

## INVESTIGATIVE REPORT

# *In vivo* Study of Skin Mechanical Properties in Psoriasis Vulgaris

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The aim of this study was to investigate the mechanical properties of the skin in psoriatic plaques before and after treatment with dithranol and in clinically uninvolved psoriatic skin in comparison with the skin of healthy controls. In total, 82 psoriatic plaques in 19 in-patients and 51 age-matched control subjects were studied with a non-invasive suction device (Cutometer). The plaques were characterized by statistically significant lower skin distensibility and elasticity, and a higher viscoelastic to elastic ratio compared with adjacent apparently normal skin. Delayed distension and hysteresis measured using a 2-mm diameter probe were decreased, but were increased when measured by a 8-mm diameter probe. These differences can be explained by the increased skin thickness in psoriasis and by the different aspects of skin mechanics determined by the 2 measuring probes. After treatment, the mechanical parameters of psoriatic plaques approached the values of adjacent control skin. The uninvolved volar forearm skin in psoriatic patients (2-mm diameter probe) showed statistically significant lower values of skin distensibility and higher values of viscoelasticity parameters compared with the skin of healthy control subjects. This suggests that the normal-appearing psoriatic skin is not entirely normal. The non-invasive method applied can be used for objective and quantitative evaluation of the effect of therapy in patients with psoriasis. **Key words:** psoriasis; skin elasticity; cutometer.

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Recently developed non-invasive bioengineering techniques allow an objective and quantitative assessment of the skin functions in psoriasis vulgaris. The most determined parameters are skin thickness, trans-epidermal water-loss (TEWL), blood flow and epidermal hydration (1–10). There have only been a few studies on the mechanical properties of the psoriatic skin (11–13).

The alteration in skin mechanics of the psoriatic plaques is due to increased skin thickness as a result of epidermal hyperproliferation, vasodilatation and oedema in the papillary dermis. Previous studies of patients with systemic sclerosis, scleredema and erysipelas have demonstrated that the measurements of skin elasticity and viscoelasticity with the Cutometer correlate with the skin induration and the presence of dermal oedema (14–16). They are reliable and more sensitive than clinical skin scoring systems.

The aim of the present study was to investigate, by means of a new non-invasive suction device, the mechanical properties of the skin in psoriatic plaques and in clinically uninvolved psoriatic skin in comparison with the skin of

healthy controls, and to determine the value of measuring skin elasticity in monitoring the effect of therapy with dithranol.

## MATERIAL AND METHODS

### *Patients*

Nineteen in-patients (15 men and 4 women, age range 27–82 years, mean age 50, median age 44 years) were studied after giving informed consent. The duration of the disease varied from 1 to 35 years (mean 13 years). The mean psoriasis area and severity index (PASI) was 17 (range 4–58). A total of 82 psoriatic plaques was measured, of which 52 were localized on the extremities (arm 6, elbow and dorsal forearm 15, volar forearm 17, thigh 16, cruris 5) and 23 on the trunk (upper back 9, lower back 6, chest 8).

### *Controls*

Fifty-one comparable healthy subjects (33 men and 18 women, age range 26–82 years, mean age 48, median 44 years) were studied.

### *Skin elasticity measurements*

Mechanical properties of the skin were determined with a non-invasive, *in vivo* suction skin elasticity meter (Cutometer SEM 474; Courage and Khazaka, Köln, Germany). The device was equipped with 2 measuring probes with apertures of 2 mm and 8 mm in diameter. The time/strain mode was used with a 5-s application of a vacuum of 450 mbar, followed by a 3-s relaxation period and 5 repeated suction. The skin deformation curve obtained is illustrated in Fig. 1. The following groups of mechanical parameters were analysed.

1. Absolute parameters:  $U_e$ , immediate distension;  $U_v$ , delayed distension;  $U_f$ , final distension (skin distensibility);  $U_r$ , immediate retraction;  $U_a$ , final retraction;  $R$ , residual deformation after the release of the first suction (resilient distension); and  $H$ , hysteresis, i.e. the difference in final distension between the fifth and the first suction.
2. Relative parameters:  $U_a/U_f$ , the ratio of total retraction to total distension, called gross elasticity;  $U_r/U_f$ , the ratio of immediate retraction to total distension, called biological elasticity; and  $U_v/U_e$ , the ratio of viscoelastic to elastic distension.

### *Skin score*

The severity of the cutaneous induration of psoriatic plaques was rated according to a 4-point scale (from 0 = normal to 3 = severe).

### *Study design*

All patients were investigated before and 10 patients (45 psoriatic plaques) were investigated after the treatment. Initially, salicylic acid 10% ointment was applied for 2–3 days to remove the squames. Thereafter, measurements of skin elasticity and clinical scoring of the induration were made. The therapy was continued with dithranol for

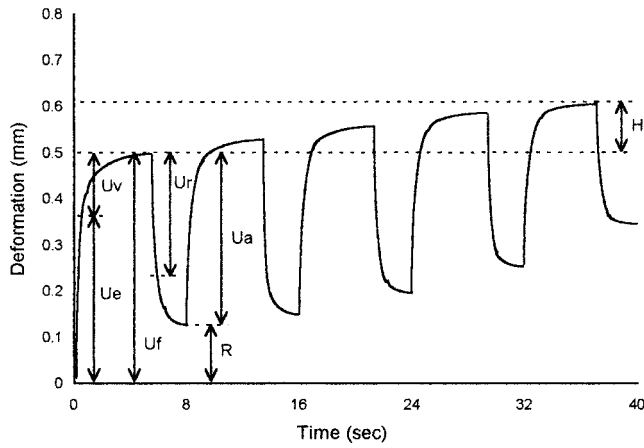


Fig. 1. Skin deformation curve obtained with the Cutometer. Ue: immediate distension; Uv: delayed distension; Uf: final distension; Ur: immediate retraction; Ua: final retraction; R: residual deformation; H: hysteresis.

11–27 days (mean 19 days). The second measurements and clinical evaluation were performed at the end of treatment. Apparently normal skin next to the each psoriatic plaque served as a control. The average values of skin mechanical parameters measured by the 2-mm diameter probe on the 2 volar forearms (centre) were compared between uninvolved skin in 17 psoriatic patients and healthy controls.

Statistical analysis

The average skin mechanical parameters of psoriatic plaques versus adjacent control areas and of uninvolved psoriatic skin versus healthy skin were analysed by an unpaired Student's *t*-test. The clinical score of induration and the mechanical parameters of psoriatic plaques before versus after treatment were analysed by the Wilcoxon test and paired Student's *t*-test. The relationship between the clinical score and Cutometer measurements was studied by the Spearman rank correlation test. A level of  $p < 0.05$  was considered statistically significant.

RESULTS

Clinical assessment

Psoriatic plaques were characterized by a mean score of induration of  $2.11 \pm 0.69$  (mean  $\pm$  SD;  $n = 82$ ). In 10 patients studied before and after treatment the initial score was  $2.27 \pm 0.62$  ( $n = 45$ ). After treatment, the induration was reduced to  $1.09 \pm 0.87$  ( $n = 45$ ;  $p < 0.001$ ).

Skin elasticity measurements

Comparison between psoriatic and adjacent clinically normal skin. Using both probes, Ue, Uf, Ur, UalUf and Ur/Uf were significantly lower and Uv/Ue was significantly higher on the psoriatic plaques. Uv and H measured by the 2-mm probe were significantly decreased, but were significantly increased when measured by the 8-mm probe (Fig. 2). The changes in R were not significant.

After treatment, there was a significant increase in Ue, Uf (2-mm probe), Ur, UalUf (8-mm probe) and Ur/Uf (8-mm probe), and a significant decrease in Uv/Ue (8-mm probe). Uv and H measured by the 2-mm probe were significantly increased, whereas they were decreased when measured by the

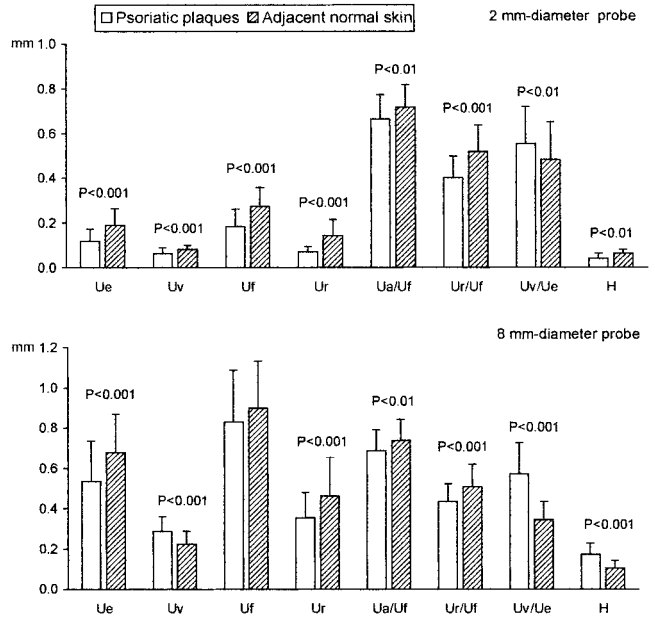


Fig. 2. Mechanical parameters of psoriatic plaques ( $n = 82$ ) and adjacent normal skin. The mean values and standard deviation are shown. *p*-Values are from *t*-tests between psoriasis and controls. For abbreviations see Fig. 1.

8-mm probe. The changes in skin mechanical parameters of the adjacent control skin were not significant except for the decrease in Ur, UalUf and Ur/Uf (2-mm probe;  $p < 0.05$ ).

Correlation between induration and mechanical parameters of psoriatic plaques. The values of Spearman correlation coefficient are presented in Table I. The induration of the psoriatic plaques significantly inversely correlated with the parameters Ue, Uf, Ur, R, H (2-mm probe) and Uv (2-mm probe), and directly correlated with the parameters UalUf (2-mm probe), Ur/Uf (2-mm probe) and Uv/Ue (8-mm probe).

Comparison between uninvolved psoriatic skin and skin of healthy controls. Using the 2-mm diameter probe, the uninvolved volar forearm skin in psoriatic patients showed sta-

Table I. Correlation between clinical score of induration and mechanical parameters of psoriatic plaques

Parameter	2-mm probe		8-mm probe	
	Spearman <i>r</i>	<i>p</i> -Value	Spearman <i>r</i>	<i>p</i> -Value
Ue	-0.4114	<0.0001	-0.3260	0.0032
Uv	-0.4960	<0.0001	0.0160	NS
Uf	-0.4423	<0.0001	-0.2535	0.0233
Ur	-0.3962	<0.0001	-0.2739	0.0140
R	-0.5465	<0.0001	-0.2234	0.0463
UalUf	0.4872	<0.0001	-0.0012	NS
Ur/Uf	0.2925	0.0052	-0.0998	NS
Uv/Ue	-0.0132	NS	0.4558	<0.0001
H	-0.5667	<0.0001	0.2160	0.0544

NS: not significant. For other abbreviations see Fig. 1.

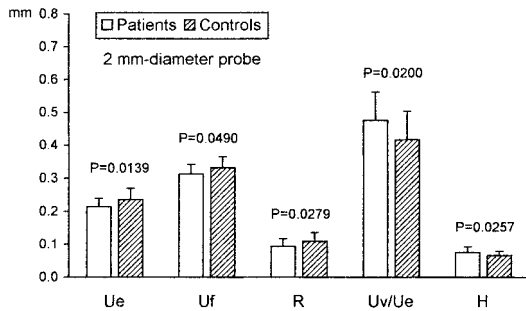


Fig. 3. Significant differences in skin mechanical parameters of uninvolved volar forearm skin in psoriatic patients ( $n=17$ ) and volar forearm skin in healthy control subjects ( $n=51$ ). The mean values, standard deviation and  $p$ -values ( $t$ -test) are shown. For abbreviations see Fig. 1.

tistically significant lower values of  $U_e$ ,  $U_f$  and  $R$ , and higher values of  $U_v/U_e$  and  $H$  in comparison with the skin of healthy control subjects (Fig. 3).

## DISCUSSION

In the present study the Cutometer was used for the first time to investigate the mechanical properties of the skin in patients with psoriasis vulgaris. Previous experience with the same skin elasticity meter had established the following general principles (14–18).

- All mechanical parameters are related to the structure and composition of the skin.
- Only the relative parameters are independent of the skin thickness and can be compared between subjects, anatomical regions and time points.
- The 2-mm probe determines the mechanical properties of the epidermis and papillary dermis, whereas the 8-mm probe determines those of the whole skin.

The present results showed that psoriatic plaques were characterized by lower  $U_e$  and  $U_f$  compared with adjacent control skin. These parameters are linked to the stretching of collagen and elastic fibres and reflect the skin's thickness and rigidity (14–18). The latter are increased in psoriasis vulgaris as a result of the epidermal hyperproliferation and the presence of oedema and vasodilatation in the dermis (4, 12, 19). The collagen and elastic fibres are stretched at rest and the skin distension is reduced. The increased skin thickness as well as the degenerative changes in the fibres network reported in psoriasis vulgaris (19) cause a decrease in elasticity parameters  $U_r$ ,  $U_v/U_e$  and  $U_r/U_f$ , i.e. a decrease in the ability of the skin to return to its initial position after deformation.

$U_v$ ,  $U_v/U_e$  and  $H$  represent the viscoelastic part of the deformation and are attributed to the displacement of the interstitial fluid, containing water and highly viscous glycosaminoglycans, throughout the fibrous network (14–18). Using both probes,  $U_v/U_e$  was increased in psoriasis vulgaris, indicating the prevalence of the viscoelastic part over the elastic part of the deformation. However, controversial changes were observed in  $U_v$  and  $H$ . These parameters measured by the 2-mm probe were decreased, while they were increased when measured by the 8-mm probe. This phenomenon can be explained by the restricted depth of measurement

with the small-diameter probe as a result of the increased epidermal thickness of the psoriatic plaques. Only the values of  $U_v$  and  $H$  measured by the large 8-mm diameter probe reflect the presence of dermal oedema in the psoriatic skin.

These results are in accordance with data reported by Serup & Northeved (12). Using a suction device (Dermaflex A; Cortex Technology, Hadsund, Denmark) equipped with a 10-mm diameter measuring probe they established a lower skin extensibility and a higher hysteresis and resilient distension of the psoriatic plaques compared with a regional control. According to Serup & Northeved, the decrease in skin distensibility is a sign of epidermal stiffness due to the elongated rete ridges, while the increase in  $H$  and  $R$  is a sign of softness explained by the oedema of the outer dermis. No significant changes in  $R$  were observed in the present study.

The present results differ from data reported by Zlatkov et al. (11). Using their own developed suction device the authors observed a decrease in skin extensibility on the psoriatic plaques after 4 weeks of heliotherapy and thalaso-therapy. However, the measurements were made using a probe with an aperture of 30 mm in diameter and thus the results of the two studies are not comparable.

Borroni et al. (13) studied changes induced by psoralen plus ultraviolet A (PUVA) in the skin of psoriatic patients by means of Dermaflex A. They found a reduction in the distensibility and elasticity of the buttock skin that is related to the photosclerosis of the papillary dermis as an early side-effect of PUVA.

Cutometer measurements correlated with the clinical score of induration. The thinning of the psoriatic plaques after treatment, i.e. the clinical improvement, was accompanied by changes in mechanical parameters towards the values of adjacent control skin. The skin distensibility ( $U_e$ ,  $U_f$ ) and elasticity ( $U_r$ ,  $U_r/U_f$ ) increased significantly, while  $U_v/U_e$  decreased significantly. Dermal oedema decreases, resulting in a decrease in  $U_v$  and  $H$  ( $p < 0.001$ ) as measured by the 8-mm probe. However, most values remained significantly abnormal. This suggests that (i) the Cutometer is more sensitive than the clinical evaluation; and (ii) a longer treatment period is necessary.

The information obtained with the 2 measuring probes is complementary. In the authors' opinion, the parameters  $U_v/U_e$  and  $H$  best characterize the psoriatic skin.  $U_v/U_e$  significantly inversely correlates with skin distensibility ( $U_e$ ,  $U_f$ ). It is a relative parameter and thus can be compared without standardization to the skin thickness. In addition, it shows similar changes as determined by the 2 probes.  $H$  measured by the 2-mm probe indirectly depends on the epidermal thickness, but when measured by the 8-mm probe directly reflects the dermal oedema of the psoriatic plaques. The changes in  $U_v/U_e$  and  $H$  can be used as indicators for the improvement of psoriasis.

Another question of interest to investigators is whether the uninvolved psoriatic skin is normal. Most of the previous studies did not reveal significant differences in blood flow (6), TEWL (7, 10), epidermal hydration (7–9), water-holding capacity (8, 9) or pH (20) between the uninvolved psoriatic skin and the skin of healthy controls. Only a few studies found statistically significant changes (5, 21, 22). The present results showed that the mechanical properties of uninvolved volar forearm skin in psoriatic patients differ significantly from these of the normal skin of healthy controls. This

suggests that some changes exist in normal-appearing psoriatic skin, mainly in the epidermis. Marks et al. (22) found ultrastructural differences in corneocytes from the paralesional areas compared with normal corneocytes. Using a Cohesograph they detected a statistically significant increased cohesion of the superficial stratum corneum in uninvolved psoriatic skin. The perilesional skin had a tougher stratum corneum than normal, in that the force required to distract a portion of corneocytes was 80% greater than for similar sites in normal controls.

In conclusion, the non-invasive and quantitative measurements of skin elasticity in patients with psoriasis vulgaris may be considered to be useful in monitoring the effect of therapy and for comparison of the efficacy of different treatment regimens.

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