Applications of Anterior Segment OCT in Refractive Surgery

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By Ying Guo, MBBS

Because of its ability to visualize the anterior segment quickly and in high resolution, anterior segment OCT (AS-OCT) can be applied to different phases of multiple procedures to improve surgical decision-making and patient outcomes.

OCT Pachymetry

George O. Waring IV, MD, FACS, associate professor of ophthalmology and director of refractive surgery at Medical University of South Carolina (MUSC) Storm Eye Institute, uses AS-OCT as "a second objective tool" for measuring corneal thickness. He notes that surgeons should be aware that pachymetry data are influenced by the method of measurement—OCT often measures corneal thickness slightly thinner than other commonly used pachymeters.[1]

AS-OCT can successfully map corneal epithelial thickness, Dr. Waring said.[2] "With epithelial thickness mapping, we can better predict potential disease states and analyze postsurgical changes," he says. One major application for epithelial thickness maps is keratoconus screening in laser-assisted in situ keratomileusis (LASIK) and surface ablation candidates, as the epithelium often compensates in early keratoconus by thinning over the cone and thickening around it.[3] Dr. Waring finds epithelial mapping most helpful in borderline keratoconus cases. "In these patients, I look for any irregular epithelial patterns that might be suggestive of forme fruste keratoconus," he says. In fact, Dr. Waring and colleagues have recently proposed novel indices for identifying keratoconic eyes based on epithelial thickness mapping.[4,5]

Mapping the corneal epithelium is also beneficial in understanding healing after laser refractive surgery. "With OCT, we can evaluate the state of epithelial hyperplasia and how it contributes to post-LASIK refractive changes," he said. "It will not only enhance our understanding of regression but also provide guidance on treatment planning for surface ablation or LASIK enhancement." Dr. Waring and colleagues have been using OCT to study epithelial healing patterns following different types of myopic and hyperopic LASIK. "There will be a lot of work in this area in the future," he says, noting recent research by Karolinne Maia Rocha, MD, and Ronald R. Krueger, MD.[6]

Dr. Waring also anticipates real-time, dynamic OCT being incorporated into excimer lasers someday. "This would allow us to develop algorithms to determine actual corneal power, once the epithelium is removed, for more predictable excimer laser enhancements," he says, "and it would also help us

better understand postsurgical epithelial and stromal changes to more precisely treat patients with reactive epithelial hyperplasia."

OCT in Refractive Procedures

In addition to LASIK and surface ablation, AS-OCT can be applied to a range of corneal and lens procedures. Dr. Waring says AS-OCT is an invaluable tool for anterior lamellar keratoplasty, particularly femtosecond laser-assisted lamellar keratoplasty and keratectomy. "Anterior segment OCT allows us to measure the depth of an anterior stromal scar," he says, "and then we can plan our lamellar dissection based on the OCT measurements."

AS-OCT is also useful for managing patients undergoing DSAEK, Dr. Waring said. OCT pachymetry maps can be used for serial and regional pachymetry mapping to determine if a patient with borderline Fuchs' dystrophy may require surgery or to evaluate graft adherence after surgery. Using OCT for real-time intraoperative assessment of interface fluid or clefts present between donor and recipient corneas is another exciting advancement.[7] "It will significantly improve outcomes with endothelial keratoplasty," Dr. Waring says.

Cataract surgery can also benefit from imaging, as OCT systems incorporated into femtosecond lasers provide intraoperative image guidance. Some believe the enhanced visualization can improve precision and potentially reduce complications.[8] According to Dr. Waring, the use of AS-OCT is leading to a much better understanding of the dimensions and variations in the human lens and capsule, which may help improve IOL design. "It also helps us plan for surgery better," he adds, "because now we can measure the anterior chamber and the lens characteristics before walking into the operating suite."

Furthermore, AS-OCT can determine corneal power based on direct measurements of both the anterior and posterior corneal curvature, whereas other modalities do so largely by extrapolation. Dr. Waring said that AS-OCT is one of his "go-to methods" for measuring "true" corneal power in post-LASIK cataract patients. "A large portion of our patients who had prior LASIK are now seeking refractive cataract surgery and we've had very good success using our post-refractive calculators with corneal OCT data to determine corneal power and IOL selection."

With respect to subclinical keratoconus, Dr. Waring notes that new indices based on epithelial thickness mapping could play an important role in grading as well as detecting the condition. "The classic gold-standard grading system, which is based on corneal topography indices, does not tell us enough of the morphologic picture, particularly with respect to the corneal ultrastructure" says Dr. Waring. "Because patients can have irregular, steep, thick, strong corneas, they can also have thin, ectatic, weak corneas that may not be as steep or irregular on topography due to undetected and marked epithelial hyperplasia," he says.

Dr. Waring foresees OCT imaging becoming critically important in lens surgery, as anterior segment OCT can be used to measure postoperative IOL position at different time points to develop algorithms that might help improve effective IOL position. "That would be of great significance," he says, "especially considering that we can now perform a primary posterior capsulotomy with the femtosecond laser, and with the development of other technologies that will reduce or eradicate lens epithelial cell and prevent posterior capsule opacification."

An Evolving Technology

Michael Mrochen, PhD, founder and CEO of IROC Science, a Swiss company that specializes in developing new optical diagnostic technologies, said that OCT imaging has evolved quickly over the past 20 years and highlights technological advances such as lower-coherence light sources to increase resolution of the A-scan, faster scanning technology to generate 3D images more quickly, and shorter computation time for image processing, which may improve structure analysis and reduce motion artifacts. Echoing Dr. Mrochen's comment, Dr. Waring notes that, "The original OCT devices had an axial resolution of about 10 µm, and now the commercially available devices have an axial resolution of 5 µm. This resolution can be even below1 µm for ultra-high-resolution OCT systems in the laboratory."

Dr. Mrochen explained that imaging the anterior segment is more challenging than the posterior segment. "Posterior segment imaging focuses on ultrastructural analysis of the retina, requiring mainly high resolution to separate the retinal layers. Typically, only small areas of about 1x1 mm are sampled for 3D scans, and only a reasonably short depth scan of less than 1 mm is required," he said. AS-OCT requires larger scanning areas (e.g., 12 x 12 mm) and an increased depth scan (e.g., 4-6 mm) to cover the cornea and the anterior chamber.

The biggest challenge with AS-OCT, according to Dr. Mrochen, is to achieve highly accurate shape measurements by minimizing eye motion error. He states that AS-OCT has the potential to replace Scheimpflug imaging for topography and tomography, but that today's anterior OCT devices do not achieve the accuracy of Placido-disk systems for topographic measurements. But future systems may provide full-eye scans including the cornea, anterior chamber, lens, vitreous and retina to allow ocular biometry, tomography and visualization of the substructures of the eye.

Dr. Mrochen notes that intraoperative OCT could be beneficial for femtosecond laser-assisted procedures such as small-incision lenticule extraction (SMILE). "By inspecting the cornea with OCT after the removal of a lenticule," he says, "surgeons might be able to identify possible remaining lenticular structures during the procedure."

While there are relatively few dedicated AS-OCTs available commercially, both Drs. Waring and Mrochen are confident OCT will continue to be one of the most important anterior segment imaging modalities. "OCT is analogous to a high-resolution CAT scan," says Dr. Waring, "except what we get is invaluable biometric and keratometric information." He believes that use of intraoperative OCT may eventually reduce the need for multiple preoperative testing modalities.

"For example," Dr. Waring says, "we can use OCT for intraoperative real-time identification of the steepest meridian when creating limbal relaxing incisions with a femtosecond laser. That would account for cyclotorsion and marking of the eye prior to surgery, simplifying the workflow for both the patient and the surgeon." He predicts that, at some point, endothelial keratoplasty performed with intraoperative OCT will become mainstream.

DISCLOSURES

Dr. Waring states that he has no relevant financial relationships to disclose. Dr. Mrochen is founder and CEO of IROC Science and a consultant to Alcon/WaveLight.

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