Optical Coherence Tomography in the Diagnosis of Skin Cancer

Amanda Levine, MD[a,b,c], Katie Wang, DO[a,b,c], Orit Markowitz, MD[a,b,c,*]

KEYWORDS

• Optical coherence tomography • Nonmelanoma skin cancer • Melanoma • Noninvasive imaging

KEY POINTS

- A review of the literature shows that optical coherence tomography (OCT) increases the overall sensitivity, specificity, and diagnostic accuracy compared with clinical and dermoscopy evaluation alone.
- Frequency Domain OCT (FD-OCT) has imaging depth of up to 2 mm, with enough cellular clarity to diagnose nonmelanoma skin cancers. Dynamic OCT (D-OCT) enables us to visualize vascular patterns in the skin, improving diagnostic accuracy. Finally, high-definition OCT (HD-OCT) has improved cellular resolution compared with FD-OCT and D-OCT, at the sacrifice of penetration depth and field of view. However, HD-OCT serves to fill the gap between reflectance confocal microscopy and conventional FD-OCT.
- OCT has also been shown to be useful in tumor margin delineation and is, thus, useful in preoperative treatment planning. In addition, OCT enables noninvasive treatment monitoring of skin cancers undergoing nonsurgical therapies.

INTRODUCTION

Over the past decade, optical coherence tomography (OCT) has emerged as a novel noninvasive imaging device that allows for the real-time, in vivo, cross-sectional imaging of skin morphology. The advantage of these noninvasive devices over histopathology is that they enable repeated imaging of the same unaltered skin sites to observe dynamic events and long-term changes over time. Therefore, OCT has been used in both clinical and research settings to aid in the diagnosis of clinical and subclinical lesions; delineate lesion margins; and, unique to OCT given its larger field of view (FOV) and increased depth, monitor lesions undergoing nonsurgical treatment.

OPTICAL COHERENCE TOMOGRAPHY

OCT imaging is based on low-coherence interferometry to detect the intensity of backscattered infrared light from biological tissues by measuring the optical path length.[1–4] With these imaging devices, there is an inverse relationship between cellular clarity and both FOV as well as depth.[1] Basically, as imaging depth and lateral resolution increases, the cellular resolution decreases (**Table 1**).

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[a] Department of Dermatology, SUNY Downstate Medical Center, 450 Clarkson Avenue, Brooklyn, NY 11203, USA; [b] Department of Dermatology, New York Harbor Healthcare System, 800 Poly Place, Brooklyn, NY 11209, USA; [c] Department of Dermatology, Mount Sinai Medical Center, 5 East 98th Street, New York, NY 10029, USA

* Corresponding author. 5 East 98th Street, New York, NY 10029.

E-mail address: omarkowitz@gmail.com

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Table 1
Summary of noninvasive imaging devices

Imaging Modality	Imaging Depth (mm)	Lateral Resolution (μm)	Axial Resolution (μm)	FOV (mm)	Probe Aperture Size
RCM	0.2	0.5–1.0	3–5	0.5 × 0.5	3.16 cm
HD-OCT	0.57	3	3	1.8 × 1.5	5 cm
FD-OCT, D-OCT/ SV-OCT	1.5–2.0	7.5	5	6.0 × 6.0	1.38 cm
HFUS (20 MHz)	10	200	80	12	10–20 mm

Abbreviations: D-OCT, dynamic OCT; FD-OCT, Frequency Domain OCT; HD-OCT, high-definition OCT; HFUS, high-frequency ultrasound; RCM, reflectance confocal microscopy; SV-OCT, speckle variance OCT.

There are several different OCT imaging modalities that have been studied. The swept-source multi-beam Frequency Domain OCT (FD-OCT) (Vivosight, Michelson Diagnostics, Kent, United Kingdom) provides 2 real-time imaging modes: b-scan (vertical, cross-sectional), similar to histology, and en face modes (horizontal), similar to that of dermoscopy and reflectance confocal microscopy (RCM). The images have an optical resolution of less than 7.5 μm laterally and less than 5 μm axially, a penetration depth of up to 2 mm, and an FOV of 6.0 mm × 6.0 mm.[1–4] A recent advancement, dynamic OCT (D-OCT) based on speckle variance OCT (SV-OCT), allows for visualization of skin microvasculature and the detection of blood flow.[1] Angiogenesis is important in the growth and spread of cancers; thus, visualization of vessel morphology is helpful in improving diagnostic accuracy.

Although conventional FD-OCT has been shown to be useful in skin imaging, its limited resolution precludes visualization of the skin at the cellular level. High-definition OCT (HD-OCT) (Skintell device, Agfa Healthcare, Mortsel, Belgium) seems to bridge the gap between conventional FD-OCT imaging and RCM offering improved axial and lateral resolution of 3 μm, with the trade-off of a more limited penetration depth of about 750 μm and FOV of 1.8 mm × 1.5 mm.[1–4]

High-frequency ultrasound is another imaging modality that has the largest penetration depth and FOV, however, lacks the cellular resolution necessary for skin visualization (<1 mm) and is, therefore, not frequently used in the diagnosis and management of skin.[5]

When comparing the different imaging methods, it is important to be aware of the imaging mode. FD-OCT, D-OCT, and HD-OCT devices all provide both vertical and horizontal en face images, creating a 3-dimensional image.[2–4] The vertical scans are helpful in that they mimic histology sections; the horizontal view, similar to RCM, helps bridge the gap of dermoscopy to histology.

Another parameter to consider is the probe aperture size to FOV ratio. Noninvasive devices have a probe that directly touches the skin and produces an image based on its FOV. Usually the FOV is much smaller than the probe itself. The smaller the aperture and the larger the FOV the less of a discrepancy between what the probe comes in contact with and what is actually being imaged. Thus, a smaller variation in the aperture to FOV ratio leads to more accurate probe placement and, therefore, a better correlation of what you are imaging and what you see clinically. This smaller variation is especially important at varying time points if, for example, you are monitoring a lesion undergoing treatment. Additionally, a small probe can be positioned to image in more cosmetically sensitive areas, such as the head and neck. Ultrasound has the best FOV to aperture size ratio followed by FD- and D-OCT as seen in **Table 1**.

FREQUENCY DOMAIN-OPTICAL COHERENCE TOMOGRAPHY

FD-OCT has mainly been used in the cross-sectional (vertical mode) similar to histology (**Table 2**).

Basal Cell Carcinoma

There have been several studies investigating the accuracy of FD-OCT in diagnosis of basal cell carcinoma (BCC). The literature indicates that FD-OCT increased sensitivity, specificity, and diagnostic accuracy compared with clinical and dermoscopy assessment alone.[6–11] There are few studies showing that FD-OCT is able to distinguish between the different BCC subtypes.[7–9] However, some studies think FD-OCT lacks the cellular clarity to make this distinction.

The major diagnostic criteria on FD-OCT for BCC are alteration of the dermoepidermal junction (DEJ) and dark ovoid basal cell islands in the dermis, which are typically surrounded by a darker, hyporeflective peripheral border.[6–11] Often