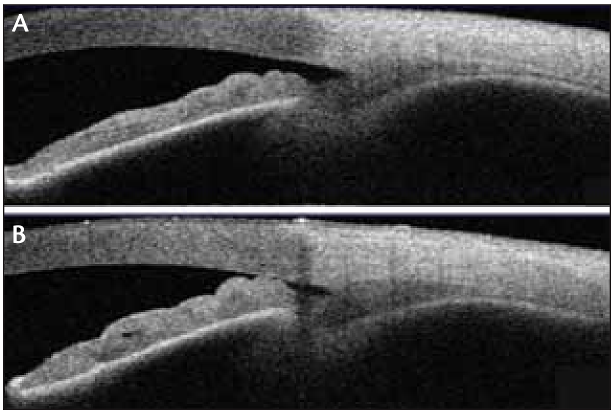
Anterior Segment Optical Coherence Tomography

This imaging modality offers important views and measurements of the anterior segment anatomy.

BY DIAMOND Y. TAM, MD

Although optic nerve damage and a progressive loss of the visual field are the final common pathways of the glaucomas, the configuration of the anterior segment is one of the most important things the clinician must assess. A determination of anterior segment anatomy (such as the angle grade, iris configuration, and lens position) provides essential guidance to proper clinical therapeutic decisions. The various ways in which physicians evaluate the anterior segment, aside from a detailed examination and gonioscopy, include technologies such as Scheimpflug photography, scanning slit-lamp systems, ultrasound biomicroscopy, and anterior segment optical coherence tomography (AS-OCT). Although Huang et al[1] first described optical coherence tomography of the eye in 1991, Izatt et al[2] described its use in the anterior segment in 1994.

AS-OCT imaging allows clinicians to document progression or changes in anterior segment anatomy, and it provides a cross-sectional view. The technology also precisely documents parameters such as the angle's width, the iris' thickness, and anterior chamber depth. In addition, it permits physicians to view dynamic images of the angle's configuration under different lighting conditions. AS-OCT is therefore a useful adjunct in the diagnosis and treatment of glaucoma.



(All figures courtesy of Iqbal Ike K. Ahmed, MD, FRCSC.)

Figure 1. AS-OCT of the angle in an eye with the room's lights on (A) and then off (B). Note the appositional closure in the dark.

Figure 2. AS-OCT allows the clinician to use a caliper tool to measure spaces precisely, here the angle recess.

IMAGING THE IRIS, LENS, AND ANTERIOR CHAMBER

Two common flaws in the performance of clinical gonioscopy include the placement of pressure on the cornea and the use of excessive amounts of light. Both typically produce the illusion of an open angle in a patient who otherwise may have narrow or even appositionally closed angles. AS-OCT provides little light artifact. It can actually dynamically show how an angle imaged in bright light may appear open but look narrow when assessed in the dark (Figure 1). The noncontact test also eliminates the problem of corneal compression.

AS-OCT can quantitatively measure the exact angle recess (Figure 2) as well as provide insight into the possible mechanism of the angle's narrowing or closure, including a

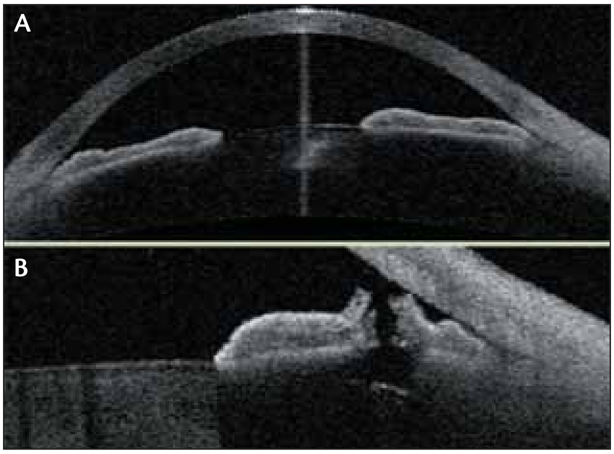


Figure 3. An eye with narrow angles as seen on low-magnification imaging of the anterior segment (A). The same eye after laser iridotomy with an angle that appears nearly unchanged and is still narrow (B).

Figure 5. A plateau iris configuration persists after cataract extraction. The central anterior chamber is deep, and the peripheral iris appears to be propped up anteriorly.

primarily lens-related mechanism, plateau iris, a mixed mechanism of combined lens rise and plateau iris, and even malignant glaucoma. In the case of a lens-related narrow angle, any contributing component of pupillary block may be alleviated by a peripheral laser iridotomy. The angle may still be at risk for closure, however, due to a large lens or high lens rise pushing the iris leaflets forward (Figure 3). Although not always as dramatic, one striking example of primary phacomorphic angle closure is microspherophakia. The definitive treatment in such cases is lensectomy; any other treatment modalities will ultimately fail to prevent intermittent, chronic, or even acute angle closure (Figure 4).

Classically in plateau iris, the central anterior chamber is deep, but the peripheral anterior chamber is shallow, leading to the illusion of an open angle on cursory examination. On gonioscopy, however, irido-trabecular proximity can be noted along with the so-called double-hump sign upon light compression. This finding occurs where it is thought the ciliary body is more anteriorly positioned or relatively enlarged, propping up the peripheral iris and resulting in the narrow angle (Figure 5). Although AS-OCT provides important information and various clues, clinicians must remember that plateau iris, or any ciliary body-mediated posterior pushing of the peripheral iris (such as a

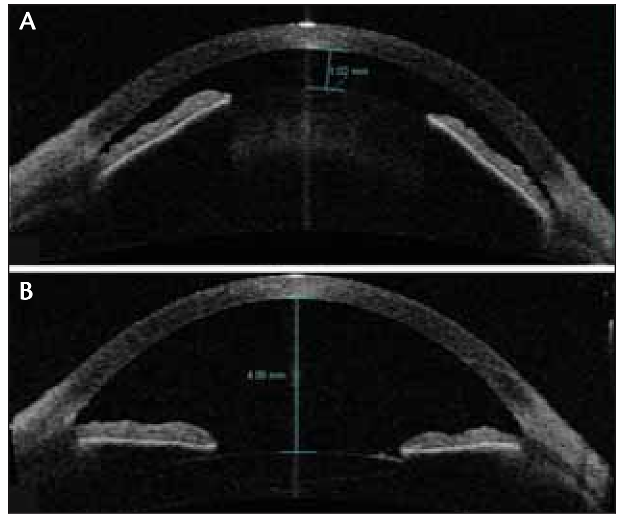


Figure 4. A patient with microspherophakia has a large amount of lens-induced anterior rotation of the iris leaflets (A). The same patient after cataract extraction with implantation of an IOL and a capsular tension ring. The angle is now open (B).

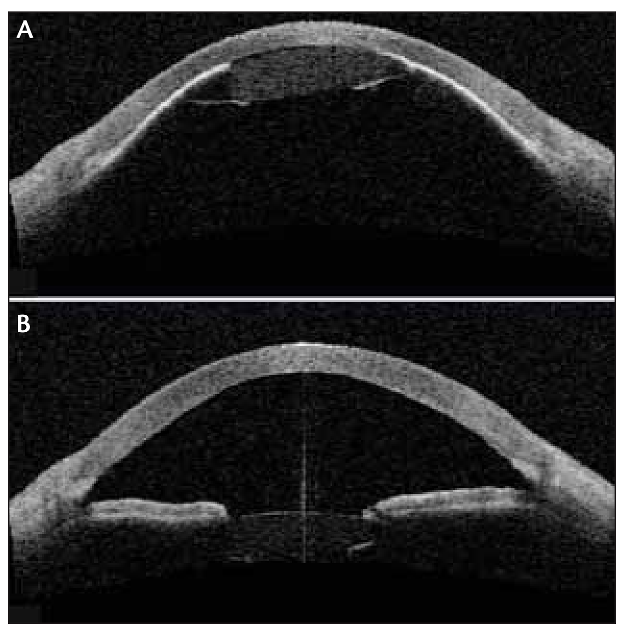


Figure 6. Malignant glaucoma with a completely obliterated anterior chamber (A). The same eye after treatment, now with an open angle (B).

cyst or tumor), cannot be diagnosed with this technology alone. AS-OCT is unable to image any tissues posterior to the iris due to its pigmentation. Physicians therefore should use ultrasound biomicroscopy for definitive documentation and evaluation of the ciliary processes.

Another relatively rare but diagnostic and therapeutically challenging entity is that of malignant glaucoma.

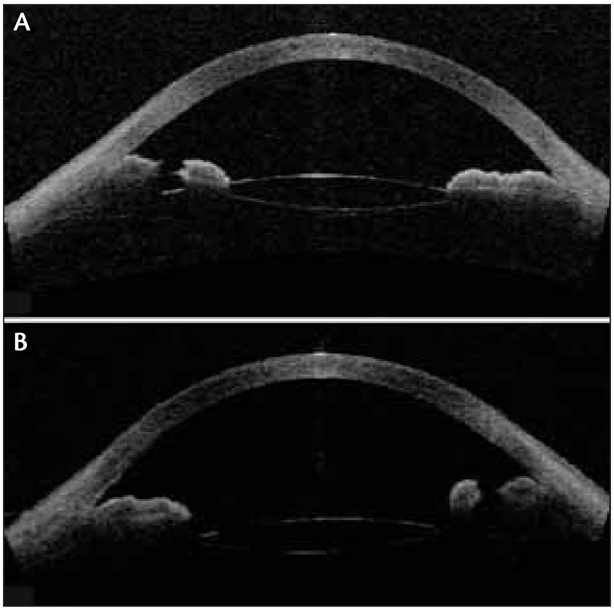


Figure 7. A subtle case of malignant glaucoma where the sulcus space is absent and the IOL has pushed up against the posterior iris. Note the closed angle with irido-trabecular contact (A). After treatment, the eye has an open angle and a restored sulcus space (B).

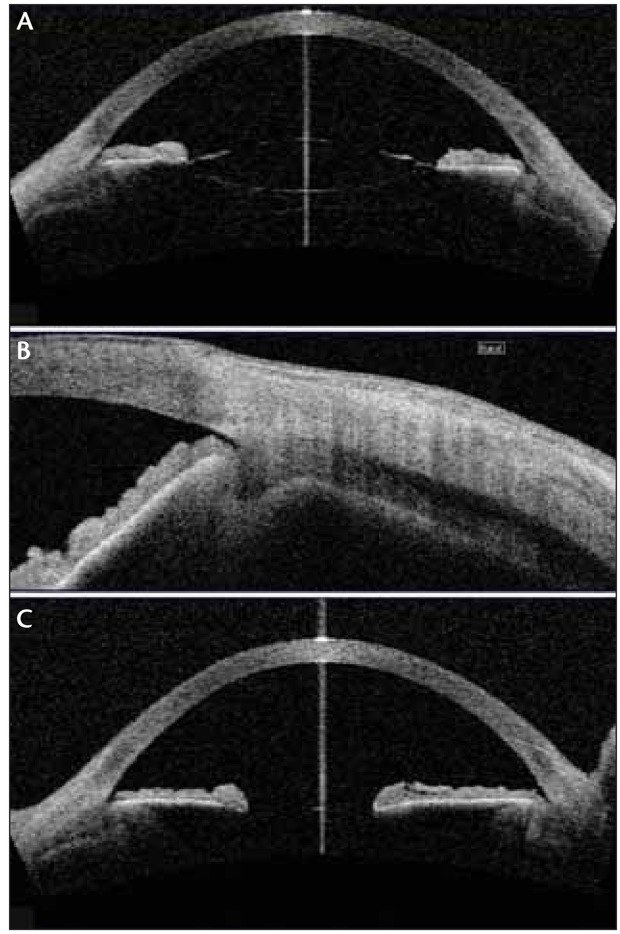


Figure 8. Narrow angles are visible in an eye that also has an obliterated sulcus space (A). In an AS-OCT scan over the sclera, suprachoroidal fluid can be seen, which is causing the forward rotation of the ciliary body resulting in angle closure (B). After treatment, the angle improves, and the sulcus space is restored (C).

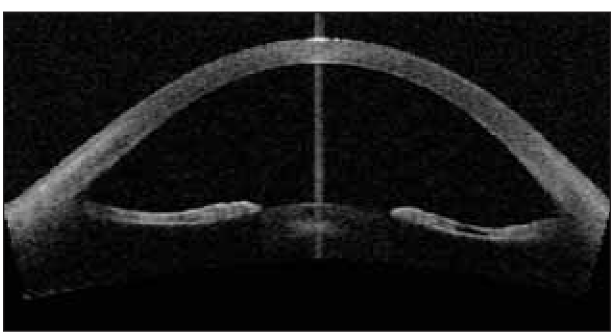


Figure 9. The concave iris contour of pigment dispersion syndrome can be demonstrated nicely with AS-OCT.

Figure 10. An AS-OCT image of a posterior lenticonus-type cataract.

Although sometimes obvious with complete obliteration of the anterior chamber and an elevated IOP (Figure 6), the manifestation of this disease can be subtle. AS-OCT is able to show an obliterated sulcus space and angle closure in a patient with a myopic shift after routine cataract surgery and elevated IOP (Figure 7). Although the technology is unable to image the ciliary processes or through the pigmented iris, it can show the suprachoroidal space and effusions, another potential cause of angle closure (Figure 8).

In addition to its utility in the imaging of narrow angles and selection of appropriate therapeutics, AS-OCT can provide unique views of pigment dispersion syndrome (Figure 9) and tilted IOLs. The technology can reveal some characteristics of the crystalline lens (Figure 10) and possibly provide a means by which to monitor and assess abnormal structures in the anterior chamber (Figure 11).

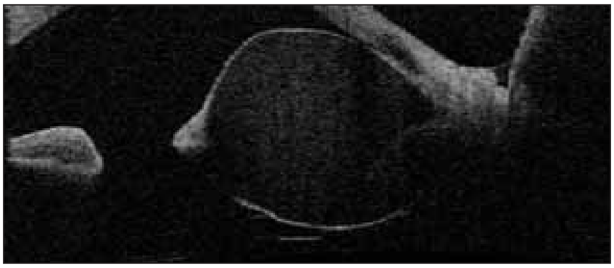


Figure 11. An AS-OCT image of a large fluid-filled iris cyst. Its anterior and posterior aspects can be visualized.

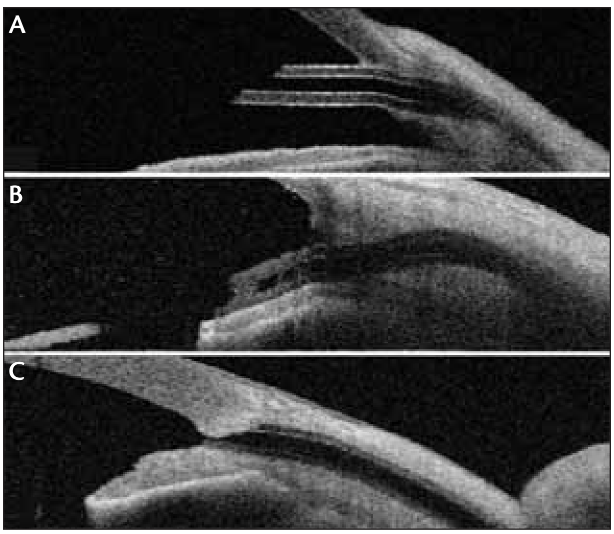


Figure 13. A tube shunt is well positioned in the anterior chamber at a safe distance from the cornea (A). A small blood clot occludes the tip of the tube, but the lumen is clear with no obstructions or blood tracking up the tube (B). In this case, the tube has almost completely retracted out of the anterior chamber (C).

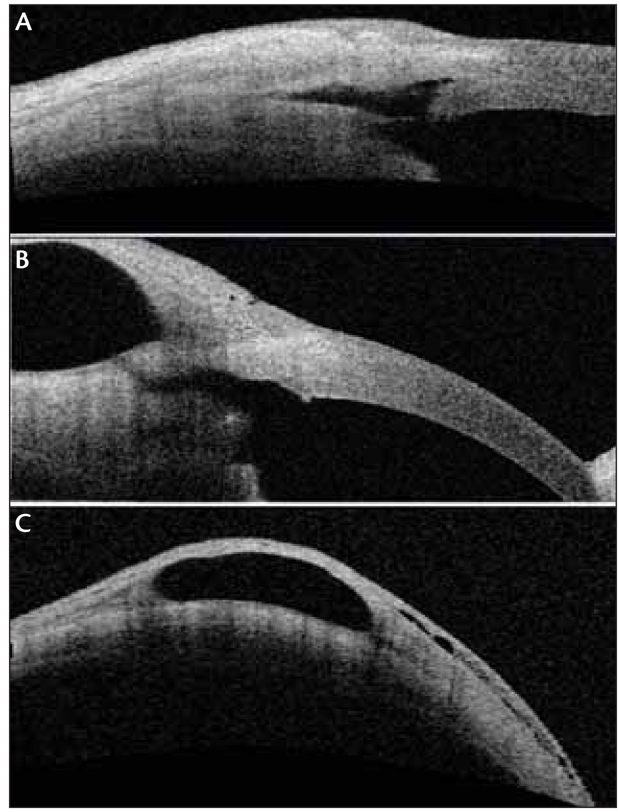


Figure 12. An AS-OCT image of a failed, flat bleb. The trabeculectomy site can be seen, but no subconjunctival bleb is visible (A). A different patient with a highly elevated, tense, encapsulated bleb. The cornea is visible on the right side of the image. The conjunctiva and Tenon's capsule appear to be thickened at upper left (B). The same patient as in Figure 12B with a scanned section of the bleb only. The cornea is not imaged in this horizontal scan with the eye in downgaze (C).

IMAGING IN GLAUCOMA SURGERY

As new glaucoma surgical technologies are developed, the role of AS-OCT continues to expand. The technology helps surgeons obtain supplemental information about the mechanism by which a surgical procedure lowers IOP in a given patient. It also aids in preoperative planning in some cases. Examples of the utility of AS-OCT in glaucoma surgery include the imaging of subconjunctival blebs in trabeculectomy; not only can the internal ostium be visualized but also the internal bleb structure itself (Figure 12). Likewise, in tube shunt surgery, the position of the device in the anterior chamber, its proximity to the corneal endothelium, and obstructions in the lumen or irregularities in the course of the tube can be readily visualized (Figure 13).

The surgical objective of canaloplasty is to produce suture-mediated re-expansion of a collapsed canal in an eye with open-angle glaucoma. Studies have shown that higher suture tension in the canal results in a greater IOP-lowering effect.[3] AS-OCT allows visualization of the distended Schlemm's canal postoperatively, confirming that suture tension has been achieved (Figure 14). Further, distal intrascleral aqueous veins are sometimes visible on AS-OCT (Figure 15). As mentioned previously, AS-OCT technology can image the suprachoroidal space, thus permitting the evaluation of such devices' success as the gold suprachoroidal microshunt (Solx Gold Shunt; Solx, Inc., Waltham, MA). This device is designed to provide a conduit by which aqueous humor can exit the anterior chamber into the suprachoroidal space and thereby lower the IOP (Figure 16).

Although the definitive surgical treatment of phacomorphic angle closure consists of lens extraction, this procedure alone does not alleviate plateau iris-related narrowing of the angle in eyes with a mixed mechanism of angle narrowing.[4] In these cases, endoscopic cycloablation in a pattern Ike Ahmed, MD, terms *endocycloplasty* may be of use. With the technique, the surgeon treats the posterior tails of the ciliary

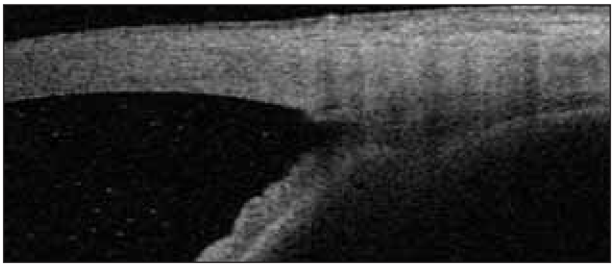


Figure 14. After canaloplasty, Schlemm's canal has been tented open with an intracanalicular suture, and a patent opening in the canal can be seen.

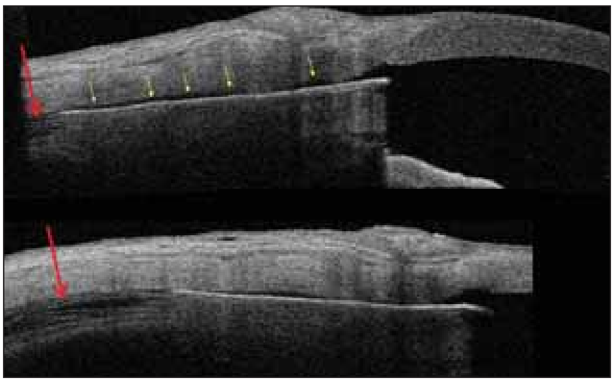


Figure 16. Fluid surrounds the body of the Solx Gold Shunt (yellow arrows) and tracks posterior to the device (red arrows).

Figure 15. An intrascleral aqueous vein imaged with AS-OCT.

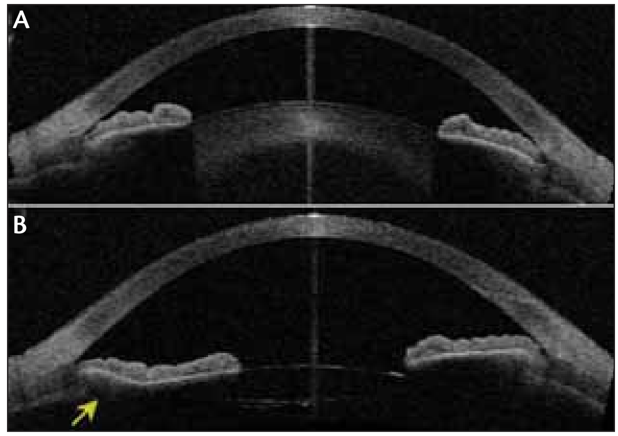


Figure 17. A patient with narrow angles due to a mixed lens and plateau iris mechanism (A). After cataract extraction and IOL implantation with 270º of endocycloplasty, a dramatic difference in the contour of the peripheral iris can be appreciated on AS-OCT. The treated ciliary processes (yellow arrow) have flattened, and the angle is wide open, even to the point of iris concavity. In contrast, the plateau iris configuration with a narrow angle is still clearly visible on the opposite untreated side (B).

processes to induce shrinkage and posterior curling, allowing the peripheral iris to fall away from the angle (Figure 17). The goal of this treatment is different from that of traditional endoscopic cyclophotocoagulation for refractory glaucoma, where the surgeon attempts to treat the entire pigmented epithelium. In endocycloplasty, the ophthalmologist merely shrinks the ciliary processes posteriorly to eliminate any propping up of the peripheral iris into the angle, a process that alleviates any ciliary body-mediated angle-closure mechanism (*for more information, see page 29*).

CONCLUSION

No technology can replace a careful clinical examination and the diagnostic and therapeutic decision making of an experienced ophthalmologist. Moreover, AS-OCT has limitations, most notably its inability to image through pigmented tissue. It is therefore inadequate for the assessment of the ciliary body, zonules, posterior chamber, or anterior vitreous.

Nevertheless, AS-OCT yields unique cross-sectional views of the anterior segment, and it has the ability to precisely measure various spaces and angles between tissues. This technology is a powerful tool not only for documenting disease and providing diagnostic clues but also for monitoring change and progression of tissue's position over time. AS-OCT's noncontact nature, excellent high-resolution real-time images, and rapid scanning rate make it an excellent adjunctive tool for both the physician and the patient. With developments in three-dimensional AS-OCT likely[5] and increasingly rapid scanning speeds,[6,7] the future applications of this technology in glaucoma are promising and exciting. ❑

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