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In vivo Imaging of *Sarcoptes scabiei* Infestation Using Optical Coherence Tomography

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Key Words
In vivo imaging · *Sarcoptes scabiei* · Optical coherence tomography · Infestation

Abstract
Background: *Sarcoptes scabiei* can be visualized with different imaging tools. Optical coherence tomography (OCT) may have the potential to describe the changes in skin morphology due to scabies infestation and visualize the parasite. ***Methods:*** Five patients from the Departments of Dermatology, Augsburg, Germany, and Roskilde, Denmark, were OCT scanned (VivoSight®; Michelson Diagnostics Ltd., UK). Mites were identified by epiluminescence and light microscopy to confirm the diagnosis. ***Results:*** OCT identified *S. scabiei* mites in all patients in vivo. Mites and burrows were visualized, and some detail on burrow content was provided. ***Conclusion:*** OCT can visualize *S. scabiei* mites in vivo, suggesting that it may be used to study the biology of the mites in vivo and provide early assessment of scabicide therapy. OCT is able to visualize structures in the skin with an 8-µm resolution. Therefore, this technology could potentially allow rapid, non-invasive, in vivo diagnosis and analysis of infestations.

Introduction

Scabies is a host-specific parasitic skin eruption and a global problem affecting people of all socioeconomic levels. Transmission occurs from an infested person after extensive contact. The mite is nearly impossible to see with the naked eye as a female mite measures 0.30–0.45 in length and the male is even smaller [1]. Therefore, scabies is diagnosed from

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the patient's symptoms and the clinical history. Dermoscopy as well as microscopy can be helpful in the clinical diagnosis to image the mite.

Imaging of the mite is of interest not only because it can be helpful in confirming the clinical diagnosis but also because the biology of the mite is poorly understood. It is known that the mites burrow into the epidermis, mate and the female mite lays eggs in the burrows. The eggs hatch and larvae appear. Fecal pellets also appear in the burrows and may aid diagnosis. Due to the lack of an in vitro system, further investigation of the mite biology is difficult and relies on in vivo observations. However, imaging tools like confocal microscopy (CM) and X-ray micro-CT have identified individual scabies mites and their burrows in vivo [2, 3], and a previous study has suggested that optical coherence tomography (OCT) may also be useful as an in vivo imaging tool [4]. This may facilitate further knowledge on the mite and its biology.

OCT is a non-invasive in vivo imaging technique, which is routinely used in ophthalmology for the diagnosis of retinal diseases. Within the last years, it has also been used in dermatology predominantly to study tumors. OCT seems to have the potential to diagnose non-melanoma skin cancer and actinic keratosis, which may potentially be valuable when monitoring non-invasive treatment of these lesions. OCT provides high-resolution (<10 μm), cross-sectional tomographic images of the skin.

Materials and Methods

We used a multi-beam OCT system (VivoSight®; Michelson Diagnostics Ltd., UK) with a low coherent infrared light (1,305 nm) that is projected into the tissue. The reflection of light is processed, and the sum of the different light refractions produces an image analogue to ultrasound, but at a significantly higher resolution. The images represent vertical cross sections of the skin, showing epidermis, the dermoepidermal junction and upper dermis. The image depends, among other factors, on the thickness of the skin and the presence of hair [5]. It shows only architectural structures and no individual cells.

Scabies patients were identified clinically. Four male patients and 1 female patient were examined. The mites were located on the feet, the interdigital finger webs, the flank and on the stomach. Before OCT scanning, the mites were localized with dermoscopy or a loupe. After OCT scanning, the mite was extracted with a needle and placed under a microscope to confirm the diagnosis. In 2 cases, we scanned the mite ex vivo. Images were further analyzed with the software ImageJ 1.46 and Voxx2, and a horizontal image was produced for further study.

Results

In all 5 cases, we identified scabies mites in vivo with OCT. In the vertical images, the mite appeared as an ovoid structure (mango-/almond-shaped) measuring approximately 0.20 × 0.30 mm or less in the epidermis just beneath the stratum corneum (fig. 1). In the horizontal images, the mite measured 0.30 × 0.15 mm. The optical density of the mite was the same as the surrounding tissue, but the mite was delineated by, respectively, a hyporeflective fringe (lumen of the burrow) and a hyperreflective fringe (the scaly burrow wall). In some images, a burrow behind the mite was visualized as well (fig. 2), depending on the scan direction. The lumen of the burrow appeared hyporeflective and either ovoid in cross

section or longitudinal depending of the cut. However, it could also appear hyperreflective if scaly.

A further finding was that the mite itself caused shadows whereby the underlying tissue did not appear in the image. Nevertheless, this was also seen underneath the scaling of a burrow or in part of it. The phenomenon has also been described in images of wounds and hyperkeratoses [6].

The horizontal image of the mite showed an oval, mainly hyporeflective structure at the end of a hyporeflective burrow with round hyperreflective structures, presumably fecal pellets and eggs (fig. 3). Specific features of the mite, such as the legs, were not visible in this image, though some hyperreflective areas also appeared in the overall hyporeflective mite. These hyperreflective areas could be anatomical irregularities of the carapace of the mite.

Ex vivo, the mite appeared as a rounded structure and legs were visible (fig. 4). Just like in the horizontal image, it was not possible to identify specific structures of the mite's body.

Discussion

Imaging permits non-invasive, in vivo studies of the skin, and different methods have been used to identify scabies mites in infested patients. The fact that scabies mites can be visualized in vivo facilitates in vivo studying of the mite and its biology, which is still not fully understood.

OCT permits quick, non-invasive real-time in vivo images of the epidermis and upper dermis where the scabies mite resides. In this study, OCT was used in 5 cases as an investigative tool for imaging scabies mites. The mites and their burrows could be visualized in both vertical and horizontal cross section in vivo as well as ex vivo, though creating a horizontal image was a time-consuming and complex process with the OCT equipment used. The mite's size could be estimated with OCT, and in some cases, it seemed to be smaller than previously suggested in the literature, or indicating male mites or young individuals. Alternatively, this could be due to the tomographic images that OCT produces: tomography implies the risk of a cross section, which does not correspond to the maximum size. The OCT system used provides the possibility of combining multiple images acquired in stacks into 3D datasets, potentially increasing accuracy and more detailed, non-real-time analysis.

Furthermore, the mites' location in the skin could be identified in the vertical OCT images. Like the CM images, the OCT images demonstrated that the mites do not remain only in the upper stratum corneum as described in other studies [7], but are also present in the upper part of the stratum granulosum. This finding suggests that the mite wanders deeper into the skin than hitherto presumed. A possible correlation between the size and location of a mite in conjunction with clinical symptoms can be investigated with OCT.

Eggs and fecal pellets were also identified with OCT, but no larvae were recognized in these cases. Infestation with a much larger animal, cutaneous larva migrans, was previously studied with OCT. Only the tunnels were visible but the larva itself was not identified [8]. It is speculated to be due to the optical quality of the living larvae.

Presumably, the most used imaging tool for in vivo studies is dermoscopy. It is easily accessible, and quick and easy to use. The diagnosis of a mite is based on pattern recognition [9]. In contrast to OCT, dermoscopy does not provide details about neither the exact location in the skin layer nor specific structures of the mite. OCT is less accessible, but with experience just as easy and quick to use as a dermoscope.

CM is another possible non-invasive method to study scabies in vivo. CM offers sufficient penetration depth and better resolution compared to OCT, which means that the mite,

specific structures of the mite and the surrounding skin are more clearly imaged [2, 10–12]. Furthermore, the technique offers the possibility of video recording [11]. On the other hand, CM is more time-consuming, provides a more narrow window with a penetration of only 250 µm, requires great precision during recording, and cannot make vertical images like OCT, but only horizontal ones.

The golden standard for visualizing scabies ex vivo is by microscope. A great deal of details about the mite's anatomy and movements can thereby be studied. An alternative way of studying scabies could be by X-ray micro-CT [3]. The method has previously visualized external as well as internal structures of a mite ex vivo at a greater detail than the microscope. Larvae and eggs, but no mites, were identified in vivo in a crusted scabies lesion. Therefore, X-ray micro-CT seems to be a useful and more detailed alternative to the microscope if the aim is to study the morphology and anatomy of the mite, though the procedure seems more time-consuming and complex. Details about larvae and eggs might also be studied with this method.

Biopsy of scabies also offers details of the mite on microscopic level. However, the procedure is painful to the patient and leaves a scar. The method does not offer a dynamic investigation and 3D imaging of the mite compared to the other imaging tools. Furthermore, it takes more time to get the image of a mite compared to the other methods because of the longer process of tissue preparation.

This study suggests that OCT has the potential of diagnosing scabies in vivo in a quick and easy way. OCT seems compatible to other imaging tools that also identify scabies mites due to its capacity to image the mite vertically as well as horizontally. In addition, OCT provides architectural structures of the skin, the mite, eggs and its burrow, but if specific details of the mite are investigated other in vivo imaging techniques such as CM and possibly X-ray micro-CT appear superior. Larvae have apparently not yet been identified with any of the in vivo imaging tools. However, OCT is an adequate imaging tool if the aim is to define the size and location of a mite, eggs and its burrow. This imaging tool seems to be relevant for studying the biology of the mite or the treatment monitoring of infested patients.

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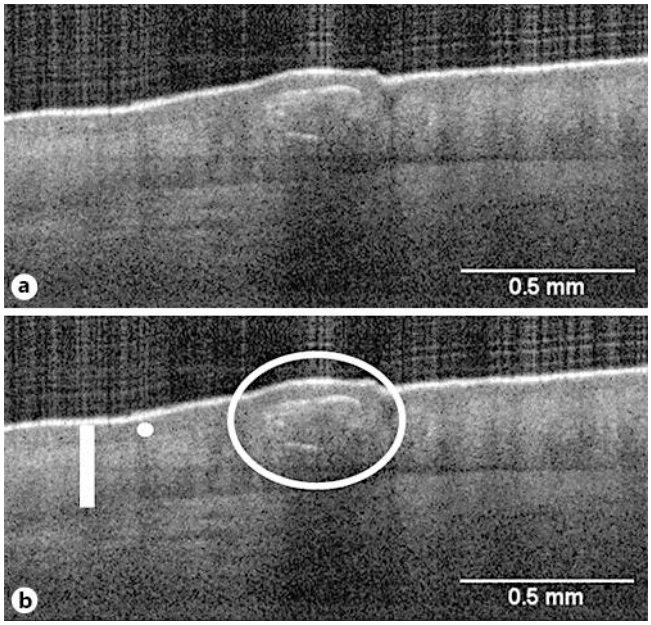

Fig. 1. **a**, **b** Vertical OCT image of the skin of an interdigital finger web. The mango-shaped mite (encircled) is surrounded by the hyperreflective burrow wall. The mite is just below the stratum granulosum (white dot). The epidermis is indicated by a white bar.

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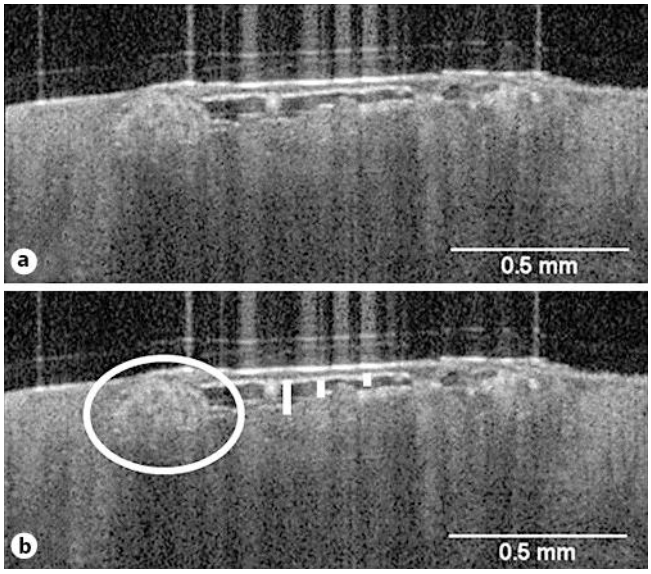

Fig. 2. **a**, **b** Vertical OCT image of a mite (encircled) at the end of a burrow. Possibly, there are eggs or fecal pellets in the burrow (burrow indicated by the vertical bars).

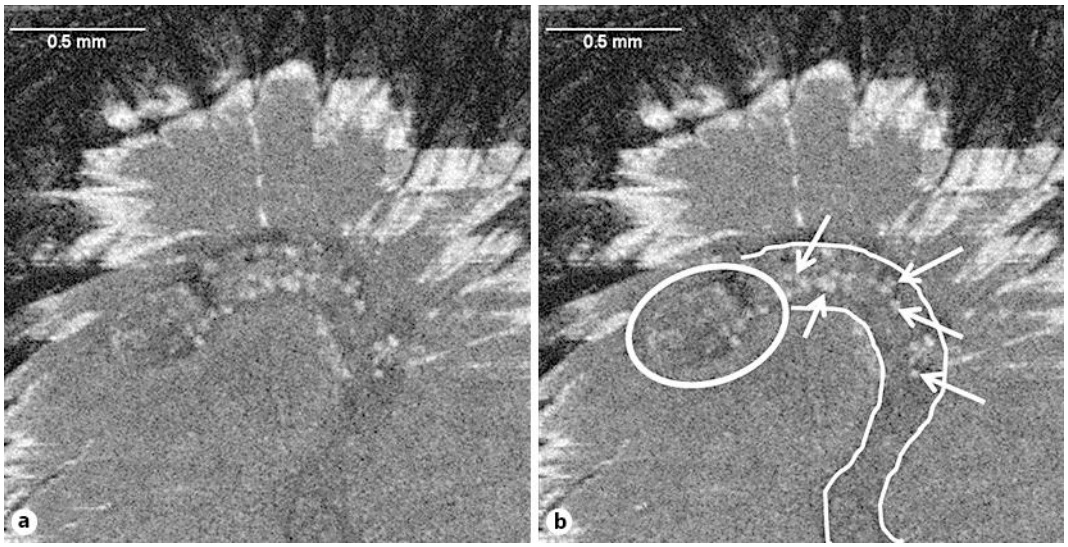

Fig. 3. **a**, **b** Horizontal OCT image of a mite (encircled) at the end of a burrow with eggs or fecal pellets (white arrows).

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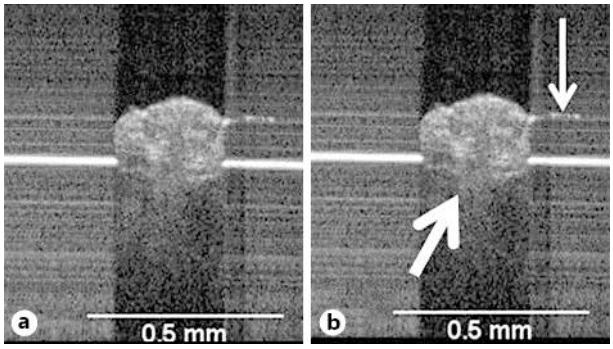

Fig. 4. **a**, **b** Vertical OCT image of a mite scanned ex vivo on a glass slide (thick arrow). The leg of the mite can be identified (thin arrow).