

'Dry' Skin in Atopic Dermatitis

II. A Surface Profilometry Study

YLVA WERNER LINDE,¹ ANDERS BENGTTSSON² and MARIE LODÉN³

¹Department of Dermatology, Södersjukhuset Stockholm, ²Department of Production Engineering, Chalmers University of Technology, Göteborg, and ³Medical Department, ACO AB, Solna, Sweden

In patients with atopic dermatitis, the skin is often 'dry' on non-eczematous areas, and feels rough to the touch. In the scanning electron microscope (SEM) this roughness corresponds to a change in the skin surface, from regular major and minor furrows into a coarse and irregular pattern. In the present study the topography of normal skin and 'dry' atopic skin was quantitatively recorded using a profilometry method. A computer-based three-dimensional reconstruction of the skin surface was made from replicas, and common roughness parameters were calculated. It was found that in the 'dry' atopic skin roughness parameters R_a , R_q , and R_{max} were significantly increased, whereas the number of peaks, R_p , was decreased. Parameters describing the shape (skewness, kurtosis, and Δa) of the profile were not significantly different. These topographical data clearly support the visual impression of the surface pattern of 'dry' atopic skin found in SEM. **Key words:** Replica technique; Scanning electron microscopy.

(Accepted March 13, 1989.)

Acta Derm Venereol (Stockh) 1989; 69: 315-319.

Y. Werner Linde, Department of Dermatology, Södersjukhuset, S-100 64 Stockholm, Sweden.

Xerosis or 'dry' skin is a commonly used description in clinical work, although it is a minor feature in the diagnostic criteria of atopic dermatitis by Hanifin & Rajka (1). More than 80% of the patients with atopic dermatitis (AD) consider their skin to be 'dry', whereas about 50% objectively have areas of 'dry' skin on clinical examination (2), defined as a rough, finely scaling non-inflamed skin surface. The feeling of roughness reflects a structural abnormality of the skin surface. In a qualitative study, this abnormality was visualized using a replica technique and SEM (2). The results indicated that there is a change in the surface morphology, from a regular pattern into a coarser and less regular one in the 'dry' atopic skin.

The aim of the present study was to obtain a quantitative description of the topography of the skin sur-

face in atopic patients with 'dry' skin. The analysis was performed using a computer controlled three-dimensional stylus-instrument system (3, 4). The method is based on the movement of a stylus across a hard replica of the skin. The electrical signals are collected and stored for a subsequent three-dimensional reconstruction of the skin surface, and for calculation of applicable mathematical parameters, which can be used to quantify the roughness.

MATERIALS AND METHODS

Patients

Ten female patients, age 18-40 years (mean 29), with atopic dermatitis according to the criteria of Hanifin & Rajka (1) participated in the study. All had 'dry' skin on the back, defined as a rough, finely scaling, non-inflamed skin surface. Ten females, age 18-40 years (mean 29), without any kind of atopy or 'dry' skin, served as controls.

A replica of the skin surface was taken from the back, according to a technique described earlier (2). A piece of silicone rubber was melted and applied to the skin surface. This negative replica was used as a cast for a hard methacrylate-based replica, used in the topographical analysis. The replicas were marked in order to facilitate the orientation in the topographical analysis.

Three-dimensional topographical analysis

A standard stylus profilometer (Perthometer C5D), together with a precision traversing table (developed at the Department of Production Engineering, Chalmers, Göteborg), (Fig. 1) were used to measure the surface (3, 4). An XT microcomputer was used to control the Perthometer table and to collect and store the data. The analogue signals ($\pm 5V$) of the vertical displacements were digitalized with a 12 bit analogue-to-digital (A/D) converter. The traces were run perpendicular to the major furrows, since previous profilometry studies have demonstrated different values of the roughness parameters depending on the directions of the scans (5, 6, 7). From each replica 75 parallel profile traces (interval 50 μm) were collected within an area of 6.0 \times 3.75 mm. Each profile trace consisted of 1024 points, i.e. the three-dimensional reconstruction of the skin surface was built up from a total of 76800 points. Prior to the analysis a mean plane was fitted to the data using the least squares method.

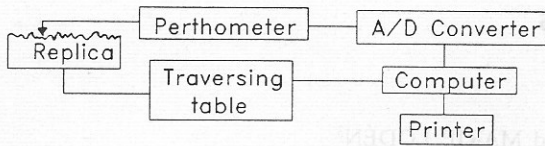


Fig. 1. Schematic drawing of the profilometry equipment used.

Roughness parameters

The surface roughness parameters were first computed for each individual profile trace, whereafter the mean values of the 75 traces on each replica were calculated. The following (International ISO Standards 4287/1) roughness parameters were calculated:

R_a (μm): The most used international parameter of roughness. This parameter comprises the arithmetic mean of the departures of the profile from the mean line.

R_q (μm): The root mean square parameter corresponding to R_a .

R_{max} (μm): The maximum peak to valley height (note: the maximum value from the 75 traces were used).

R_n : The number of peaks per cm.

Δa : The arithmetic mean slope in radians of the profile.

Skewness: The measure of the symmetry of the profile about the mean line. It is an indicator of the cumulative width of peaks in relation to the cumulative width of the furrows, i.e. of the asymmetry of the height distribution in relation to the middle line. Skewness is negative when the relief is mainly formed of broad peaks (plateaus), and positive when the furrows mainly have horizontal bases. This parameter is without unit.

Table 1. Roughness parameters in normal and 'dry' atopic skin

Mean \pm S.D., n.s. = not significant

	Normal (n=10)	Atopic skin (n=10)	Level of signifi- cance
R_a (μm)	11.9 \pm 4.4	19.5 \pm 6.2	$p < 0.05$
R_q (μm)	15.2 \pm 5.4	24.3 \pm 7.6	$p < 0.05$
R_{max} (μm)	125.7 \pm 37.8	160.5 \pm 33.4	$p < 0.05$
R_n (number of peaks/cm)	24.6 \pm 5.0	20.3 \pm 4.0	$p < 0.05$
Δa (radians)	0.48 \pm 0.21	0.68 \pm 0.22	n.s.
Skewness	- 0.31 \pm 0.08	- 0.28 \pm 0.09	n.s.
Kurtosis	3.45 \pm 0.65	3.03 \pm 0.30	n.s.

Kurtosis: A measure of the sharpness of the surface profile. Kurtosis = 3 for a Gaussian distribution. Kurtosis < 3 indicates that the base of distribution curve is wider than a Gaussian curve. This parameter is also without unit.

T_p : The bearing length is the length of bearing surface, i.e. the sum of the section lengths obtained by cutting the profile peaks by a line parallel to the mean line, within the sampling length and at a given section level of R_{max} (%). A bearing length ratio at different depths was calculated from the sum of the profile bearing lengths divided by the sum of the samplings lengths. Bearing area ratio curves were established for the two types of skin which grafically showed how the ratio varied with the percentage level of R_{max} .

Scanning electron microscopy

After the surface analysis all replicas were gold-sputtered, examined and photographed at low magnification ($\times 25$) in a scanning electron microscope (Philips SEM 515). The possible influence of the stylus instrument on the replica was studied at a higher magnification ($\times 500$).

Statistics

Wilcoxon's rank sum test was used to compare the roughness parameters between atopics and controls. The level of significance was chosen at 5% ($p < 0.05$).

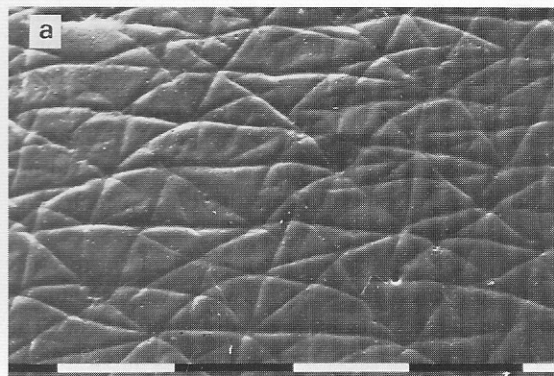
RESULTS

The roughness parameters R_a , R_q and R_{max} were significantly increased in the 'dry' atopic skin, whereas the number of peaks, R_n , was decreased. Skewness was negative in both groups. There were no significant differences in skewness, kurtosis and Δa between the two groups (Table I).

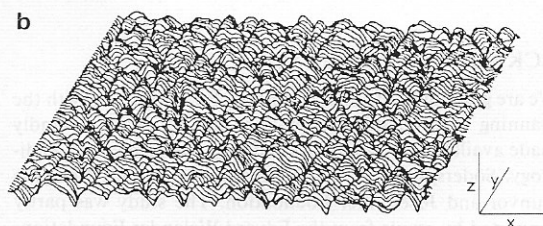
Fig. 2a shows a SEM picture of a replica from normal skin and the corresponding computer based three-dimensional reconstruction is shown in Fig. 2b. Corresponding figures from a 'dry' atopic skin are shown in Fig. 3a, b. Fig. 4a shows a typical bearing area for the analysed surface of normal skin, at the level 63% of R_{max} . A corresponding bearing area for the analysed surface of 'dry' atopic skin, at the same percentage of R_{max} , is shown in Fig. 4b. As can be seen in the figures, normal skin exhibits a regular system of furrows, whereas in the atopic skin the pattern is less regular. The difference in number of peaks and the fact that the stylus traversed the surface perpendicular to the major furrows are also illustrated.

Examination of the replicas at a high magnification in SEM showed that the stylus made minor traces on the replica.

Fig. 5 shows the graphic representation of the relationship between the mean values of the bearing area ratio and different section levels in atopic and normal

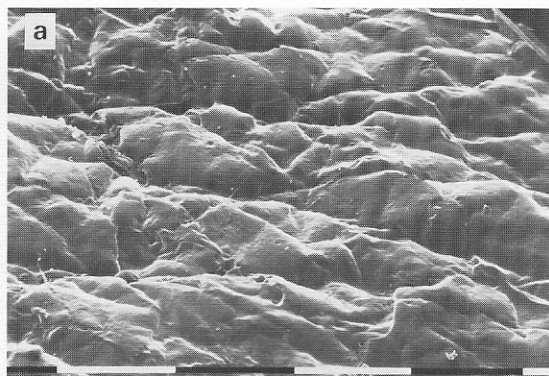


Direction of major furrows →

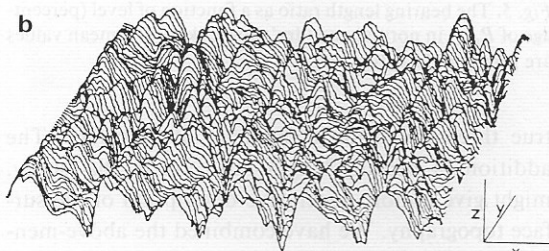


Direction of major furrows ↙

Fig. 2a. SEM micrograph of a replica from normal skin (bar 1 mm). 2b. Three-dimensional reconstruction of the same replica ($x=x9$, $y=x9$, $z=x45$). Note the difference in orientation between the two.



Direction of major furrows →



Direction of major furrows ↙

Fig. 3a. SEM micrograph of a replica from 'dry' atopic skin (bar 1 mm). 3b. Three-dimensional reconstruction of the same replica (Magnifications as in 2b). Note the difference in orientation between the two.

skin. It can be seen that the curves almost overlap when the bearing area ratio is shown in relation to R_{max} .

DISCUSSION

The skin surface is traversed by furrows which create a variety of geometric patterns on different parts of the body. In normal skin there is an orderly system of major furrows running in parallel. The major furrows of the skin surface pattern are regarded to be characteristic of the subject, the age and the location on the body, whereas the minor furrows are more sensitive to external effects, such as hydration (9). This pattern has been visualized in the SEM by the replica technique (2, 8), by light microscopy (11) and by macrophotography (9) by skin surface biopsy. In the SEM, the 'dry' skin surface of patients with atopic dermatitis shows an irregular pattern, with broad irregular running major furrows and loss of minor furrows (2).

With the introduction of profilometry it has become possible to objectively compare different condi-

tions of the skin surface. To describe the roughness of the skin surface, most investigators have used the conventional roughness parameters, e.g. R_a , R_q and R_{max} . However, these parameters do not reflect the

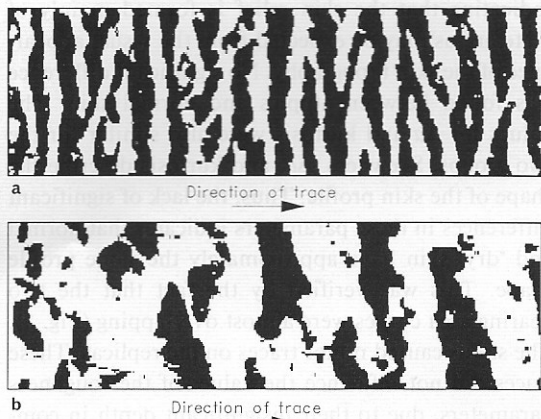


Fig. 4. The bearing area at 63% of R_{max} in a replica from (a) normal skin, and from (b) 'dry' atopic skin.

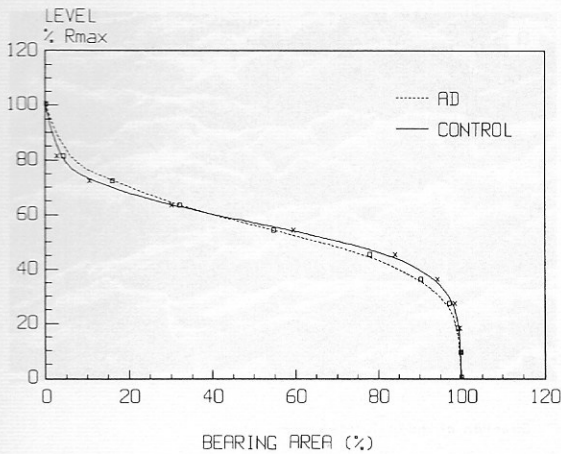


Fig. 5. The bearing length ratio as a function of level (percentage of R_{max}) in normal and 'dry' atopic skin. The mean values are presented, $n=10$.

true three-dimensional character of a surface. The addition of bearing length ratio, as in this study, might give a more conclusive description of the surface topography. We have combined the above-mentioned parameters. To our knowledge no quantitative data of the changes of 'dry' atopic skin has been performed so far. Gloor et al. (11) studied the clinically normal skin of patients with AD using profilometry. They found no difference in R_a or R_{max} compared with controls.

In the present study we found a significant increase in the roughness parameters R_a , R_q , and R_{max} in 'dry' atopic skin, whereas the number of peaks, R_n , was reduced. The results indicate that in the 'dry' skin of atopics, the peaks are fewer, but higher than in normal skin. In both groups the skewness was negative, indicating that the skin relief is formed mainly of plateaus, as may be expected from the visual appearance of the skin topography. No significant difference was found between atopics and normal skin. The values for Δa and kurtosis were also similar for the two groups. Skewness, Δa , and kurtosis describe the shape of the skin profile. Thus, the lack of significant differences in these parameters indicates that normal and 'dry' skin have approximately the same profile shape. This was verified by the fact that the two bearing area curves were almost overlapping (Fig. 5). The stylus caused minor traces on the replicas. These traces did not influence the values of the roughness parameters, due to their insignificant depth in comparison to the much larger changes in the surface profile.

The profilometry method has mostly been used in evaluation of emollients and of artificial hydration of the skin (6, 7, 8, 12). Cook & Craft (6) compared normal with 'dry' skin on the legs and found, as we also did, that the peaks, R_n , were fewer in dry than in normal skin. In contrast to our results, they did not find any significant difference in R_a between dry and normal skin.

In conclusion, by means of profilometry together with computer-aided analysis we have been able to quantitate the roughness of 'dry' atopic skin. The feeling of roughness to the touch is associated with an increase in height parameters and a decrease in the number of peaks. The 'dry' skin in patients with atopic dermatitis really seems to be rough.

ACKNOWLEDGEMENTS

We are grateful to Ms Edel Alsterborg for skilful help with the scanning electron microscopy. The microscope was kindly made available by Dr Göran Bredberg, Department of Audiology, Södersjukhuset. The microscope was a gift from the Gunvor and Josef Anér Foundation. The study was partly supported by grants from the Edvard Welander Foundation.

REFERENCES

- Hanifin JM, Rajka G. Diagnostic features of atopic dermatitis. *Acta Derm Venereol* (Stockh) 1980; suppl 92: 44-47.
- Werner Linde Y. 'Dry' skin in atopic dermatitis. A clinical study. *Acta Derm Venereol* (Stockh) 1989; 311-314.
- Bengtsson A, Rönnerberg A. The absolute measurement of running-in. *Wear* 1986; 109: 329-342.
- Bengtsson A, Rönnerberg A. Wide range three-dimensional roughness measuring system. *Precis Engng* 1984; 6: 141-147.
- Makki S, Barbenel JC, Agache P. A quantitative method for the assessment of the microtopography of human skin. *Acta Derm Venereol* (Stockh) 1979; 59: 285-291.
- Cook TH, Craft TJ. Topographics of dry skin, non-dry skin and cosmetically treated dry skin as quantified by skin profilometry. *J Soc Cosmet Chem* 1985; 36: 143-152.
- Cook TH, Craft TJ, Brunelle RL, Norris F, Griffin WA. Quantification of the skin's topography by skin profilometry. *Int J Cosmet Sci* 1982; 4: 195-205.
- Nicholls S, King CS, Marks R. Short term effects of emollients and a bath oil on the stratum corneum. *J Soc Cosmet Chem* 1978; 29: 617-624.
- Lavker RM, Kwong G, Kligman AM. Changes in the skin surface patterns with age. *J Gerontol* 1980; 35: 348-354.
- Tring FC, Murgatroyd LB. Surface microtopography of normal human skin. *Arch Dermatol* 1974; 109: 223-226.

11. Gloor M, Nolzen F, Wirth H, Stuhler TH. Hautoberflächenprofil, Hautoberflächenlipide und zell-kinetische Parameter in der Epidermis. Untersuchungen an gesunden Versuchspersonen und Patienten mit neurodermitis atopica. *J Soc Cosmet Chem* 1985; 36: 153–157.

12. Mignot J, Zahouani H, Rondot D, Nardin PH. Morphological study of human skin relief. *Bioeng Skin* 1987; 3: 177–195.

METHOD

Subjects
 Six female patients (age range 17 to 35 years) who were commonly affected with chilblains of the toes and/or feet were studied. Four patients had a family history of chilblains and three a personal history of Rosacea phenomenon. Ethical committee approval was obtained as well as signed consent from each individual.

Profilometer apparatus and calibration apparatus
 The hands either feet of the patients were washed in a specially-constructed container which incorporated an UVB fluorescent lamp (Phillips TL 30W/12) arranged so that both surfaces of the digits could be irradiated simultaneously. The patients were then bathed in an ultraviolet-sterilizing solution which included zinc ions (ZnO₂ 2 mm thick). The digital platform (T. Cooper) (OXFORD) was fixed to the solution and divided into two channels by an ultraviolet opaque barrier. The profilometer was calibrated by fitting the digital platform to one channel with an ultraviolet-sterilizing solution into the other channel. The digital platform was fixed to the base in a channel with the ultraviolet-sterilizing solution and the platform was fixed to the base in a channel with the ultraviolet-sterilizing solution. The digital platform was fixed to the base in a channel with the ultraviolet-sterilizing solution and the platform was fixed to the base in a channel with the ultraviolet-sterilizing solution. The digital platform was fixed to the base in a channel with the ultraviolet-sterilizing solution and the platform was fixed to the base in a channel with the ultraviolet-sterilizing solution.

The digital platform in each channel measured using a light-emitting diode (LED) is shown in Fig. 1. It may be seen that there is a vertical ultraviolet radiation of water length between the two channels. The digital platform was fixed to the base in a channel with the ultraviolet-sterilizing solution and the platform was fixed to the base in a channel with the ultraviolet-sterilizing solution.

Patients treatment
 The treatment hand and/or foot of each patient was divided into only two-one of the (L) to receive UVB irradiation and was subjected to the treatment during (UVA). Patients were irradiated three times a week for two weeks during October 1987. The initial treatment was 2 min (UV dose of 0.154 J/cm²). This was increased at each visit to show for recommendation and that on the last irradiation the dose

A randomized double-blind study was carried out to assess the prophylactic value of ultraviolet irradiation in the autumn as a means of preventing the development of chilblains on the toes and fingers during the course of the winter. Placebo irradiation was applied by means of an optical filter which absorbed all ultraviolet radiation from the lamps but allowed the visible light component to be transmitted, thus giving patients the impression that both limbs were being treated. Patients were reviewed at monthly intervals during the winter. The response between patients was variable: some patients developed chilblains whilst others remained symptom free. However, in no patient did the ultraviolet treated limb differ from the untreated limb. We conclude that the ultraviolet phototherapy is of no value in the prophylaxis of chilblains. *Key words:* Profilometer, Optical filter, H. caten.

(Accepted February 28, 1989.)
 Acta Derm Venereol (Stockh) 1989; 69: 319–322
 Dr B. J. Drury, Cheshire Hospital, Chester, CH1 2TW, Great Britain

Chilblains or pernio are intermittent lesions commonly occurring in susceptible individuals as an apparent reaction to cold. It usually is thought to play a role in increasing the thermal conductivity of the skin through the exact mechanism of constriction of cutaneous vessels (1). The lesions are symptomatic of vasoconstriction which give rise to throbbing pain and itch, usually occurring at the onset of cold spells in the winter and lasting two to three weeks. The condition is usually a mild self-limiting one, with only the more symptomatic or persistent cases presenting to the medical profession. Treatment should be directed primarily towards avoidance of cold, but the use of sensible clothing and footwear.

The use of local and general ultraviolet irradiation has long been recommended for the prophylaxis and treatment of acute chilblains (2). It has been claimed that the effects of prophylactic therapy are long-lasting and afford patients protection throughout the winter (3). Among the many treatment options avail-