FOURIER DOMAIN OCT BUYER'S GUIDE

Fourier domain OCT (also called spectral domain OCT) is quickly overtaking conventional time-domain OCT as the clinical standard for the next decade. With superior speed, resolution and sensitivity, Fourier domain OCT (FD OCT) may be the ideal solution for any new OCT purchase.

However, there are many differences between time-domain and Fourier domain OCT technologies. Moreover, the features and capabilities of FD OCT are constantly evolving. New devices have been introduced to the market in just the last few weeks, and it is quite possible that next year's FD OCT devices will look quite different from the models available today.

So how can a newcomer to the FD OCT market decide which instrument to buy and when to make the large capital investment? This buyer's guide attempts to outline several basic concepts to consider when shopping for an FD OCT system. It is based on my opinions and is not meant to be a comprehensive discussion of FD OCT. It is, however, a starting point for discussions with vendors who are marketing this exciting new technology.

Above all, use caution when deciding on the best instrument for your practice. The FD OCT revolution has just begun and this tool is likely to be around for more than a decade. Consumers should not rush into a purchase without carefully considering all current and future options for this technology. Good luck!

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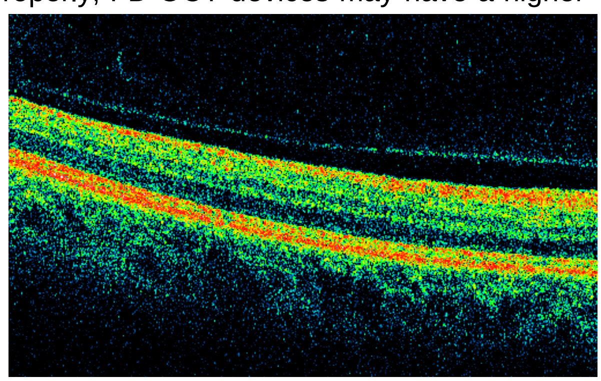
① Assessing Image Quality

Image quality is of primary importance in any OCT instrument because diagnostic and treatment decisions may hinge on subtle findings from individual images. When adjusted properly, FD OCT devices may have a higher sensitivity than conventional time-domain OCT instruments. This does not mean that the vitreous should appear black, however! Vitreous tissue interfaces should be visible with OCT and, in the case of vitreomacular traction syndrome, are critical components of the diagnosis. For example, in the image on the right, very little noise is seen in the aqueous layer between the hyaloid face and the ILM. High intensity speckles *are* present within the vitreous cortex and probably represent actual tissue interfaces. FD OCT devices that employ filtering, noise reduction or speckle removal run the risk of removing clinically-relevant data. Therefore, **look for devices that show vitreous tissue interfaces as well as a certain amount of 'white' noise in the vitreous cavity.** In this way, clinicians can feel confident that they will see vitreomacular traction problems without being distracted by large amounts of noise.

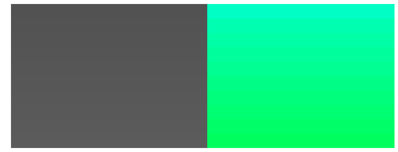


FD OCT image in a normal patient with an evolving PVD. Notice the lack of signal in the aqueous between the hyaloid face and the ILM versus the abundant signals within the vitreous tissue itself.

Too much noise can be a major problem in any OCT system and may lead to difficulties in differentiating subretinal fluid from outer retinal edema or in measuring retinal thickness accurately. Cataracts and other media opacities may compound this problem. In order to assess the signal-to-noise ratio for a given FD OCT instrument, here are a few tips:

1. **Look at the outer retinal signal in every B-scan**. If the intensities in the outer retina are too dark, it may be difficult to detect subretinal fluid when present. Consistently bright outer retinal tissue, especially in patients with subretinal pathology, is probably necessary for a clinically-useful instrument.
2. **Look at images from patients with retinal diseases (especially subretinal pathology), not B-scans from normal subjects**. FD OCT images from normal subjects may look superb, while images from the same machine for a patient with a retinal disease may produce disappointing results. When shopping for an FD OCT instrument, make sure to ask to see many examples of images from patients with a wide range of retinal diseases.

3. **Always look at B-scan images in pseudocolor to determine noise levels for a given instrument**. Although grayscale images may be pleasing to look at, they may also hide substantial amounts of noise and can make an inferior instrument appear clinically acceptable. Pseudocolor images have a higher dynamic range than grayscale images (hundreds of times the color depth) and will better demonstrate instrument noise that can interfere with clinical performance. For example, the image on the right represents a range of OCT signal intensities (lowest at the top, highest at the bottom) shown in both grayscale (left) and in pseudocolor (right). The change in color from cyan to green evident on the pseudocolor side represents the underlying difference in intensity levels. This difference cannot be appreciated as well on the left side since the grayscale map has fewer differentiable shades of gray.



A range of OCT intensity values shown in both grayscale and pseudocolor.

4. **The sensitivity of FD OCT machines drops as the patient moves away from the instrument's 'sweet spot.'** Software in some devices may allow the user to select the instrument's 'sweet spot.' Regardless of where it is set, however, variations in the pseudocolor display between B-scans acquired for the same patient may indicate signal quality problems. Large drops in image quality associated with patient/tissue movement may lead to missed diagnoses or wasted time for the ophthalmic photographer.

5. **If you anticipate using your FD OCT instrument as a 3D-OCT scanner** (see www.3D-OCT.com for more details), **look carefully at all images from sample 3D-OCT scans - not just line scans**. High-resolution line scans may look wonderful in a presentation or brochure but may lead to buyer's remorse if the lower resolution 3D-OCT scans are inadequate for a clinician's needs.

② Assessing Software Quality

Software is becoming increasingly important in OCT - both for more clinically relevant measurements and for ease-of-use. Because FD OCT instruments may be up to 100 times faster than time-domain OCT, the volume of information acquired during image capture can be enormous. Therefore, don't plan on printing your B-scans on a color printer! **It will become increasingly necessary for clinicians to use FD OCT software to view and manipulate large OCT datasets**. One of the benefits of this evolution is that patient education may be enhanced through better disease visualization. However, make sure you choose a software package that you feel comfortable using in front of your patients, so you are not left feeling embarrassed and technologically challenged.

As discussed above, one consequence of FD OCT's increased speed is the enormous amount of data captured in a given OCT scan. The large computer files used to store FD OCT data may result in increased loads on internal networks and storage systems. How will you be able to review large FD OCT data files in your clinic? How will you show these scans to your patients? How will this affect your overall productivity? **FD OCT data that can be easily viewed, manipulated and stored across a turn-key network system may be more practical for immediate and efficient clinical use**.

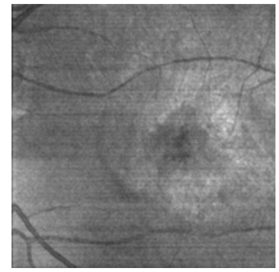
Flexible viewing options are another nice feature of some FD OCT systems. C-scan OCT sectioning is now possible with many devices, and 3D-OCT instruments may enable the user to spin, roll and slice 3D renderings of retinal tissue in a very realistic manner. Custom OCT slicing (i.e. circular or oblique sections) is also possible with many instruments.

One of the key benefits of FD OCT devices is the ability to align OCT data between patient visits and with other imaging modalities, such as fluorescein angiography. **Intervisit alignment enables precise quantitative comparisons between OCT examinations**, which should improve the ability of retinal specialists to monitor the effects of therapeutic interventions. **Alignment of OCT data with other imaging modalities enables point-to-point comparisons** (i.e. click on a fundus image to see OCT data from that region, or click on a B-scan to see the corresponding point on the retina) that may assist in disease localization and allow a better understanding of the underlying pathophysiology.

Several factors affect the ability of FD OCT software to align OCT data.

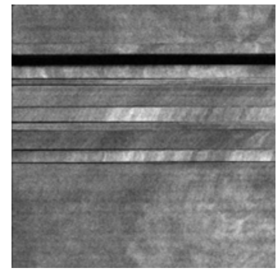
1. Invariant landmarks, such as blood vessels, act as fiducial markings for alignment of OCT data with fundus images or between visits. Therefore, **it is critical that invariant landmarks are consistently**

detected and located**. 3D-OCT devices that capture dense cubes of B-scans may have an advantage over instruments that capture more widely spaced data, such as conventional time-domain OCT devices which capture 6 radial-line scans. The image on the right demonstrates the excellent detail that can be obtained with 3D-OCT by integrating OCT intensity values for each A-scan. But regardless of the protocol used for image capture, make sure that you understand how each FD OCT device detects invariant landmarks and uses them to register OCT data to fundus images or between examinations.



3D-OCT projection data showing excellent blood vessel details (similar to a red-free image)

2. Eye movements disturb the relationship between invariant landmarks within a given OCT scan by causing skips, jumps or 'jags' in the OCT data. Longer acquisition times and poor patient fixation further compound this problem. In the image to the right, several eye movements and a blink obscure the underlying retinal vascular structure. Short acquisition times reduce the likelihood of large saccades during capture, but do not solve this problem entirely. Therefore, **it is important to understand how each FD OCT device aligns their OCT data in the presence of saccades and fixation losses**.



Fixation losses & blinks can disrupt the view of invariant landmarks

3. In order to compare FD OCT data easily to other imaging modalities, FD OCT devices must have access to fundus images from these modalities. **Instruments that incorporate fundus imaging or are integrated into a larger fundus imaging system will have an immediate advantage in multi-modal image comparisons**.

Recent advances in the understanding of OCT anatomical correlates have led to the realization that the interface previously thought to represent the outer retinal boundary may, in fact, be the junction of the photoreceptor inner and outer segments. Beyond this error of interpretation, conventional OCT instruments often misdetect retinal interfaces, leading to errors in retinal thickness maps and volumes. Finally, clinically relevant features, such as pigment epithelial detachments and subretinal fluid volumes, are not quantified at all. **Forward-looking FD OCT instruments should incorporate improved algorithms for retinal boundary delineation and quantitative sub-analysis**. These new measurement systems will, in turn, affect the normative databases that will be even more useful for the purposes of glaucoma monitoring.

When considering an FD OCT purchase, don't forget about the thousands of time-domain OCT scans that may reside on DVD-RAMs in your clinic from years of diagnostic testing! **Look for instruments with software systems that provide legacy support of time-domain OCT data** instead of requiring you to keep two instruments up and running.

③ Assessing Hardware Quality

Two common hardware parameters used to classify FD OCT machines are axial resolution and A-scan acquisition speed. High-resolution (4-6 micron) OCT systems are typically more affordable than ultra-high resolution OCT systems, which use expensive light sources. However, light sources are getting cheaper by the month, so stay tuned! A-scan acquisition speed is also rapidly evolving. Currently, speeds up to 40,000 A-scans per second are possible (compared to only 400 A-scans per second with conventional time-domain OCT). The main advantage of rapid A-scan acquisition is the ability to capture high-resolution B-scans in less time (and with less eye movement).

One feature of recent FD OCT devices is the **integration of imaging hardware such as angiography, autofluorescence or color fundus imaging**. As discussed above, simultaneous or near-simultaneous multi-modal image capture may facilitate alignment of OCT data. Multi-functional devices may also be a more efficient use of clinic space and photographer time. Furthermore, multi-modal image capture may expand billable services for your practice.

Probably the most important differentiating factor in terms of hardware is not listed on the device specifications page. When you make a large capital investment in an FD OCT machine, it is important to know that the manufacturer will maintain and support the device in the future. Purchasing an instrument from a fly-by-night company may lead to an expensive doorstop in the coming years. In general, **stay with companies that have a proven track record of instrument quality, service and support**.

④ A Brief Glimpse of the Future

Several technologies currently under development are likely to enter the OCT market in the coming months and years. Doppler OCT is a technique that measures blood flow in retinal and choroidal vessels. Swept source OCT achieves ultrahigh axial resolution by sweeping a narrow bandwidth light source through a broad optical range. And full field OCT uses a two dimensional sensor instead of the traditional one dimensional A-scan sensor to increase capture speeds.

With all of these new technologies on the horizon, exciting instruments should be entering the market at a consistent pace. Ultimately, the greatest benefit from this rapid technological evolution will be realized by the patients who receive better care from more informed doctors thanks to these wonderful new diagnostic techniques.

Twenty Questions to Consider When Shopping for an FD OCT Device

Image Quality

Does the device show signal in the vitreous that is consistent with expected vitreous tissue interfaces?

Is the outer retina as bright as the inner retina?

Do images from patients with cataracts and retinal diseases (especially AMD) look good?

Do images look as good when displayed in pseudocolor as they do when shown in grayscale?

Does the tissue's pseudocolor change markedly as the retina moves up and down on the screen?

Do rapidly-acquired 3D-OCT scans look as good as higher resolution line scans?

Software

Is the software user friendly?

Can you operate the software with minimal training and effort?

How will the data be transferred from the capture machine to the clinic room for patient viewing?

Can the image data be displayed in different useful and attractive ways?

Are vascular landmarks easy to identify in OCT projection images?

How does the machine account for saccades and fixation losses during acquisition?

Can OCT data from one visit be aligned accurately to previous visits?

Can OCT data be aligned accurately to color images, angiograms or autofluorescence images?

Does the software identify the proper retinal boundaries?

Does the system support normative databases?

Can the system import data from existing time-domain OCT devices?

Hardware

Is the instrument easy to use and patient-friendly?

Does the instrument incorporate color fundus imaging or angiography?

Does the manufacturer have a proven track record of quality, service and support?