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Abstract. The skin is not only the largest organ of the human body, but it is also a barrier to the environment. The major part of the human skin is in constant contact with textile materials. The objective of this study was to characterize textile materials and to investigate their influence on the skin properties. For this purpose, two different textile materials (polyamide and polyester) were objectively characterized by optical coherence tomography and surface structure 3D-profilometry. In addition, subjective textile properties like haptic sensation and stiffness, as tactile characteristics felt by volunteers, were analyzed. The objective textile characteristics and subjective parameters were compared to the barrier properties measured by *in vivo* laser scanning microscopy . Comparable results were achieved between barrier properties and subjective assessment in relation to the textile characteristics in favor of the polyester fabric. Consequently, the optical method used in dermatology for the analysis of the skin can be applied to characterize and evaluate textile fabrics and their interaction with human skin *in vivo*. [DOI: 10.1117/1.3562978]

Keywords: optical coherence tomography; laser scanning microscopy; barrier function.

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1 Introduction

The outer layer of the human skin—the stratum corneum—consists of unnucleated corneocytes.[1,2] Representing the barrier of the human organism to the environment, the stratum corneum not only prevents the body from water loss[3] and electrolytes (desiccation), but also environmental hazards[4] and micro-organisms from penetrating.[5]

The skin is a sensitive organ which is susceptible to any kind of irritation.[6] This is due to the high density of nerve cells located in the skin.[7] However, the skin sensitivity of the population can vary significantly particularly in dry or inflamed skin that might respond intensively to external mechanical stress. Such irritations are generated, inter alia, by textile materials covering the major part of the skin. Today, an ample range of manufacturing and treatment processes aimed at producing clothing textiles with advantageous skin physiological properties are available.[8] For atopic dermatitis, e.g., specific clothing has been developed.[9–11]

So far, textile fabrics have been characterized for their material properties only, such as type of material (wool, polyester, etc.), abrasion resistance, number of filaments, type of weaving, tensile strength, bending strength, elongation, and abrasion.[12] Besides various mechanical measuring methods, optical analysis techniques, such as light microscopy and electron scanning microscopy have been applied.[13] No use has been made of techniques, which identify the skin physiological properties of textile materials.

In the present study, textile materials were characterized for their skin compatibility and surface structure, noninvasive, state-of-the-art optical methods, i.e., optical coherence tomography,[14,15] 3D-surface profilometry[16] and laser scanning microscopy (LSM).[17,18] These methods are widely used in *in vivo* dermatological and cosmetological research.[19] For this purpose, two different fabrics were compared with different haptic properties according to the treatment exhibited. These materials were objectively evaluated by optical methods and, moreover, tested on volunteers to obtain a subjective haptic assessment on the skin friendliness of the samples. In a standardized rubbing experiment, the samples were then tested on the skin *in vivo*, and by subsequently analyzing changes in barrier properties with *in vivo* LSM.[20]

2 Materials and Methods

2.1 *Textile Materials*

The investigation was carried out on two different textile materials [polyamide (PA 6.6) and polyester]. The mass per unit area of the desized and thermofixed tabby weave polyester material amounted to 207.5 g/m^2. The desized tabby weave polyamide material exhibited a mass per unit area of 167.4 g/cm^2.

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2.2 *Volunteers*

The experiments were carried out on the volar forearm of 26 healthy volunteers between 20 and 50 yrs of age (mean age 35.7 yr) of both genders (8 men; 18 women). A mechanical stress test with the different textile samples and subsequent barrier assessment were performed on the forearm of six healthy volunteers. Twenty volunteers were questioned about their haptic sensations of the samples when the textiles were in contact with their skin. Approval for this study had been obtained from the Ethics Committee of the Charité–Universitätsmedizin Berlin.

2.3 *Stress Test*

The selected textile materials were tensioned on an applicator of 3×5 cm in size and 1000 g in weight. This applicator was moved 40times over a marked skin area of 4 cm ×10 cm on the volar forearm, the constant weight generating a constant pressure of the fabric onto the skin during the movement.

2.4 *Optical Coherence Tomography*

The bulk structure of the textile materials was analyzed by means of optical tomography using a "SkinDex 300" system (ISIS Optronics, Mannheim, Germany). This optical coherence tomomgraphy (OCT) system has been described in detail by Lademann et al.[14]

2.5 *Surface Profilometry*

The surface structure of the employed textile was measured with a "PRIMOS" noncontact surface 3D-profilometer (GFMesstechnik GmbH, Teltow, Germany).[16,21] This system is generally used for analyzing the skin surface structure *in vivo*. In the present study, the 3D-profilometer delivered camera images, color-coded roughness images, and roughness profiles. In addition, it determined the surface roughness arithmetically. The system has been previously described.[21]

2.6 *Laser Scanning Microscopy*

The *in vivo* LSM "Stratum" (Optilas Ltd., Melbourne, Australia) was used for analyzing the surface structure of the stratum corneum. In order to visualize the corneocyte architecture as a marker of epidermal barrier status, the fluorescent mode of the LSM was used. 0.1 mL/cm^2 of an aqueous solution containing 0.1% of the fluorescent dye, fluorescein, was applied to the skin areas of the volunteers after the standardized contact with the textile material. After an exposure time of 1 min, the excess solution was carefully removed with filter paper. The measuring area of the LSM was 260×250 μm. Each treated skin area was measured at least 4times. The system was previously described in detail by Jung et al.[22]

3 Results and Discussion

While the investigation of textile materials hitherto had exclusively been aimed at characterizing the mechanical

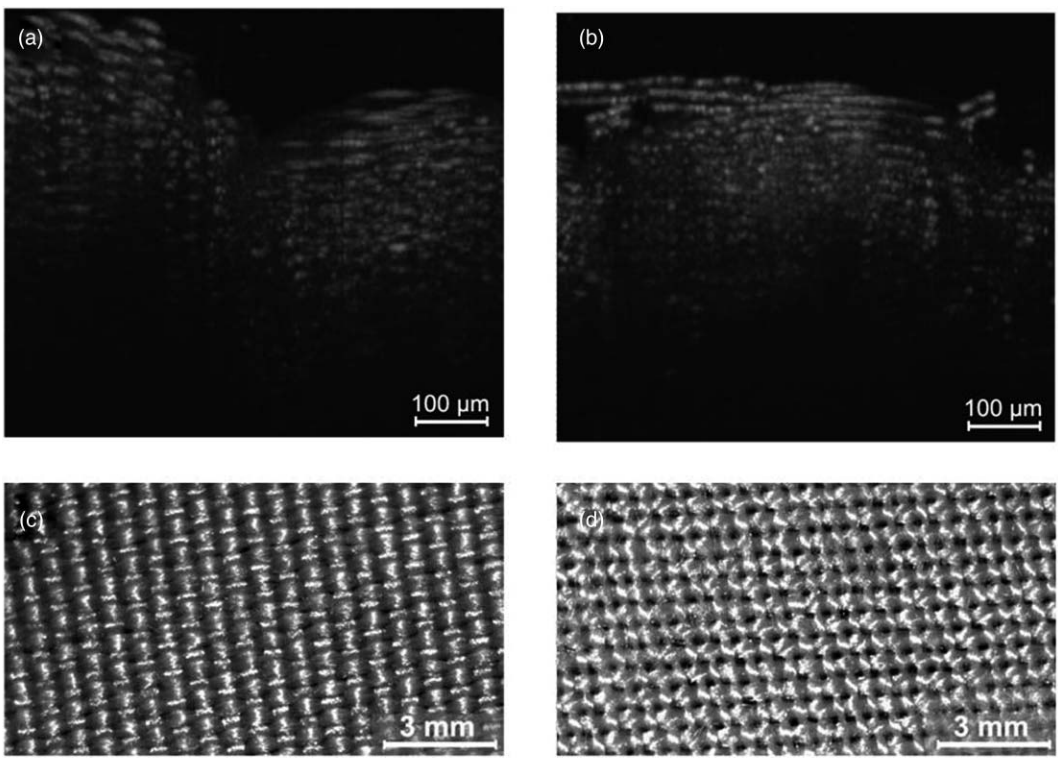

Fig. 1 (a) Characterization by optical coherence tomography OTC picture of polyamide fabric. (b) Characterization by optical coherence tomography OTC picture of polyester fabric. (c) Top view picture captured by Primos system of polyamide fabric. (d) Top view picture captured by Primos system of polyester fabric.

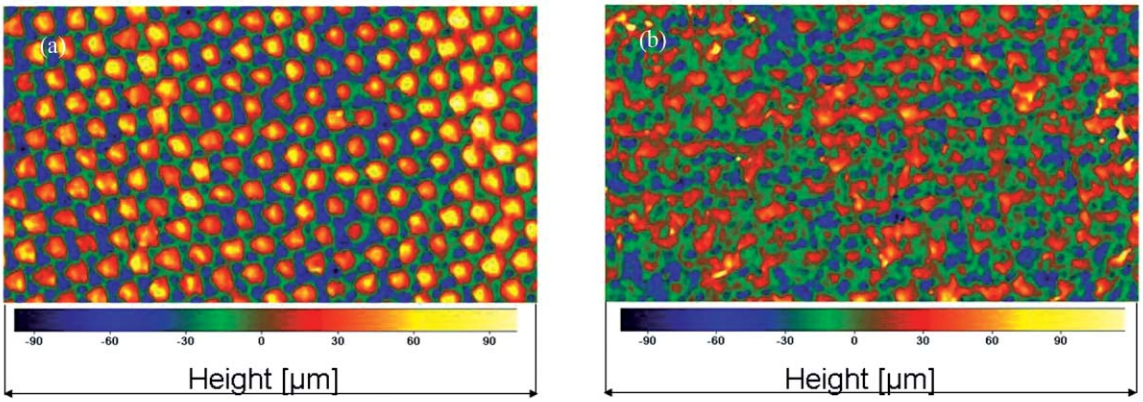

Fig. 2 (a) Surface structure 3D-profilometry with the Primos system of polyamide fabric. (b) Surface structure 3D-profilometry with the Primos system of polyester fabric.

properties of these materials, the purpose of the optical methods applied in the present study was to gain insight into characteristics of the fabric and the subsequent effect on human skin. The applied methods are standard procedures as used in dermatology and cosmetology for *in vivo* investigations on humans.

Figures 1(a) and 1(b) represent OCT images of the polyamide and the polyester fabric cross sections. It is visible that the bulk structure of the polyamide fabric [Fig. 1(a)] is essentially rougher than that of the polyester fabric [Fig. 1(b)]. On the photos of the two textile materials [Figs. 1(c) and 1(d)] taken with the PRIMOS surface 3D-profilometer, differences in structures

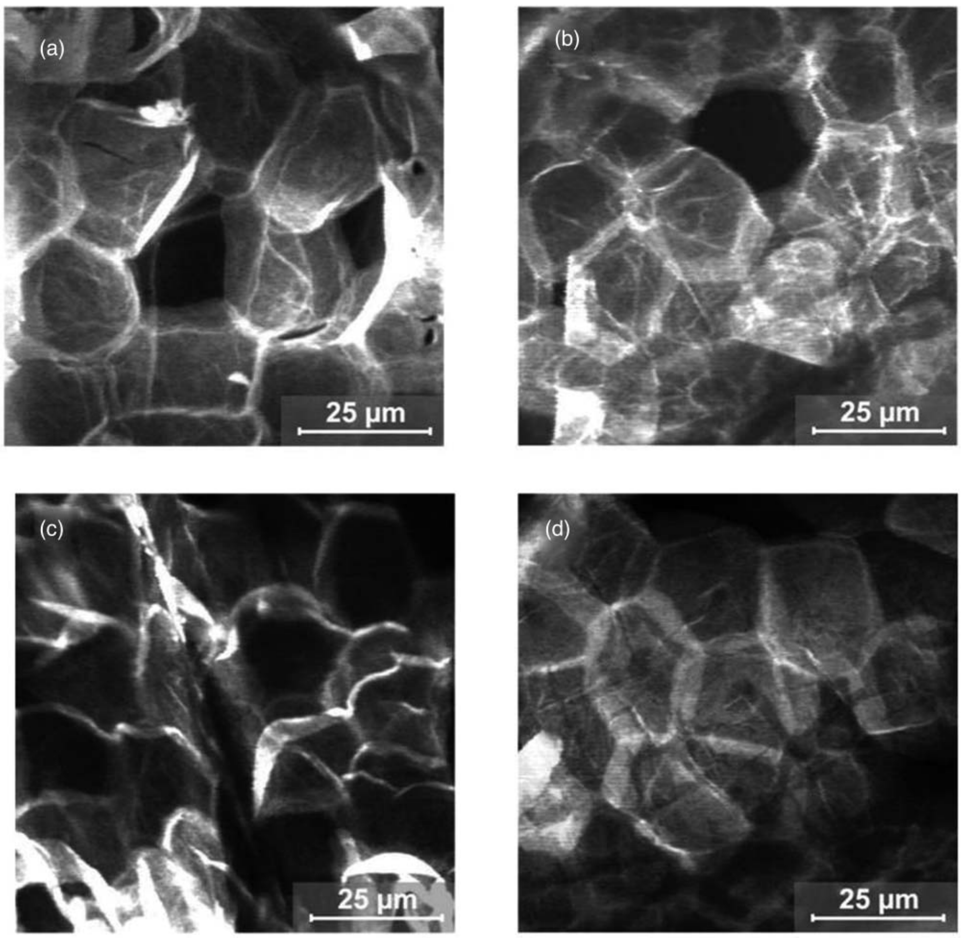

Fig. 3 (a) Baseline picture (before standardized textile-skin rubbing) as barrier properties measured by *in vivo* LSM from the polyamide area. (b) Baseline picture (before standardized textile-skin rubbing) as barrier properties measured by *in vivo* LSM from the polyester area. (c) After polyamide rubbing: barrier properties measured by *in vivo* LSM from the polyamide area. Note the mountainous and inhomogeneous structure, which corresponds to a damaged barrier. (d) After polyester rubbing: barrier properties measured by *in vivo* LSM from the polyester area. Note the intact and homogeneous structure similar to a flat honeycomb before contact with the polyamide material.

of the samples are clearly visible. This impression is confirmed by the surface topography, which permits the estimation of the roughness of the two materials (polyamide fabric [Fig. 2(a)] and polyester fabric [Fig. 2(b)]). The measured roughness value of the polyamide surface (29.8=B10.6 =B5m SD roughness depth) compared to that of the polyester surface (24.6=B11.0 =B5m SD roughness depth) is increased.

Twenty out of twenty volunteers assessing the haptic properties of the fabrics scored polyester favorable over polyamide regarding their sensation when the two textile materials were in contact with the skin. The volunteers considered the polyester material to be far more comfortable on their skin than the polyamide material. Thus, the feelings of the volunteers unambiguously reflected the objective results of the OCT measurements and the surface roughness profilometry.

In the last part of the study, it was investigated whether the two textile materials affect the barrier functions when standardized rubbing on the skin with the fabric was performed. The results obtained by laser scanning microscopy showed that under standardized conditions the polyamide material disturbs the structure of the skin barrier [Fig. 3(c)] while polyester [Fig. 3(d)] induced almost no detectable changes in LSM. In Figs. 3(a)–3(d), the LSM images before [Figs. 3(a) and 3(b)] and after skin contact [Figs. 3(c) and 3(d)] with the textiles are compared. While the corneocytes have an intact homogeneous structure similar to a flat honeycomb before contact with the polyamide material [Figs. 3(a) and 3(b)], their arrangement after the textile-skin contact [Fig. 3(c)] resembles a somewhat mountainous structure, which corresponds to an extremely dry or damaged barrier.[23] On the contrary, the polyester material had not caused damage to the barrier under the same conditions [Fig. 3(d)]. Thus, the objective results from the textile analysis obtained by OCT and skin surface profilometry were confirmed by both the subjective, haptic skin physiological sensation of the volunteers and the *in vivo* response of the skin barrier (stratum corneum).[24,25] Consequently, new perspectives are opening up for the optical examination methods used in this study when textile materials are evaluated during the development process and differentiation of multiple textile materials. Based on optical methods, time consuming, expensive *in vivo* studies can be reduced and new, more comfortable textile materials can be introduced to the market quicker, more cost-favorable, and more user-friendly. With the increasing number of people suffering from skin irritations and diseases like atopic dermatitis,[11] the development of textiles with favorable properties is becoming increasingly important. In this context, objective optical procedures like optical coherence tomography, laser scanning microscopy, and surface profilometry are decisive instruments at early development stages.

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