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Optical Coherence Tomography Used as a Modality to Delineate Basal Cell Carcinoma prior to Mohs Micrographic Surgery

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Key Words
Optical coherence tomography · Imaging · Mohs micrographic surgery · Basal cell carcinoma · Squamous cell carcinoma · Bioengineering

Abstract
Optical coherence tomography (OCT) has potential as a modality for in vivo imaging of non-melanoma skin cancer (NMSC). By allowing identification of sub-surface margins of NMSC lesions, the use of OCT could improve the rate of complete excision and reduce the average number of stages during Mohs micrographic surgery (MMS). The objective of this study was to use OCT to delineate the apparent sub-surface margins of NMSC lesions prior to their excision by MMS. Lesions were scanned with reference to a physical marker on the skin, and the apparent margins were then identified from the OCT images and marked on the skin. Photographs of these margins and the Mohs defect were correlated and compared. OCT appears capable of visualizing the transition from lesional to normal tissue. In this case study, margins marked by use of the OCT system before surgery exhibit excellent correlation with the MMS defect. OCT offers the promise of better outcomes by enabling accurate margin mapping of NMSC in advance of MMS. Priorities now are to demonstrate this capability in a larger study, and to understand clearly indications and contraindications for use.

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Background

Optical coherence tomography (OCT), a non-invasive optical imaging technique, is a biomedical technology used to characterize tissue microstructure. OCT is routinely utilized in ophthalmology for retinal imaging, and is continually evolving as a technology to image a wide variety of other tissue types, including skin [1]. OCT has similarities to ultrasound, providing real-time cross-sectional representation of tissue, but OCT enables higher resolution through its use of optics rather than acoustics.

While the skin surface is easily examined by visual inspection, skin imaging technologies are appealing because they enable visualization of deeper cutaneous structures. However, the dense architecture, light-scattering properties, and small size of relevant anatomic components present challenges to imaging human skin. Standard imaging techniques such as CT and MRI, in their commonly used forms, can lack the resolution necessary for meaningful depiction of skin structure. Ultrasound does better, but studies have found it to offer no significant advantage over clinical inspection for determination of lesion extent [2], and it has not performed as well as OCT in determining lesion depth [3].

In contrast, confocal microscopy depicts the skin sub-surface with good resolution but limited depth. OCT offers the possibility of high resolution skin imaging without compromising depth, and OCT techniques have been applied in a variety of cutaneous disorders, including malignancies, inflammatory dermatoses, skin infections, and vascular lesions [4, 5].

Recently, a multi-beam OCT system enabling high-resolution tissue imaging was introduced to commercial markets, providing lateral resolution of >7.5 μm over a 1-mm focal range. This is twice the lateral resolution of existing commercial single beam systems over a similar focal depth, based around the limitations of beam waist diameter over a given Raleigh range in a fixed-focus Fourier domain implementation [6].

This modality has been used previously for the imaging of oral and gastrointestinal malignancies [7, 8], and its high-resolution capability is promising for investigation of skin architecture. When applied to skin, OCT enables visualization of relevant structural elements such as the dermal-epidermal junction, dermal papillae, cutaneous vasculature, and stratum corneum thickness [9–13]. Additionally, OCT allows convenient design features, such as a compact, lightweight hand-held probe and a user-friendly interface presenting b-mode cross-sectional images in real time, requiring minimal operator training. The combination of its high resolution and ease of use could facilitate the application of multi-beam OCT technology for skin imaging.

OCT offers potential for in vivo imaging of non-melanoma skin cancer (NMSC). NMSC are the most common human cancers, collectively conferring high morbidity and consuming substantial healthcare resources. Because early diagnosis of NMSC provides the greatest chance of cure, and as the current diagnostic standard for NMSC requires excision of tissue for histopathologic analysis, a non-invasive method for evaluation of clinically suspicious lesions could be highly useful as a diagnostic paradigm for NMSC. Ideally, OCT images can characterize skin microstructures non-invasively.

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In the context of Mohs micrographic surgery (MMS), the gold standard and a commonly employed treatment approach for NMSC, imaging information can be used to guide the clinical approximation of tumor boundaries prior to excision. If the imaging capabilities of multi-beam OCT could facilitate delineation of lesion borders a priori, then the use of this technology in conjunction with MMS might decrease the average number of excised layers per case, shortening the duration of the procedure and reducing cost. Furthermore, MMS provides an ideal framework for the initial evaluation of multi-beam OCT imaging in cutaneous models, since it allows for cross-correlation of OCT-derived visual information with confirmed histologic margins. The goal of this pilot study is to examine the feasibility of multi-beam OCT for use in MMS by applying this technology to predict the lateral boundaries of a basal cell carcinoma (BCC).

Materials and Methods

A single patient with biopsy-proven BCC on the left cheek, presenting for MMS, is documented in this manuscript. Consent was obtained in accordance with an Investigational Review Board-approved protocol (Independent Investigational Review Board, Plantation, Fla., USA).

This study used a commercially available, FDA 510(k)-cleared OCT system (VivoSight; Michelson Diagnostics, Orpington, UK).

A series of pen marks were made on the skin some distance from the BCC lesion, allowing photographs from before, during and after the MMS procedure to be correlated. The lesion was photographed to establish a baseline, using both a standard camera (Canon Ixus 120 IS; Canon, Tokyo, Japan) in macro mode and a digital dermatoscope (DermLite FOTO; 3Gen, San Juan Capistrano, Calif. USA) on a Coolpix 995 camera (Nikon, Tokyo, Japan).

An adhesive paper ring (hole reinforcements; WH Smith, UK) was affixed to the skin such that the hole was centered on the clinically apparent lesional margin. Two marks were made on the ring, separated by 90 degrees, to allow the probe orientation to be recorded. With the probe applied gently to the skin, the OCT instrument was then used to take a series of fifty 5-mm wide × 2 mm deep cross-sectional images of the region enclosed by the ring, with each image separated by 0.1 mm so that a total area of 5 × 5 mm was evenly sampled. It was possible to visualize about 1.25 mm into the skin of this particular patient. The images were then viewed, and based on visualization of morphological features within the sample, the apparent transition point between tumor and benign perilesional skin was identified. This judgment was aided by reference to a 'normal'-appearing skin sample contralateral to the lesion, which was imaged first to serve as a frame of reference for evaluating the patient's local skin morphology. By reference to the imaging frame number and the adhesive ring, the frame containing the identified transition point could be transposed to a point on the patient's skin, and a mark was made to denote the predicted margin. This procedure was repeated an additional three times, so that the superior, inferior, lateral, and medial lesion boundaries were delineated. An additional photograph was then taken to record the predicted tumor margins.

The Mohs procedure was then performed in the usual fashion, with no reference to the indicated borders determined by OCT analysis. Once the margins were found to be clear of tumor under frozen-section analysis, an additional photograph showing both the Mohs defect and the previously drawn alignment marks was taken. By superimposing and aligning the marks, the accuracy of the OCT-derived margin could be compared to that achieved by the Mohs procedure.

Results

The BCC lesion was removed by MMS in two stages. The pre-operative margins determined by OCT imaging, the final MMS defect, and a composite image in which the two photographs are aligned using the reference markers are shown (fig. 1). The

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margins marked by use of the OCT system before surgery closely approximate the final two-stage MMS defect on all sides. Also shown are examples of the OCT images at the tumor margin and within the tumor (fig. 2).

Discussion

We report the use of multi-beam OCT to predict the boundaries of a BCC prior to MMS excision, with good correlation between OCT-aided lesion mapping and MMS. Interestingly, the boundaries of this particular BCC extended beyond the clinically apparent extent of tumor, and were successfully predicted by OCT in advance of an MMS procedure that required two stages. This finding suggests that OCT might be a useful adjunct to MMS, by revealing lateral tumor margins that extend beyond apparent surface cues. The use of OCT could potentially reduce the number of layers required for MMS and minimize removal of perilesional benign tissue. This case study provides further evidence that OCT can be used to identify NMSC tumor margins, and a larger prospective trial of OCT imaging in conjunction with MMS is currently underway.

The use of OCT to image NMSC depends on recognizing characteristic features of normal skin and NMSC. The challenge now is to reduce the subjectivity of such judgments. A detailed atlas of OCT features correlated with well-understood dermatopathological features, along with a quantitative analysis of the physical basis for OCT signal intensity as a function of tissue type, will go a long way to addressing this concern.

Funding Sources

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Disclosure Statement

Dr. McKenzie is a Founder and Director of Clinical Development at Michelson Diagnostics.

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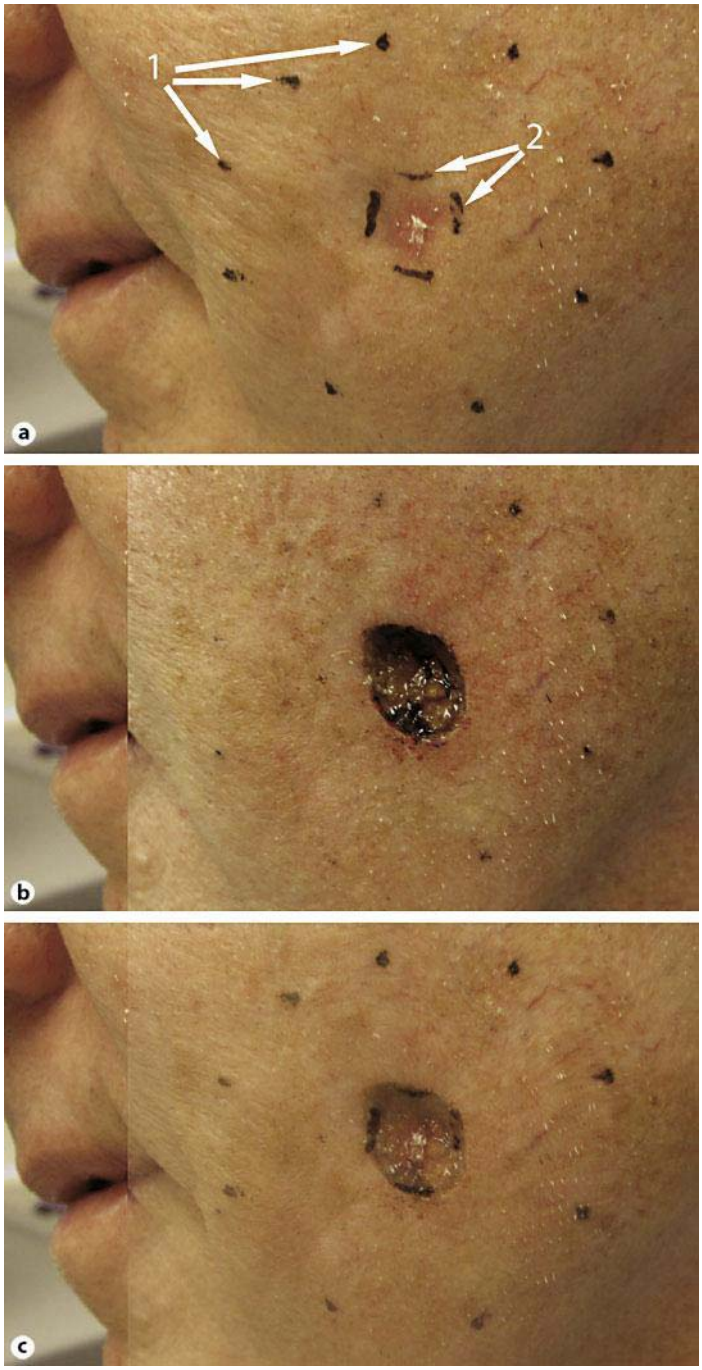

Fig. 1. a Margins of the tumor, marked using OCT prior to surgery. Arrows labeled (1) show reference marks for correlation of photographies. Arrows labeled (2) show marks indicating the extent of the lesion identified by OCT. **b** Mohs defect at the end of the second stage. The image appears as a composite with the Mohs defect set at 100% opacity to ensure that the scale and orientation are identical to **a** and **c**. **c** Image **b** above overlaid on **a**. The lesional margins identified by OCT imaging closely approximate the Mohs defect.

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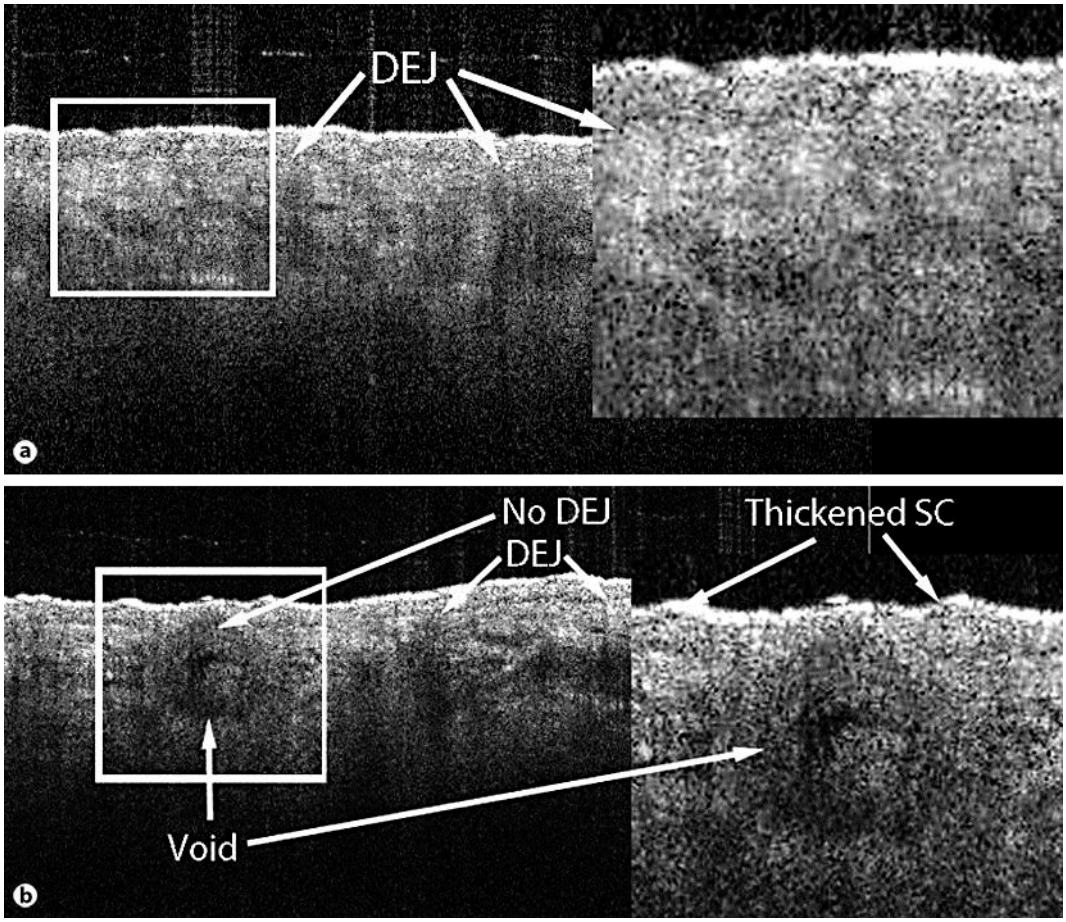

Fig. 2. **a** Lesional margin, as determined by OCT imaging. Note the complete and uninterrupted dermal-epidermal junction (DEJ) and the thin and regular stratum corneum (SC), which is almost entirely obscured by the entrance port (**inset**). **b** Within BCC lesion, 0.5 mm from the margin shown in **a**. Note the disruption of the DEJ and the slightly thickened SC just visible above the entrance port. Also notable are the lower general signal in the dermis, and the large hyporeflective areas.

References

1 Zysk AM, Nguyen FT, Oldenburg AL, Marks DL, Boppart SA: Optical coherence tomography: a review of clinical development from bench to bedside. J Biomed Opt 2007;12:051403.

2 Marmur ES, Berkowitz EZ, Fuchs BS, Singer GK, Yoo JY: Use of high-frequency, high-resolution ultrasound before Mohs surgery. Dermatol Surg 2010;36:841–847.

3 Mogensen M, Nurnberg BM, Forman JL, Thomsen JB, Thrane L, Jemec GB: In vivo thickness measurement of basal cell carcinoma and actinic keratosis with optical coherence tomography and 20-MHz ultrasound. Br J Dermatol 2009;160:1026–1033.

4 Mogensen M, Thrane L, Jorgensen TM, Andersen PE, Jemec GB: OCT imaging of skin cancer and other dermatological diseases. J Biophotonics 2009;2:442–451.

5 Mogensen M, Thrane L, Joergensen TM, Andersen PE, Jemec GB: Optical coherence tomography for imaging of skin and skin diseases. Semin Cutan Med Surg 2009;28:196–202.

6 Bazant-Hegemark F, Stone N, McKenzie G, Holmes J: Optical coherence tomography aids cancer detection. Biophotonics International 2007;46–47.

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7 Jerjes W, Upile T, Conn B, Hamdoon Z, Betz CS, McKenzie G, et al: In vitro examination of suspicious oral lesions using optical coherence tomography. Br J Oral Maxillofac Surg 2010;48:18–25.

8 Standish BA, Lee KK, Mariampillai A, Munce NR, Leung MK, Yang VX, et al: In vivo endoscopic multi-beam optical coherence tomography. Phys Med Biol 2010;55:615–622.

9 Gambichler T, Orlikov A, Vasa R, Moussa G, Hoffmann K, Stucker M, et al: In vivo optical coherence tomography of basal cell carcinoma. J Dermatol Sci 2007;45:167–173.

10 Olmedo JM, Warschaw KE, Schmitt JM, Swanson DL: Optical coherence tomography for the characterization of basal cell carcinoma in vivo: a pilot study. J Am Acad Dermatol 2006;55:408–412.

11 Bechara FG, Gambichler T, Stucker M, Orlikov A, Rotterdam S, Altmeyer P, et al: Histomorphologic correlation with routine histology and optical coherence tomography. Skin Res Technol 2004;10:169–173.

12 Olmedo JM, Warschaw KE, Schmitt JM, Swanson DL: Correlation of thickness of basal cell carcinoma by optical coherence tomography in vivo and routine histologic findings: a pilot study. Dermatol Surg 2007;33:421–425; discussion 5–6.

13 Gambichler T, Moussa G, Regeniter P, Kasseck C, Hofmann MR, Bechara FG, et al: Validation of optical coherence tomography in vivo using cryostat histology. Phys Med Biol 2007;52:N75–N85.