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In-vivo diagnostic with optical coherence tomography - use in dermatology

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ABSTRACT

Optical low coherence tomography (OCT) is a newly developed bioengineering method for noninvasive in-vivo investigation of human skin, especially of the epidermis.
Based on the principle of a Michelson interferometer, OCT allows the detection of the path length of an infrared light beam after backscattered inside the skin sample by comparison with a reference beam. The depth resolution is limited by the coherence length of the light source, which is about 15 µm.
OCT supplies cross-sectional images of the skin with a penetration depth of about 0.5 to 1.5 mm. The stratum corneum can be distinguished from the living epidermis and the upper dermis.
We investigated healthy skin of several localisations, inflammatory diseases, intra- and subepidermal blisters and epidermal tumors. First images are presented to demonstrate the possibilities of this promising new method.

Key words: optical low coherence tomography, bioengineering method, dermatology, skin diseases

2. INTRODUCTION

Optical coherence tomography (OCT) is a newly developed method for in-vivo investigation of tissue. In the last years it was mainly used in ophthalmology for examination of the eye[1-5]. Because of the high resolution reached by OCT of low scattering media the method was called "optical biopsy"[6].
In contrast to the eye, human skin is a high scattering tissue. Therefore, the problems of attenuation and multiple scattering needed a modification of the OCT system for application in dermatology[7-11]. Investigation of healthy skin and several skin lesions gave promising results. Some exemplary images will be shown to demonstrate the potential use as a diagnostic method in dermatology.

3. METHOD

Optical coherence tomography is based on the principle of Michelson interferometry. The light source is an infrared superluminescence diode of 830 nm. The light beam is divided into a reference and a sample beam. Interference of both beams occurs only within the short coherence length of the light source which is about 15 µm. The coherence length determines the axial resolution. By lateral scanning of the signal, OCT provides two-dimensional cross-sectional images. The detected amplitude of the interference modulation is displayed in a grey scale. A lateral resolution of 10 µm can be reached. For all pictures shown in this paper the measuring time was 2 to 10 s/mm scan length depending on the lateral resolution.
The skin area of interest is positioned against an aperture of the OCT system by mild pressure. Pre-treatment of the skin with glycerine increases the transparency of the stratum corneum and enhances therefore the image quality.

4. RESULTS

Investigation of the skin using OCT was well tolerated by the subjects and had no side effects.

The detection depth of the signal was about 0.5 to 1.5 mm. Different structures could be seen in OCT of human skin which were interpreted by comparison with corresponding histological sections. OCT images of healthy skin of the forearm (Fig. 1) showed a layer below the surface signal which was limited by a second more intense horizontal line. This border corresponded to the basement membrane zone. Therefore, the superficial layer was interpreted as epidermis which appeared in OCT images more dense than the dermis.

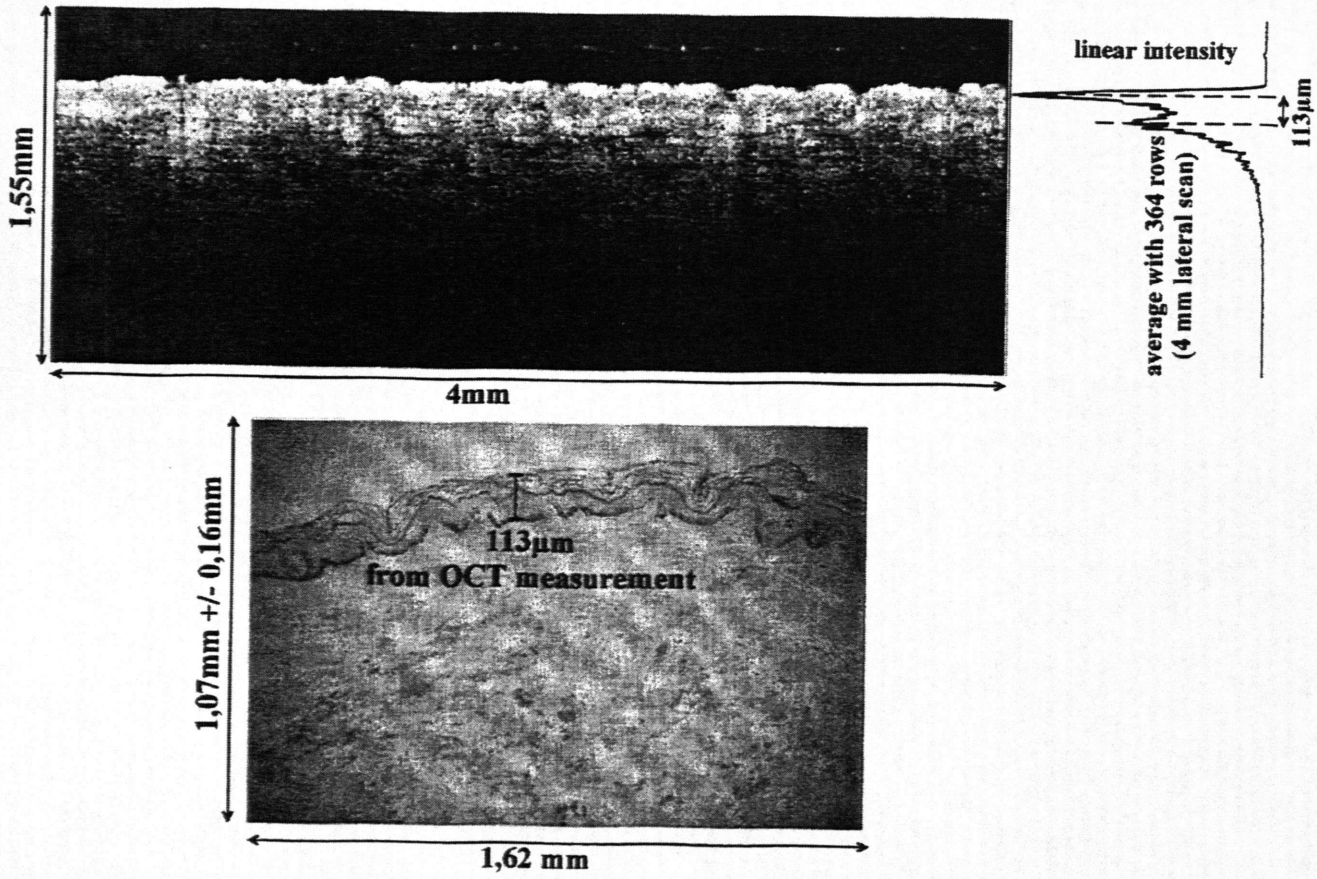

Fig. 1: Healthy skin of the forearm. The intensity peak below the entrance signal corresponds to the basement membrane zone.

OCT images of the fingertip were different (Fig. 2). Two layers could be distinguished. The superficial one corresponded to the thick stratum corneum, the second one to the epidermis. The resolution was high enough to show sweat gland ducts in the horny layer.

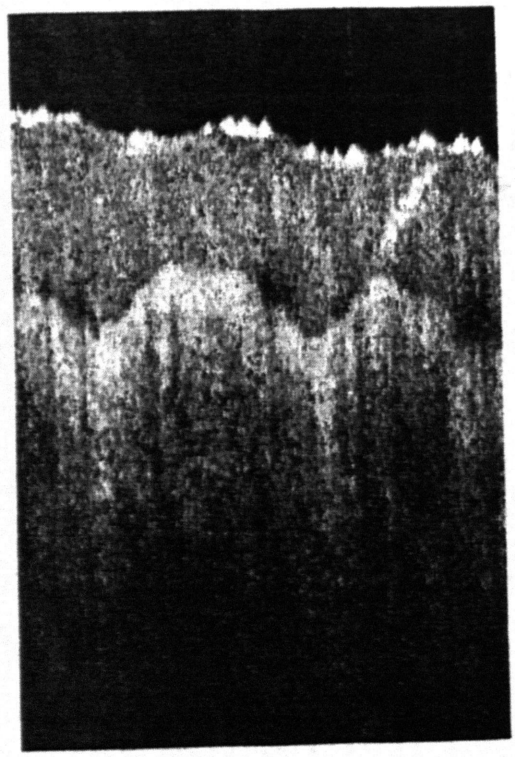

Fig. 2: Healthy skin of the fingertip. Note the sweat gland duct. 1 mm x 1.5 mm.

A mechanically induced blister on the thumb showed a sharply demarcated cleft below the stratum corneum in OCT (Fig.3). The intraepidermal cleft location was confirmed by histology of the roof of the blister.

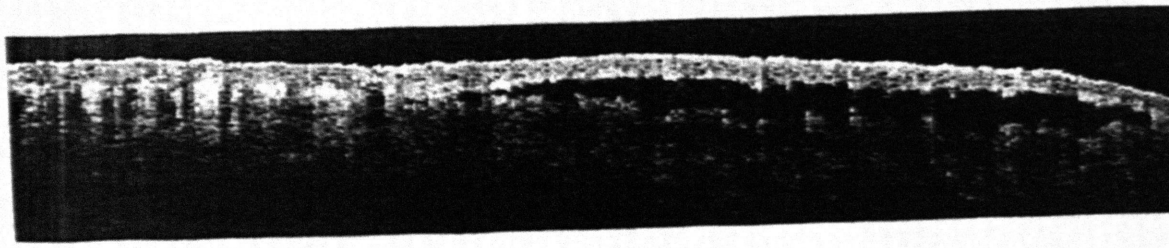

Fig. 3: An intraepidermal blister on the thumb. The cleft location is below the stratum corneum in OCT. 9 mm x 1.6 mm.

OCT of a malignant melanoma showed irregular structures in the lower epidermis which corresponded to the tumor cell aggregations in histology (Fig.4).

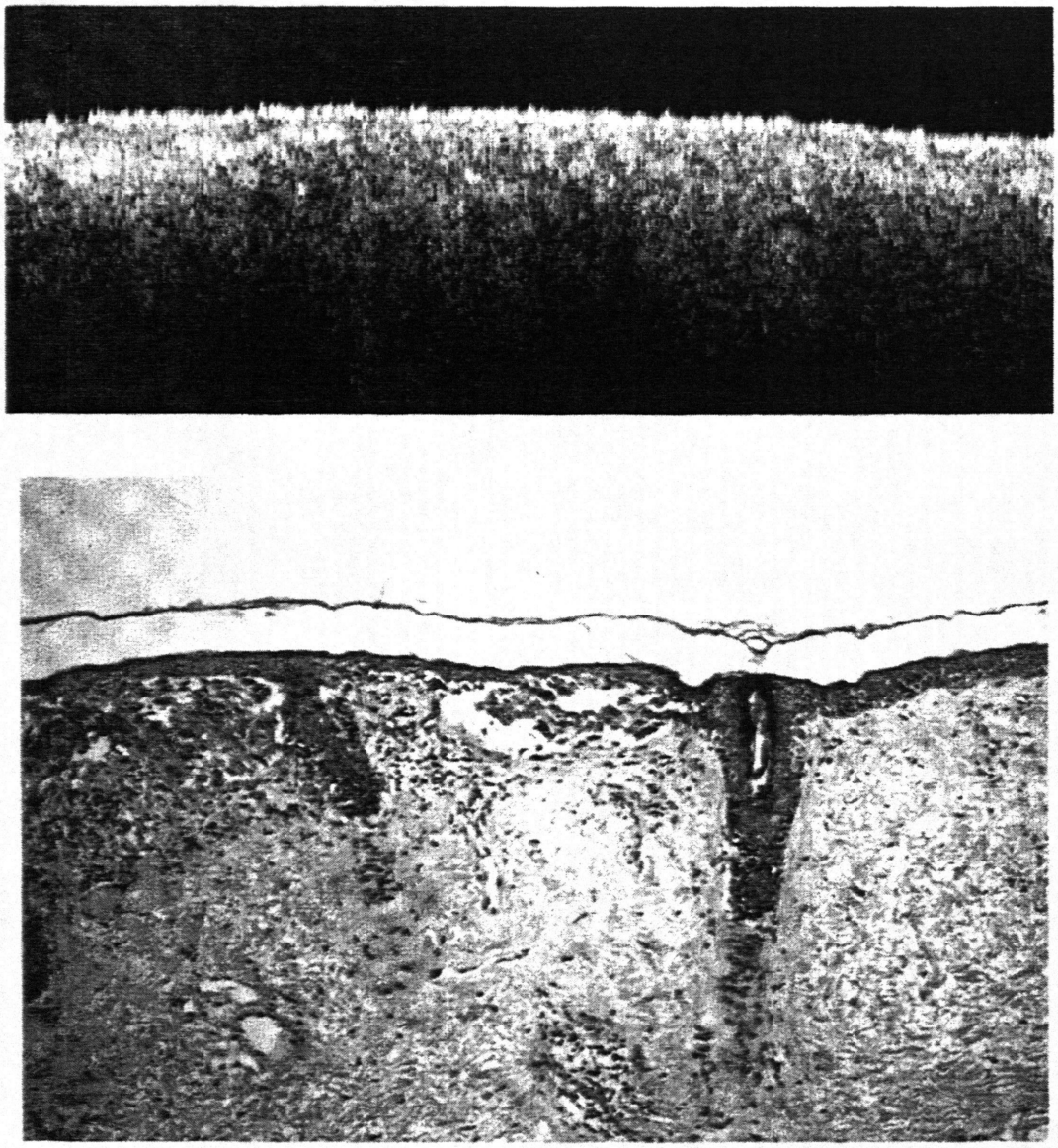

Fig. 4: OCT and corresponding histology of a malignant melanoma, on the right side see the border to healthy skin. OCT image: 2 mm x 0.8 mm, histology x 200.

A scabies mite in the horny layer with a burrow behind could be detected by OCT (Fig.5).

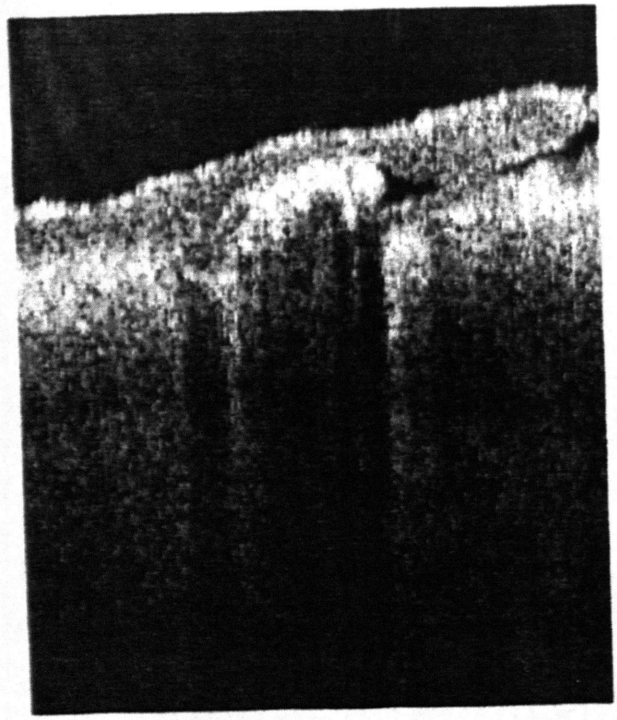

Fig. 5: OCT of a scabies mite in the center of the image. 1 x 1.2 mm.

5. DISCUSSION

Images of human skin obtained by a modified OCT system demonstrated the possibilities of this method for use in dermatology. Superficial parts of the human skin could be visualized by OCT. The stratum corneum, the epidermis, and superficial parts of the dermis could be distinguished in OCT images. On the palm the thick stratum corneum appeared homogeneous and signal dense. On the border to the living epidermis a more transparent zone was seen corresponding to the stratum lucidum. The epidermis was again relatively dense. On the arms and legs no stratum corneum could be detected in OCT images. The superficial layer corresponded to the epidermis. Below the basement membrane zone the intensity of the signals decreased. Upper parts of the dermis could be differentiated with signal poor blood vessels.

OCT images of skin lesions corresponded well to histology. The resolution was not high enough to show single cells, but OCT provides informations about the architecture of a lesion and cell aggregates. In bullous diseases it was possible to detect the cleft location exactly by OCT.

First investigations of high scattering tissue by OCT suggest that this new method may play a future role for in-vivo diagnostic of skin tumors, especially of malignant melanoma. It may also be interesting for diagnostic of bullous autoimmune disorders and for investigation of pharmacologic and treatment effects like steroid atrophy or wound healing. The advantages of OCT in comparison to other morphologic techniques are its high resolution, the simple application without any side effects, and the low costs.

Further developments are in work to make the system more flexible and to increase the measuring velocity up to real time.

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