CLINICAL UPDATE

Femtosecond Laser Brings New Level of Precision to Cataract Procedures

Dr. Kevin Miller uses the Alcon LenSx femtosecond laser to assist with several steps of cataract surgery, under imaging guidance. The femtosecond laser enables physicians in the UCLA Stein Eye Institute's new outpatient surgical center to operate more efficiently and with increased precision.

The femtosecond laser has increased the accuracy of the most common surgical procedure in the United States, according to the surgeon who was instrumental in bringing the advanced tool to the UCLA Stein Eye Institute last year.

The Alcon LenSx, now used for precision cataract procedures at the Institute's outpatient surgical center, emits optical pulses at the unimaginably short duration of a femtosecond—one-millionth of one-billionth of a second.

"A femtosecond laser can be thought of as a microscalpel, incising the cornea and lens capsule and breaking up the cataract on a microscopic scale with an incredible level of precision," says Kevin M. Miller, MD, Kolokotrones Chair in Ophthalmology. "With a femtosecond laser, I can operate more efficiently and more precisely. The laser reduces the time the eye is open and eases stress on the eye's internal structures. And with such accuracy at our disposal, we anticipate the laser will open new avenues of treatment that have never been possible before."

Surgeons at Stein Eye have been using the femtosecond laser to assist with several steps of cataract surgery, including corneal incisions to remove the cataract and manage astigmatism, lens softening, and making an opening in the capsular bag.

For cataract procedures, the femtosecond laser system is gently docked to the patient's eye and optical coherence tomography imaging is used to map the eye's internal structures. Before the operation, the surgeon programs the location and size of the incisions as well as the region of the lens to be softened. After

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Macular Imaging with Spectral Domain OCT Proving Beneficial for Glaucoma Patients

A growing body of evidence points to the benefits of macular imaging with spectral domain optical coherence tomography (SD-OCT) in glaucoma patients—both for early detection and for monitoring disease progression, according to Kouros Nouri-Mahdavi, MD, MSc, associate professor of ophthalmology and director of the Glaucoma Imaging Research Laboratory at the UCLA Stein Eye Institute.

The advances over the last decade in SD-OCTs, which facilitate an assessment of the layers of the macula through structural and imaging measures, have led to a shift in the thinking about glaucoma progression. "For a long time we believed that the central part of the retina, where the macula is located, sustains damage very late in glaucoma. But new evidence has shown that the damage to the retinal ganglion cells in the central part of the retina actually occurs early in the

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imaging, the surgeon can make adjustments to the location and size of the incisions and the region of lens softening. A foot pedal is then depressed, which fires the laser to create the incisions and lens fragmentation pattern. The eye is undocked from the laser, and the patient is moved under the operating microscope. The surgeon proceeds to remove the cataract and implant the intraocular lens to complete the surgery.

Cataract procedures are already highly successful, Dr. Miller notes, but the femtosecond laser offers an incremental improvement in the precision and reproducibility of the incisions for modifying the patient's astigmatism and for removing the cataract. "It can make a 90-degree turn inside the cornea, which we can't possibly do with a metal blade or diamond knife," Dr. Miller says. "And it eliminates surgeon variability by stamping out a perfect incision every time."

But the femtosecond laser does more than produce precise repeatable incisions in cataract procedures. It also makes a perfectly round and centered opening in the anterior lens capsule—the capsulorrhexis. This has benefits that go beyond the cosmetic and into the realm of improving safety, Dr. Miller notes.

In addition, by pre-softening the cataract, the femtosecond laser reduces the amount of cumulative dissipated energy needed—thereby reducing the time spent emulsifying the cataract with ultrasound. This is particularly important for dense-cataract patients, improving safety by limiting exposure as well as leading to faster recovery.

The femtosecond laser is one of many new tools being used at the Institute's outpatient surgical center, which opened in February 2015. Located in the Edie & Lew Wasserman Building, the facility includes six operating rooms, examination areas, and support facilities devoted to the full range of ophthalmic treatment.

"The outpatient surgical center's facilities are excellent and complement the talents of our medical team," says Bartly J. Mondino, MD, chairman of the UCLA Department of Ophthalmology and director of the Stein Eye Institute. "Everything about the center was planned with enlightened ideas about patient well-being and medical efficiency."

While focusing on patient comfort and the most up-to-date surgical equipment, the center also serves as an incubator for future advanced applications. To promote teaching and training, an adjacent seating gallery allows visiting doctors to observe surgical procedures without scrubbing, while monitors display the same view of the eye the surgeon is seeing through the microscope. A video system captures surgical procedures, which can be distributed as educational tools, reviewed by colleagues at other institutions, and used for live streaming at conferences.

The facility features the Intraoperative Refractive Guidance Systems, including the Zeiss Callisto Markerless System, the Alcon Verion Image Guided System, and the Alcon Optiwave Refractive Analysis System, all of which increase the level of precision in procedures. The Zeiss and Alcon Verion systems track the position and orientation of the eye during surgery, creating a digital overlay that is linked directly to surgical tools in the operating room. The Alcon Optiwave measures the eye's power, which assists the surgeon in choosing the most accurate lens implant.

Looking forward, Dr. Miller believes new lens designs will take advantage of the technology's capabilities, including the precisely sized and positioned capsulorrhexis. "Multifocal lenses have to be perfectly centered on the pupil to function at their optimum," he says. "Locking the lens implant in would ensure quality each time. That is just one example of what I anticipate will be many new compelling reasons to use the femtosecond laser in the future." ○

Macular Imaging with Spectral Domain OCT Proving Beneficial for Glaucoma Patients

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disease," says Dr. Nouri-Mahdavi. "By using SD-OCT to measure the mass of ganglion cells in the macula, we can gauge the damage to these cells at various stages of the disease, making it useful both potentially for detection of early glaucoma and for identifying deterioration of the disease in later stages." While early detection is important for treating and preventing visual loss from glaucoma, he notes, the ability to detect worsening of the disease is critical for monitoring the impact of treatment.

Dr. Nouri-Mahdavi notes that approximately half of the retinal ganglion cells (RGCs)—the cells damaged in glaucoma—are located in the macula within 4–5 millimeters of the foveal center, and these tend to be the last ganglion cells to die. That means that in advanced disease, when other structural parameters such as those involving the optic nerve head and retinal nerve fiber layer (RNFL) are no longer useful, measurements of the macula can still be used to detect deterioration, he says.

Another important reason to image the macular region in glaucoma is that the macula is the only part of the retina where the RGCs are present in up to 6 to 7 layers, with 30 to 35 percent of retinal thickness. "It is much easier to measure where these cells are piled up," says Dr. Nouri-Mahdavi. "Moreover, there is likely to be low measurement variability in the central macula, which is populated by only smaller blood vessels. From a technical point of view, the macula is a fairly flat area, so performing segmentation—measuring layers separately—is a reasonably simple task."

The OCT technology is such that machines can now measure individual layers of the macula, one by one. Dr. Nouri-Mahdavi and colleagues are investigating whether measuring the ganglion cell layer by itself provides information that is more useful than what could be gathered by using the combined inner layers of the

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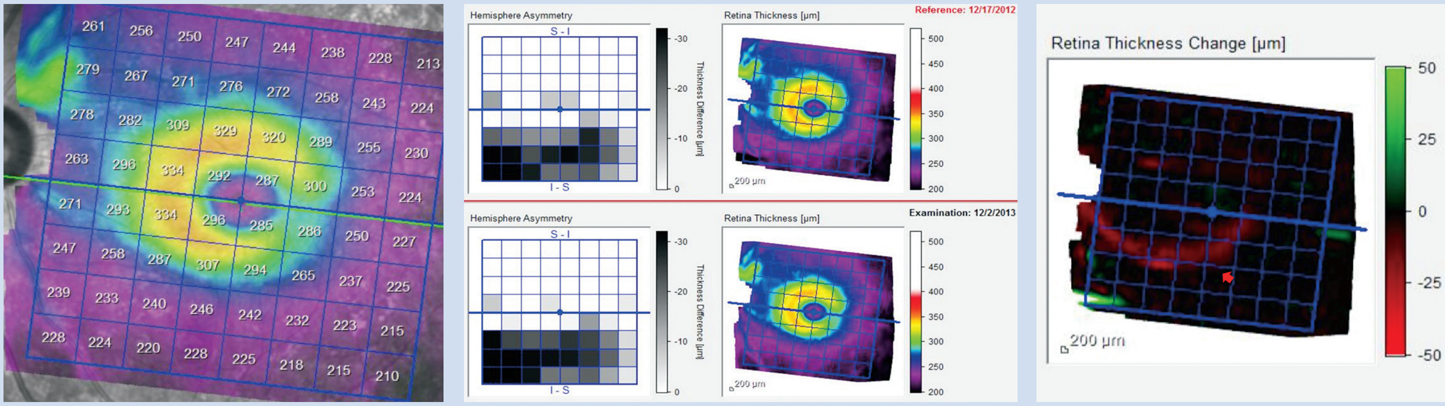

An example of follow-up macular images on an SD-OCT device. (Left) The macular image showing macular full thickness measurements in an 8 x 8 array centered on the fovea, the macular center. (Center) The baseline and follow-up images are accurately superimposed. (Right) The difference in thickness between the baseline and follow-up image is represented. The red arcuate area demonstrates a localized region where the entire thickness of the macula has thinned out, suggesting progression of glaucoma damage.

macula. In addition, many devices now come with software that is customized for glaucoma analysis, Dr. Nouri-Mahdavi notes.

Dr. Nouri-Mahdavi's research group has found that regional ganglion cell-inner plexiform layer (GC-IPL) measures perform similarly to localized RNFL measures when it comes to the detection of early glaucoma when there are only early signs of damage on the visual field test. "Many studies have shown that if we use both RNFL imaging and ganglion cell imaging measuring either ganglion cell complex (GCC) or GC-IPL, a subgroup of eyes will demonstrate early damage on the RNFL while showing nothing on the macular analysis, while other eyes will display evidence of damage on the macular images but no evidence of damage on the RNFL," Dr. Nouri-Mahdavi says. "That tells us these approaches are providing both complementary and confirmatory information, which is very useful."

Given that some patients show obvious early damage on the macular analysis while others do not, it becomes important to determine which types of patients are most likely to benefit. Dr. Nouri-Mahdavi explains that if there is evidence of glaucoma damage in the central 10 degrees on the visual field, there is more likely to be evidence of damage on the macular images as well. Researchers have found a "macular zone of vulnerability"—an area in the inferior part of the macula corresponding to the inferotemporal sector of the nerve where macular damage is most likely to occur early in glaucoma. The axons going to that area tend to be those from the inferior macular region, making this region a prime area of interest for measuring ganglion cell damage, Dr. Nouri-Mahdavi says.

One of the major advantages to SD-OCT as a tool for detecting glaucoma progression is that the reproducibility of the images is high—whether in the same session or over time. "There's little 'noise,' which means that if you see changes over time, they're very likely to be real," Dr. Nouri-Mahdavi explains.

He notes that there are limitations to the use of SD-OCT for macular imaging in glaucoma. Macular diseases are common in older patients, and retinal disease other than glaucoma can interfere with the result. "With any measure, there is always change associated with aging," Dr. Nouri-Mahdavi says. "The challenge is to tease out any age-related changes in order to detect actual glaucoma progression."

When is macular imaging with SD-OCT most beneficial? Dr. Nouri-Mahdavi points to three categories of patients. One relates to anatomy—patients for whom the RNFL or optic nerve rim loss is closer to the temporal area of the nerve, or whose fovea-to-disc axis is tilted downward toward the inferior pole of the nerve—corresponding to the macular zone of vulnerability, where early damage is most likely to be found. A second category of patients for whom SD-OCT is useful consists of those with retinal ganglion cell loss in the central region, such as highly myopic patients or those with normal-tension glaucoma. And a third group of patients likely to benefit are those with advanced glaucoma. Dr. Nouri-Mahdavi's group has an ongoing study testing the hypothesis that the macula is the only structure showing residual thickness in advanced glaucoma, with potentially adequate dynamic range. The initial experience with such patients at the Stein Eye Institute is promising, he says.

Dr. Nouri-Mahdavi believes as many as half of glaucoma specialists in the United States are not conducting macular imaging with SD-OCT, continuing to rely on RNFL imaging only. But the newer approach continues to become more widely used in clinical settings—a trend Dr. Nouri-Mahdavi expects to continue. "In glaucoma diagnostics, we always require confirmation of change, and with macular imaging we can confirm the RNFL findings with a different modality on the same visit," he says. "Macular OCT imaging is useful for the entire spectrum of glaucoma, from early detection to progression. It is focused on the most visually important part of the retina. It has an excellent reproducibility profile, and is complementary to optic nerve head and RNFL imaging. Given all of these factors, it is expected to play an important role in the near future for glaucoma detection and treatment."

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