

Choroidal Imaging With Swept-source Optical Coherence Tomography

By Jose M. Ruiz Moreno, MD, PhD



Although indocyanine-green angiography has helped us to study and achieve a better understanding of the choroid, adequate morphologic examination using spectral-domain optical coherence tomography (SD-OCT) has not been possible until recently. This is due to the presence of pigment cells that attenuate the incident light and the limited depth of penetration inherent to SD-OCT technology.

Choroidal thickness in healthy eyes as determined by SD-OCT decreases with age. No study, however, has been able to determine the age at which the choroid becomes thickest or to describe the characteristics of choroidal thickness among pediatric population.

Visualization with SD-OCT of the choroidal/scleral junction has been reported as between 74-96% with SD-OCT. The high-penetration swept-source longer-wavelength DRI OCT-1 Atlantis (Topcon), however, has an innovative 1- μ m band light source, longer than that of conventional machines, that provides higher penetration enabling deep choroidal imaging.

STUDIES USING DRI OCT-1 ATLANTIS PROTOTYPE

We performed 2 studies using DRI OCT-1 Atlantis, presented at the Euretina 2012 meeting, to obtain more information about how the choroid changes with age and to determine any advantages in DRI OCT-1 Atlantis for imaging the choroidal/scleral junction. The first study evaluated macular choroidal thickness in normal children's eyes as measured by a prototype DRI OCT-1 Atlantis using a cross-sectional comparative, noninterventional study design. We performed this study because there are no data available to determine at what age the choroid is the thickest.

We looked at the macular region of 83 pediatric eyes of 43 patients using the DRI OCT-1 Atlantis prototype from Topcon, which uses a tunable laser operated at 100,000 Hz and A-scan repetition rate in the 1- μ m wavelength region. A horizontal choroidal thickness profile of the macula was created by manually measuring subfoveal choroidal thickness (from the posterior edge of the retinal pigment epithelium to the choroid/sclera junction), and 3 further determinations were performed every 750 μ m temporal and nasal to

TABLE 1. STUDY 1 DATA

	Pediatric population	Controls	P value
n (eyes)	83	85	
Mean Age in Years (range)	9.6 \pm 3.1 (3 to 17)	53.2 \pm 16.6 (25 to 85)	P < .001 Student t test
Mean Spherical Equivalent (range)	0.3 \pm 2.0 D (3.75 to -5.25)	-0.16 \pm 1.4 D (3.25 to -5.0)	P = .06 Student t test
Mean Subfoveal CT (range)	312.96 \pm 65.3 μ m (158 to 469)	305.6 \pm 102.6 μ m (152 to 624)	P = .19 Mann-Whitney U
Mean Macular CT (range)	285.2 \pm 56.7 μ m (153 to 399)	275.2 \pm 92.7 μ m (132 to 551)	P = .08 Mann-Whitney U
Subfoveal CT 95% CI	298.7 -327.3 μ m	281.9 -329.4 μ m	
Macular CT 95% CI	272.9 -297.8 μ m	250.0 -293.3 μ m	
% of definite choroid/sclera junction	100%	100%	

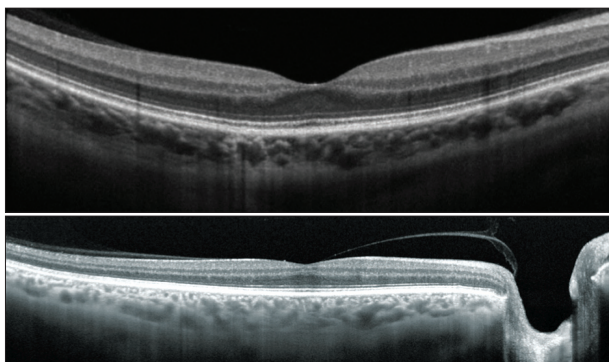


Figure 1. SD-OCT image (top) vs DRI OCT-1 Atlantis image (bottom).

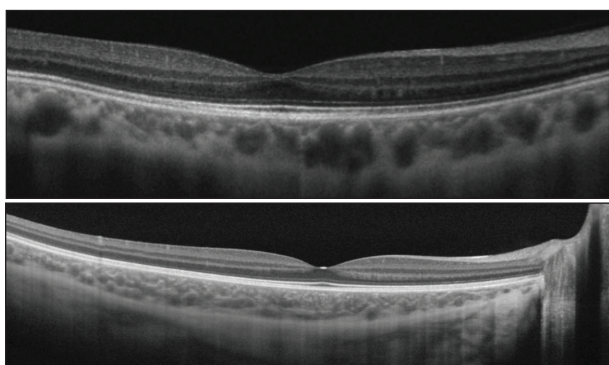


Figure 2. SD-OCT image (top) vs DRI OCT-1 Atlantis image (bottom).

the fovea. Choroidal thickness was independently determined by 3 observers, and we had a control group comprised of 75 eyes from 50 normal healthy volunteers older than 18 years of age.

Table 1 shows the data that were obtained from the patients in the study. The mean subfoveal choroidal thickness profiles were similar between the pediatric and control groups, but the temporal choroidal thickness was greater among the pediatric patients. The second study compared choroidal thickness measurements taken with SD-OCT with measurements taken with DRI OCT-1 Atlantis. Figures 1 and 2 show typical SD-OCT image (top) vs an image taken with DRI OCT-1 Atlantis (bottom).

The study was performed as a cross-sectional comparative, noninterventional study. The macular regions of 209 eyes of 119 patients (mean age: approximately 55) were studied with the same DRI OCT-1 Atlantis prototype as in the first study and also the 3D OCT-2000 (Topcon) with the following settings: scan pattern line: 6.0 mm; resolution: 1024 Hz; over scan count: 50; fixation position: macula; reference position: choroid; and over scan retry count: none.

A horizontal choroidal thickness profile of the macula (6.0 mm) was created by manually measuring subfoveal choroidal thickness (from the posterior edge of RPE to the choroid/sclera junction), and 6 further determinations were

TABLE 2. STUDY 2 DATA

Number of eyes: 209
Mean age: 55.2 ± 21.1 years (range 5 to 92)
Mean SE was -1.2 ± 3.3 D (range +6.5 to -22)
Mean subfoveal CT:
SS-OCT: 239.5 ± 109.2 μm (range 12 to 502)
SD-OCT: 243.7 ± 108.5 μm (range 25 to 584)
P = .187, Student t test paired data
Mean macular horizontal CT:
SS-OCT: 203.4 ± 91 μm (range 14 to 444) vs
SD-OCT: 204.2 ± 89.2 μm (range 16 to 433)
P = .757, Student t test paired data
The horizontal CT profile was very similar

performed every 500 μm temporal and nasal to the fovea. The choroidal thickness was independently determined by 2 observers.

Table 2 shows the data collected from patients in the study. The mean subfoveal choroidal thickness in patients measured by DRI OCT-1 Atlantis was 239 μm ± 109.2 vs 243.7 μm ± 108.5 μm with 3D OCT-2000. The mean macular horizontal choroidal thickness was 203.4 μm ± 91 μm with DRI OCT-1 Atlantis vs 204.2 μm ± 89.2 μm with 3D OCT-2000. The conclusion that the horizontal choroidal thickness profile was very similar with DRI OCT-1 Atlantis and 3D OCT-2000, but that the percentage of definite choroidal/scleral junction that was visible was significantly greater with the DRI OCT-1 Atlantis prototype (Figure 3).

SUMMARY

The extraordinary quality of the images obtained with DRI OCT-1 Atlantis allows in-depth study and analysis for all the retinal layers, including the nerve fiber layer and Henle layer. The range of imaging, not only in length but also in depth, allows us to see everything in great detail including the vitreous, retina, choroid, and sclera. High penetration of the scan allows choroidal study through serous or fibrovascular detachments of RPE or neurosensory retina. High exploration speed in the line mode allows a faster procedure, which will be beneficial to patient compliance, even in young children and more difficult patients. The patient does not see the scan, avoiding any displacement of the eye as it follows the light of the scan, as happened in the preceding model. Finally DRI OCT-1 Atlantis is able to produce high-quality scans for even difficult patients such as those with extremely high myopia. ■

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Visualization for High-speed Vitrectomy

By Florian Balta, MD



The Topcon OMS 800 OFFISS (Optical Fiber Free Intravitreal Surgery System) is a premium microscope for cataract and vitreous surgeries. Some of the key features of this microscope include a stereo variator, slit illumination, and an electromagnetic locking system. It also has dual motorized focusing systems, a stain-proof coated objective lens, 3-directional illumination, a yellow filter to protect against phototoxicity, an X-Y translator, and a programmable multifunction foot switch.

Figure 1 shows the Topcon OMS 800 with OFFISS. By eliminating the need for fiberoptic illumination, the OFFISS system allows the surgeon to use both hands for manipulating surgical instruments during vitrectomy—true bimanual vitrectomy—which is possible using the 40-D lens. The effect of the OFFISS system is maximized by the electromagnetic brake system, the motorized OFFISS system, the built-in stereo variator, and the slit illumination.



Figure 1. The Topcon OMS 800 with OFFISS.

There are 2 main lenses. The 40-D lens offers a 50° angle of observation and a larger space between the lens and the eye (Figure 2A). The 120-D lens allows 130° of visual field over the ora serrata (Figure 2B).

The important question, however, is: Does it work?

CASE EXAMPLES

Figure 3 shows the system in place. Figure 4 shows the 120-D lens being used for a case of proliferative diabetic retinopathy. We then switch to the 40-D lens. The quality of the image with the 40-D lens (Figure 5) is excellent, allowing us to see the fine details of the retina and obviating the need for a contact lens.

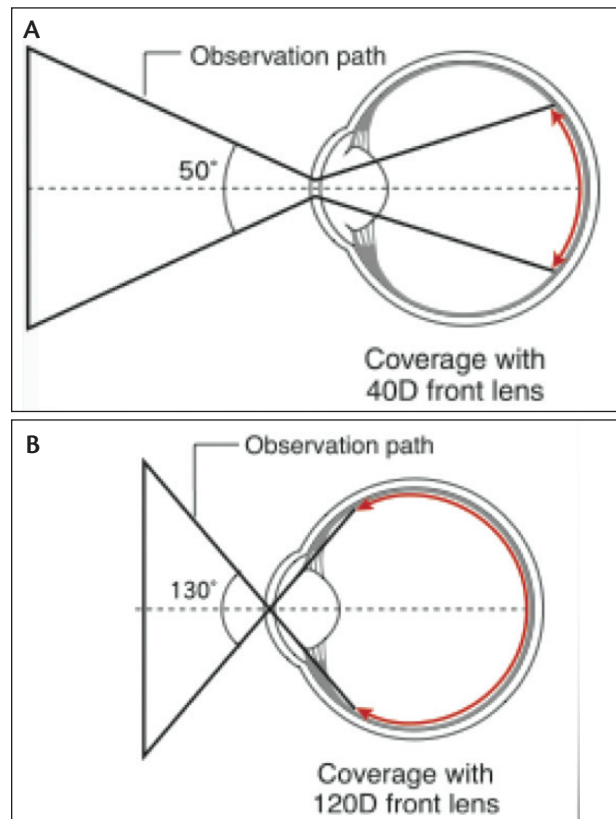


Figure 2. The 40-D lens offers a 50° angle of observation and a larger space between the lens and the eye (A). The 120-D lens allows 130° of visual field over the ora serrata (B).

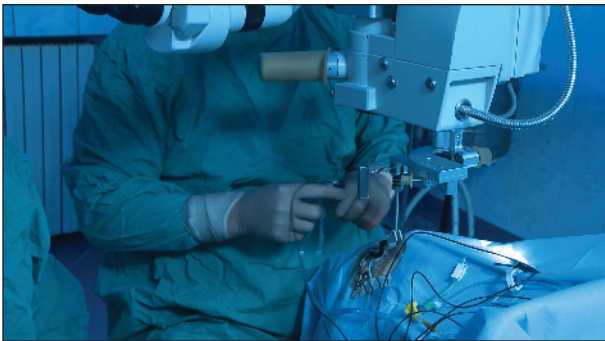


Figure 3. The Topcon OMS 800 with OFFISS in place.

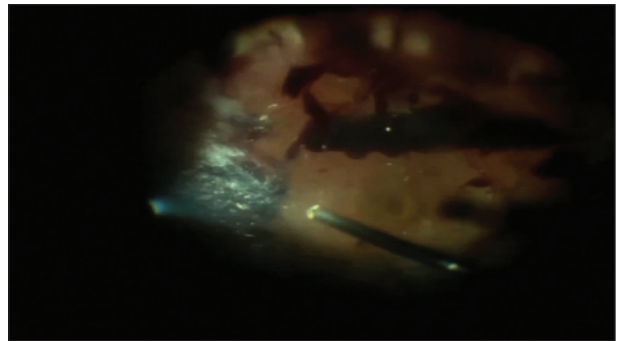


Figure 4. The 120-D lens being used for a case of PDR.

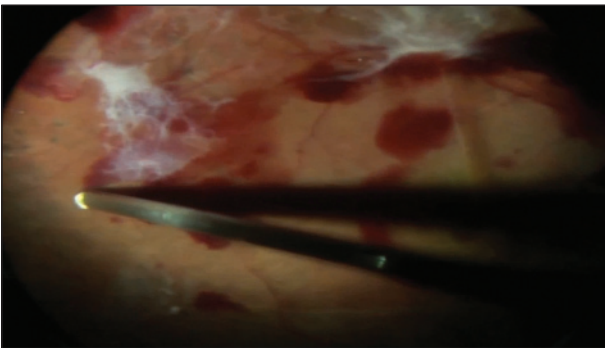


Figure 5. Resolution with the 40-D lens.

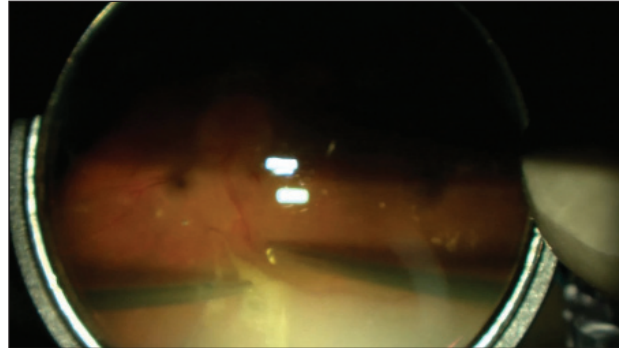


Figure 6. True bimanual surgery under slit illumination.



Figure 7. The 120-D lens for view of the periphery.

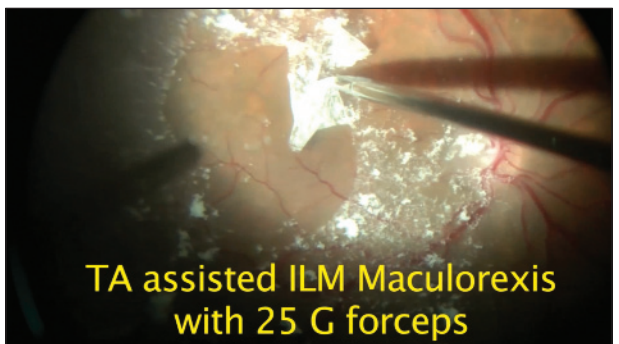


Figure 8. View of the macula with the 40-D lens.

Figure 6 shows how we are able to use true bimanual surgery under slit illumination. With the forceps we grab the membrane and then use the high-speed cutter as scissors to remove the membrane.

Figure 7 demonstrates the quality of the view with the 120-D lens in the periphery as the flap of the retinal break is dissected using an illuminated spatula and forceps. After we dissected the vitreous from the retina, we used the cutter to separate the vitreous and to free the retina to completely remove the vitreous traction at that site.

Figure 8 is another example of how well we can see the macula under the 40-D lens.

SUMMARY

The Topcon microscope with OMS-800 with OFFISS system allows us to perform true bimanual surgery, which improves the quality of surgery by making it safer and faster. Using the noncontact 40-D lens, the entire macula can be seen, and, in combination with the high-speed cutter, we can achieve optimal results for our patients. ■

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Multifunctional Glaucoma Analysis Made Possible by the 3D OCT-2000

By Urs Vossmerbaeumer, MD, PD, MSc, FEBO, DIU



Effective management of glaucoma relies on a broad spectrum of examinations over many years. Qualitative and quantitative assessments of the optic nerve, chamber angle, corneal thickness, and intraocular pressure (IOP), as well as functional tests, are required. Traditionally, a large variety of instrumentation is necessary. Now, however, the 3D OCT-2000 with non-dilated fundus photography and high-definition OCT allows us to document the optic disc, the nerve fiber layer, and cupping, eliminating the need for additional diagnostic equipment.

Nerve fiber layer. To assess the 3D OCT-2000's ability to detect glaucomatous damage via the nerve fiber layer, we looked at a subset of patients from a larger study of 83 eyes of 48 patients. That study compared normal eyes to those with ocular hypertension but no damage, and to eyes with damage from glaucoma. Our purpose was to see whether measuring the nerve fiber layer with OCT would reveal differences in thickness. We found that the nerve fiber layer was significantly thicker in the normal eyes and the eyes with ocular hypertension but no glaucoma damage than in the eyes with glaucomatous optic atrophy. This result showed that, in a small study, we could distinguish between those patients with elevated IOP and only those who had glaucomatous damage.

Chamber Angle. In another study, we evaluated the 3D OCT-2000 in terms of whether it could quantitatively assess the chamber angle. We assessed 666 eyes in 400 patients, dividing the groups into hyperopic eyes, myopic eyes, and normal eyes. The eyes with myopia were found to have a mean aperture of 40° vs 30° in the eyes with hyperopia.

IOP/corneal thickness. We also wanted to see if OCT could replace pachymetry for measuring the corneal thickness and its relationship with IOP. Using OCT in the anterior segment mode on the 3D OCT-2000, we not only get a reading from a single spot, as with corneal pachymetry, but we also get a full-fledged corneal thickness map for the entire OCT scan, which can then be correlated with the IOP measurements.

We performed another large study of almost 700 eyes to obtain the correlation of IOP to corneal thickness measured with the 3D OCT-2000. The correlation was that for every 1 mm Hg increase in IOP, corneal thickness increased by 25 μm , which is statistically significant. Our findings are not surprising and, most important, are consistent with previous studies using ultrasound pachymetry or anterior segment tomography.

SUMMARY

In my opinion, the capabilities of the 3D OCT-2000 are such that this 1 machine can do the jobs of several that we have traditionally relied upon. We get not only a qualitative evaluation of the angle with the 3D OCT-2000, but also an evaluation that is quantitative. We measure not merely the cupping of the optic disc, rather, we can obtain a true nerve fiber layer measurement. Finally, the corneal thickness map that is generated by the 3D OCT-2000 helps us to better assess and evaluate IOP. ■

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Imaging the Vitreous and the Vitreoretinal Interface

By Paulo E. Stanga, MD



Ophthalmology enjoys a unique advantage over other areas of medicine because the eye is the only organ in which the anatomy is readily visible by the transparent media of the aqueous and the vitreous. Since the advent of our use of time-domain optical coherence tomography (OCT) in 1996, the quality of imaging with OCT has vastly improved. The big push in OCT development, of course, coincided with the availability of new pharmaceutical treatments for age-related macular degeneration (AMD) due to the need to measure the effectiveness of anti-VEGF agents.

Topcon launched the first commercial Fourier-domain OCT in 2006. Fourier-domain technology allowed us to individualize new tissue landmarks, such as the interface between the inner and outer segments of the photoreceptors, which previously was unthinkable.

In 2012, however, after 12 years of clinical experience with OCT, ophthalmologists need more depth and detail. To answer this need, a new swept-source OCT that is significantly faster at obtaining A-line scans at 100 000 scans per second and that has a longer wavelength (1050 nm) has been developed—the Deep Range Imaging (DRI) OCT-1 Atlantis (Topcon). The advantages of swept-source imaging and the longer wavelength of the DRI OCT-1 Atlantis include faster imaging speed, uniform quality of imaging, improved vitreous visualization, increased penetration and visibility of the choroid and sclera, reduced eye movement, and reduced light scatter. It is also important to note that the increased length of the scans, 12 mm, is equivalent to 40°.

CASE EXAMPLES

Branch retinal vein occlusion. Using the DRI OCT-1 Atlantis for a patient with branch retinal vein occlusion

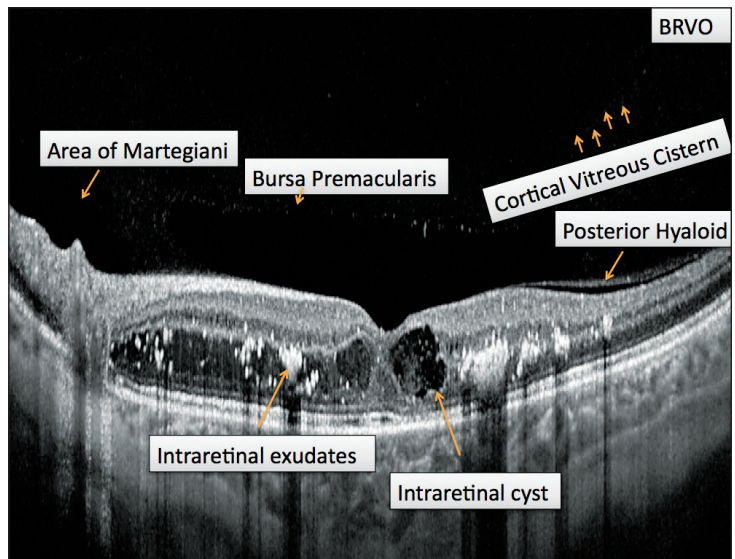


Figure 1. Patient with BRVO.

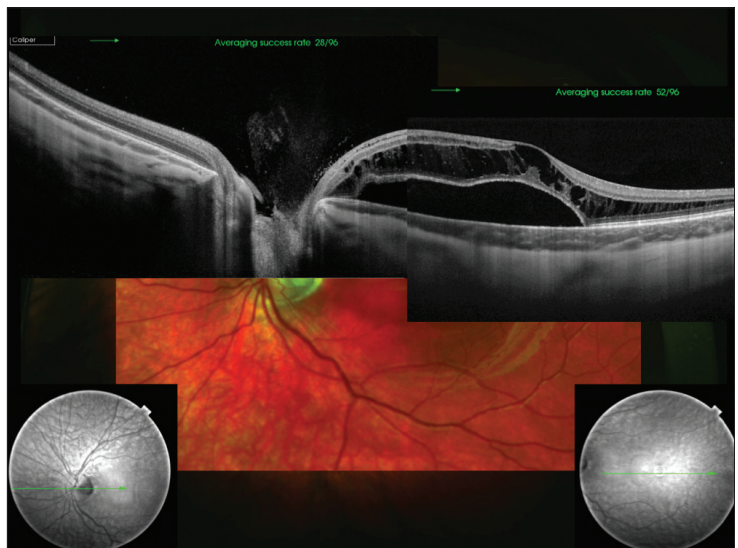


Figure 2. Five-year-old patient with maculopathy.

(Figure 1), it is possible to see the area of Martegiani in front of the optic disk, the bursa premacularis, the posterior hyaloids, intraretinal exudates, and an intraretinal cyst.

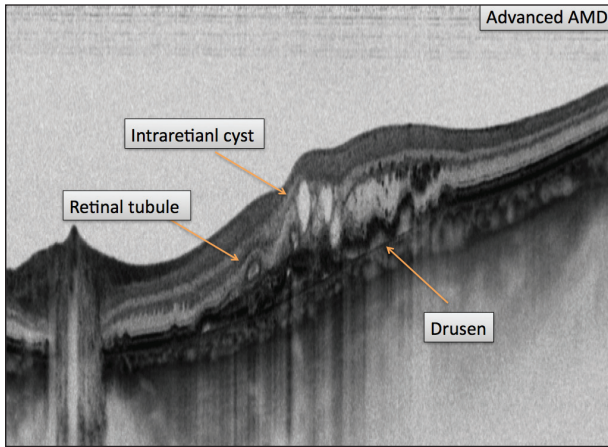


Figure 3. Advanced AMD.

Maculopathy. Figure 2 shows a composite of 2 images from a 5-year-old patient with maculopathy. In these images, the intraretinal and subretinal fluid and the photoreceptor outer segments dangling from this area of schisis can be seen with no shadowing. We did not find any interaction between the optic disc and the area of schisis. What is clearly seen, however, is the tractional component in this lesion. The vitreous is attached and epiglial tissue is present, which seems to be inducing worsening of the schisis.

AMD. Figure 3 shows a patient with advanced AMD in which the retinal tubule is clearly seen. An intraretinal tubule can easily be confused with an intraretinal cyst if the resolution of the scan is not high enough. In this scan, the drusen are well defined and, again, there is no shadowing behind the drusen.

DRI OCT-1 Atlantis imaging is also helpful in cases in which there may be a question as to whether continuing anti-VEGF injections will help a patient who has

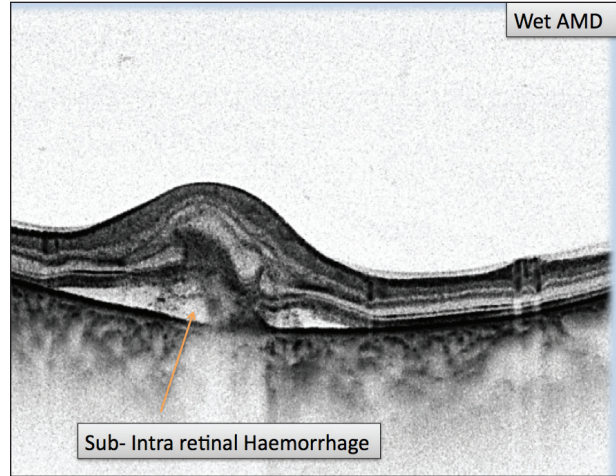


Figure 4. The black-over-white detail on the DRI OCT-1 Atlantis makes it easier to see details in the outer retina.

already had multiple injections. Using the black-over-white detail (Figure 4), it is easier to see details in the outer retina. The DRI penetrates through the subretinal hemorrhage, demonstrating that, yes, there is fluid, and continuing injections is a good course of treatment.

Full thickness defect. Figure 5 is a scan of a patient with a full-thickness defect. Most important, the persistence of the inner-outer segments junction and the bridge of the internal limiting membrane are shown.

Cortical vitreous. Figure 6 is a scan from one of the patients in our cortical vitreous study. One can clearly see the bursa premacularis, the posterior hyaloids, the area of Martegiani, and a system internal to the bursa macularis. I have never seen the bursa macularis in vivo—this is the first time that we have been able to image it so clearly.

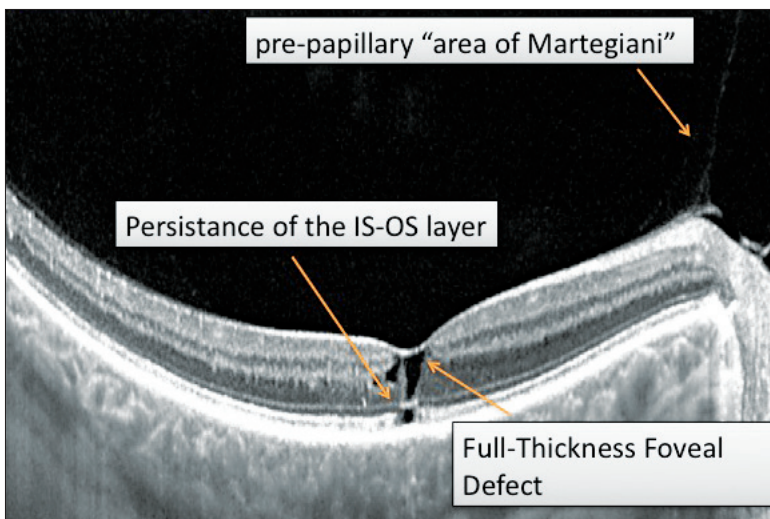


Figure 5. Full-thickness defect.

DRI OCT-1 ATLANTIS IN THE VITREORETINAL INTERFACE

Vitreomacular adhesion (VMA) occurs with incomplete separation of the posterior vitreous body at the macula and is the beginning of a disease spectrum that can lead to macular hole. The advent of OCT has allowed easy and accurate identification of VMA and has led to a better understanding of pathology at the vitreoretinal interface and its role in processes including retinal vein occlusion, epiretinal membrane, macular holes, diabetic macular edema, and AMD. The vitreous, although normally transparent, scatters with eye movement and is unstable at times. The benefits of a swept-source OCT system are that it is

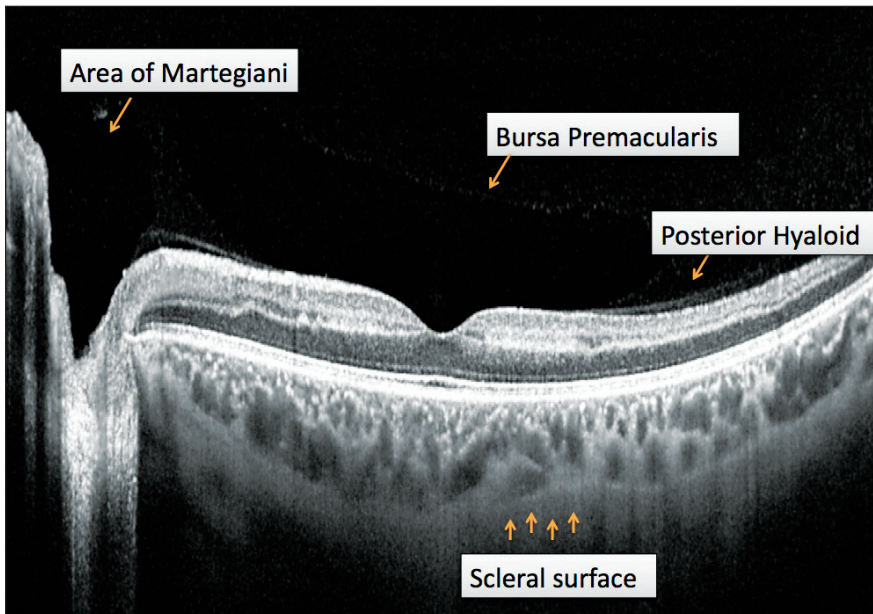


Figure 6. Cortical vitreous.

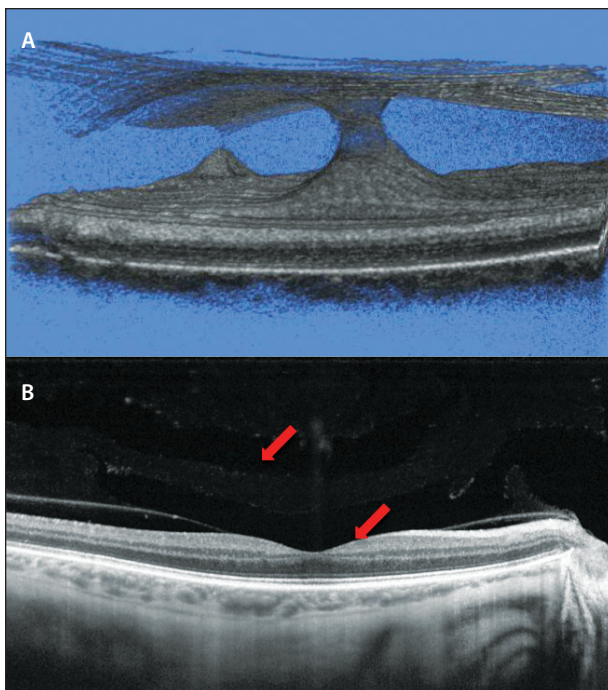


Figure 7. Vitreomacular traction: the 3D OCT-2000 (A) vs the DRI OCT-1 Atlantis (B).

less sensitive to sample motion and it is 2 times faster (100 kHz) compared with even the 3D OCT-2000 (Topcon).

VMAAs can be multifocal and, because more treatments are now being delivered via intravitreal injection, it is extremely important to be aware of cortical vitreous action.

Figure 7 shows what is seen with the 3D OCT-2000 (A) vs the DRI OCT-1 Atlantis (B) in a case of vitreomacular traction. It is much easier to see the attachment and any alterations in the fovea with the DRI.

SUMMARY

With a significant number of therapies being delivered

via intravitreal injections, it is becoming increasingly important to being able to image anatomical changes in vivo, not only at the level of the vitreoretinal interface, but also in the cortical vitreous. It is also important to image any changes in choroidal thickness and vascularity and to understand the role of these changes in disease. Swept-source DRI OCT1-Atlantis imaging is a new tool to allow us to achieve these goals. ■

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