid-coated fabric might provide a basis for new preventive and therapeutic options in AE and needs to be further evaluated in larger patient cohorts.

The authors declare conflict of interest

REFERENCES

1. Bischof Vukušić S, Flinčec Grgac S, Budimir A, Kalenić S. Cotton textiles modified with citric acid as efficient antibacterial agent for prevention of nosocomial infections. Croat Med J 2011; 52: 68–75.

2. De Benedetto A, Rafaels NM, McGirt LY, Ivanov AI, Georgas SN, Cheadle C, et al. Tight junction defects in patients with atopic dermatitis. J Allergy Clin Immunol 2011; 127: 773–786.
3. Palmer CN, Irvine AD, Terron-Kwiatkowski A, Zhao Y, Liao H, Lee SP, et al. Common loss-of-function variants of the epidermal barrier protein filaggrin are a major predisposing factor for atopic dermatitis. Nat Genet 2006; 38: 441–446.
4. Weidinger S, O'Sullivan M, Illig T, Baurecht H, Depner M, Rodriguez E, et al. Filaggrin mutations, atopic eczema, hay fever, and asthma in children. J Allergy Clin Immunol 2008; 121: 1203–1209.
5. Ring J, Möhrenschlager M, Weidinger S. Molecular genetics of atopic eczema. Chem Immunol Allergy 2012; 96: 24–29.
6. Novak N, Kruse S, Kraft S, Geiger E, Klüken H, Fimmers R, et al. Dichotomic nature of atopic dermatitis reflected by combined analysis of monocyte immunophenotyping and single nucleotide polymorphisms of the interleukin-4/interleukin-13 receptor gene: the dichotomy of extrinsic and intrinsic atopic dermatitis. J Invest Dermatol 2002; 119: 870–875.
7. Chamlin SL, Kao J, Frieden IJ, Sheu MY, Fowler AJ, Fluhr JW, et al. Ceramide-dominant barrier repair lipids alleviate childhood atopic dermatitis: changes in barrier function provide a sensitive indicator of disease activity. J Am Acad Dermatol 2002; 47: 198–208.
8. Nemoto-Hasebe I, Akiyama M, Nomura T, Sandilands A, McLean WH, Shimizu H. Clinical severity correlates with impaired barrier in filaggrin-related eczema. J Invest Dermatol 2009; 129: 682–689.
9. Alomar A. Can microbial superantigens influence atopic dermatitis flares? Chem Immunol Allergy 2012; 96: 73–76.
10. Gauger A, Mempel M, Schekatz A, Schäfer T, Ring J, Abeck D. Silver-coated textiles reduce Staphylococcus aureus colonization in patients with atopic eczema. Dermatology 2003; 207: 15–21.
11. Gauger A, Fischer S, Mempel M, Schaefer T, Foelster-Holst R, Abeck D, Ring J. Efficacy and functionality of silver-coated textiles in patients with atopic eczema. J Eur Acad Dermatol Venereol 2006; 20: 534–541.
12. Schade H, Marchionini A. Der Säuremantel der Haut nach Gaskettenmessungen. Klin Wochenschr 1928; 7: 12–14.
13. Schmid-Grendelmeier P, Anliker MD, Brand CH, Hürlimann A, Izakovic J, Lübbe J, et al. Basis-/Begleittherapie und Prävention bei Dermatosen. Konsensus Statement. Internationale Zeitschrift für ärztliche. Fortbildung 2005; 38.
14. Mirza R, Maani N, Liu C, Kim J, Rehmus W. A randomized, controlled double-blind study of the effect of wearing coated pH 5.5 latex gloves compared with Standard powder-free latex gloves on skin pH, transepidermal water loss and skin irritation. Contact Dermatitis 2006; 55: 20–25.
15. Diepgen TL, Sauerbrei W, Fartasch M. Development and validation of diagnostic scores for atopic dermatitis incorporating criteria of data quality and practical usefulness. J Clin Epidemiol 1996; 49: 1031–1038.
16. Fiume MM, Heldreth BA, Bergfeld WF, Belsito DV, Hill RA, Klaassen CD, et al. Safety assessment of citric acid, inorganic citrate salts, and alkyl citrate esters as used in cosmetics. Int J Toxicol 2014; 33 (2 suppl): 16S–46S.
17. Kim SH, Hwang SH, Hong SK, Seo JK, Sung HS, Park SW, Shin JH. The clinical efficacy, safety and functionality of anion textile in the treatment of atopic dermatitis. Ann Dermatol 2012; 24: 438–443.
18. Park KY, Jang WS, Yang GW, Rho YH, Kim BJ, Mun SK, et al. A pilot study of silver-loaded cellulose fabric with incorporated seaweed for the treatment of atopic dermatitis. Clin Exp Dermatol 2012; 37: 512–515.
19. Tavaria FK, Soares JC, Reis IL, Paulo MH, Malcata FX, Pintado ME. Chitosan: antimicrobial action upon staphylococci after impregnation onto cotton fabric. J Appl Microbiol 2012; 112: 1034–1041.
20. Marchionini A, Pascher G, Röckl H (1963) Der pH-Wert der Hautoberfläche und seiner Bedeutung im Rahmen der Bakterienabwehr. In: Pillsbury DM, Livingood CS (Hrsg) Proceedings of the XII. Int. Congress of Dermatology. Vol 1, Int. Congress Series Nr. 55, Excerpta Medica Foundation, Amsterdam, S. 396–403.
21. Miajlovic H, Fallon PG, Irvine AD, Foster TJ. Effect of filaggrin breakdown products on growth of and protein expression by Staphylococcus aureus. J Allergy Clin Immunol 2010; 126: 1184–1190.
22. Niebuhr M, Scharonow H, Gathmann M, Mamerow D, Werfel T. Staphylococcal exotoxins are strong inducers of IL-22: A potential role in atopic dermatitis. J Allergy Clin Immunol 2010; 126: 1176–1183.
23. Eberlein-König B, Schäfer T, Huss-Marp J, Darsow U, Möhrenschlager M, Herbert O, et al. Skin surface pH, stratum corneum hydration, transepidermal water loss and skin roughness related to atopic eczema and skin dryness in a population of primary school children. Acta Derm Venereol 2000; 80: 188–191.