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

'Dry' Skin in Atopic Dermatitis

II. *A Surface Profilometry Study*

YLVA WERNER LINDE,[1] ANDERS BENGTSSON[2] and MARIE LODÉN[3]

[1]*Department of Dermatology, Södersjukhuset Stockholm,* [2]*Department of Production Engineering, Chalmers University of Technology, Göteborg, and* [3]*Medical 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_n, 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 surface 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 (± 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 6.0×3.75 mm. Each profile trace consisted of 1 024 points, i.e. the three-dimensional reconstruction of the skin surface was built up from a total of 76 800 points. Prior to the analysis a mean plane was fitted to the data using the least squares method.

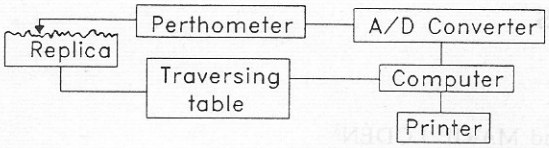


Fig. 1. Schematic drawing of the profilometry equipment used.

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 ±S.D., n.s. = not significant

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

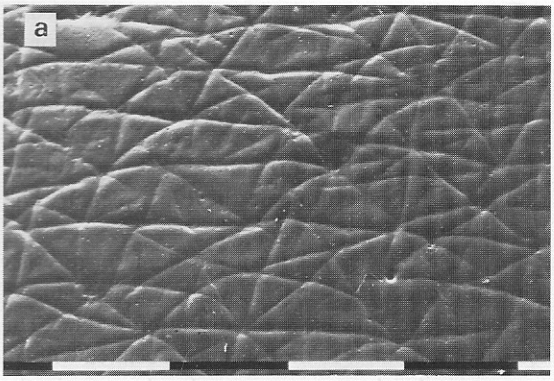
RESULTS

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. 2*a* shows a SEM picture of a replica from normal skin and the corresponding computer based three-dimensional reconstruction is shown in Fig. 2*b*. Corresponding figures from a 'dry' atopic skin are shown in Fig. 3*a*, *b*. Fig. 4*a* 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. 4*b*. 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



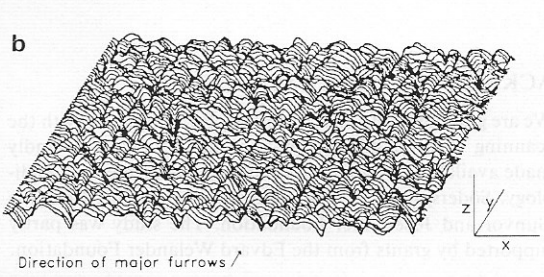
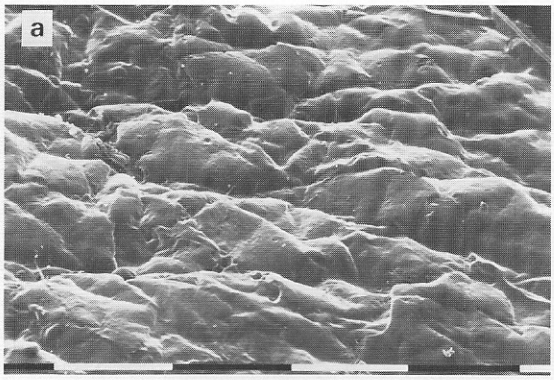


Fig. 2a. SEM micrograph of a replica from normal skin (bar 1 mm). 2*b*. Three-dimensional reconstruction of the same replica ($x=x9$, $y=x9$, $z=x45$). Note the difference in orientation between the two.



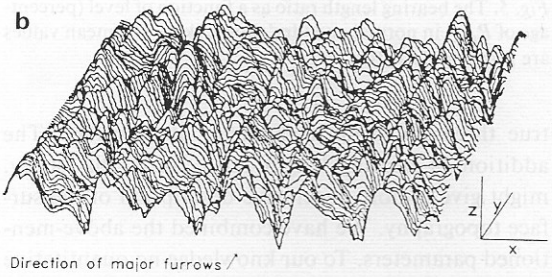


Fig. 3a. SEM micrograph of a replica from 'dry' atopic skin (bar 1 mm). 3*b*. Three-dimensional reconstruction of the same replica (Magnifications as in 2*b*). Note the difference in orientation between the two.

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 conditions 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

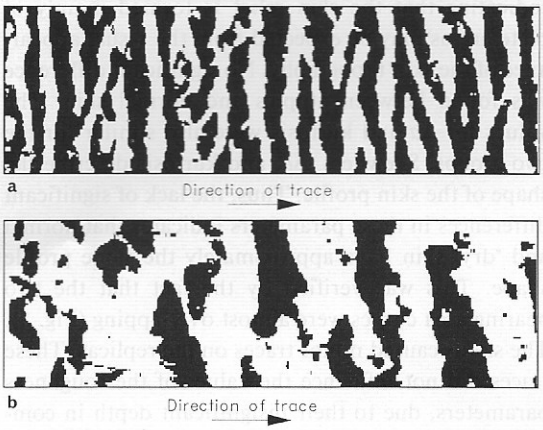


Fig. 4. The bearing area at 63% of R_{max} in a replica from (*a*) normal skin, and from (*b*) 'dry' atopic skin.

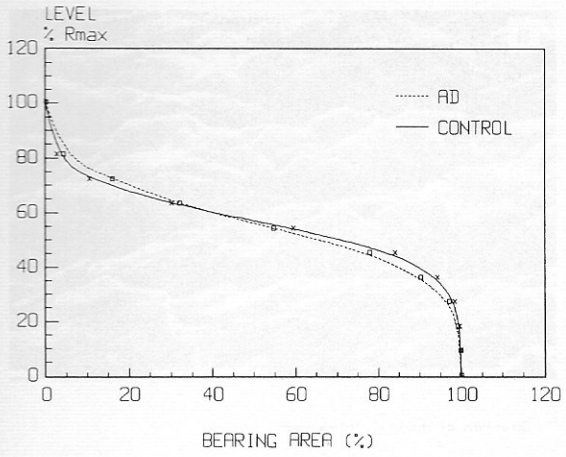


Fig. 5. The bearing length ratio as a function of level (percentage of R_{max}) in normal and 'dry' atopic skin. The mean values are presented, $n=10$.

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

1. Hanifin JM, Rajka G. Diagnostic features of atopic dermatitis. Acta Derm Venereol (Stockh) 1980; suppl 92: 44–47.
2. Werner Linde Y. 'Dry' skin in atopic dermatitis. A clinical study. Acta Derm Venereol (Stockh) 1989; 311–314.
3. Bengtsson A, Rönnberg A. The absolute measurement of running-in. Wear 1986; 109: 329–342.
4. Bengtsson A, Rönnberg A. Wide range three-dimensional roughness measuring system. Precis Engng 1984; 6: 141–147.
5. Makki S, Barbenel JC, Agache P. A quantitative method for the assessment of the microtopograhy of human skin. Acta Derm Venereol (Stockh) 1979; 59: 285–291.
6. 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.
7. 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.
8. 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.
9. Lavker RM, Kwong G, Kligman AM. Changes in the skin surface patterns with age. J Gerontol 1980; 35: 348–354.
10. Tring FC, Murgatroyd LB. Surface microtopography of normal human skin. Arch Dermatol 1974; 109: 223–226.

11. Gloor M, Nolzen F, Wirth H, Stuhlert 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.