

Compensating for a Tilted Eye During Docking

Catalys Precision Laser System



By Jason Jones, MD

I purchased and installed the Catalys Precision Laser System (OptiMedica Corporation) in May 2012. Docking has been very easy to learn and use, even though I was not experienced

with lasers for vision correction. After about 10 cases, I felt competent at docking. From a workflow perspective, the process is a quick three steps, and I could not be happier with the system's performance.

The Catalys uses a two-piece Liquid Optics Interface that has a uniquely designed suction ring and method of gently stabilizing the patient to the system. The interface does not flatten or applanate the cornea but rather bathes the ocular surface in saline solution, so there is a minimal elevation in IOP.

WORKFLOW

The first step in docking the Catalys is to position the patient on the system's integrated chair, which features a customized headrest designed to keep the patient in a steady yet comfortable position throughout the procedure.

Next, the patient is stabilized to the system. I start by placing the suction ring between the eyelids and onto the eye, which I view directly. The suction ring is positioned over the cornea, relatively concentric to the limbus, and then vacuum is initiated. I typically do not use or require a speculum. The suction ring couples to the conjunctiva and sclera with a supple, pliable structure at the ring's bottom, and I find that it fits comfortably into even a fairly tight palpebral fissure. Moreover, the direct visualization and hands-on nature of this step enable me to initiate effective docking even when patients have difficulty fixating. Next, saline is placed into the cup, the patient is brought underneath the laser head, and then an integrated joystick is used to X, Y, and Z the patient into docking with the interface's disposable lens.

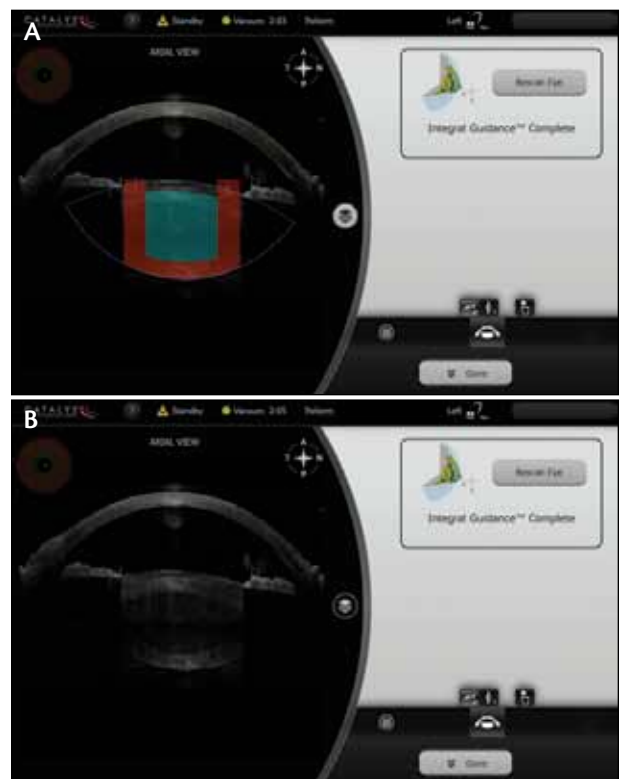


Figure. OCT imaging demonstrates slight tilting of the lens. Note the colored overlay of treatment (blue) and safety zones (red) (A) matching the contour of the capsular surfaces compared to the OCT scan without an overlay (B).

I can watch the two devices come together using on-screen guides that tell me proper X, Y, and Z positioning and monitor horizontal and vertical forces on the eye. In my experience, these guides and force monitors make proper docking easy. The system then directs me through a capture-and-lock process to integrate the suction ring to the disposable lens. The IOP does not rise during the capture or lock step, and the total increase in pressure is just 10 to 15 mm Hg.¹ After treatment, the vacuum is released, and the patient is brought down away from the laser head.

PERFORMANCE

Several elements reassure me during the docking process with the Catalys. First, the low pressure of the system has been documented.¹ I believe that this quality increases patients' safety, particularly when they have glaucoma or other vascular compromise. The other benefit is that docking is very comfortable for my patients. They do not report pain or pressure during the docking or treatment process and are able to maintain their vision throughout the procedure, which is reassuring to them and improves the ease of initiating and maintaining proper docking. In my experience, subconjunctival hemorrhaging is also minimal with the Catalys.

With this platform, a tilted lens is not a problem. During docking, the suction ring's design and direct visualization make it difficult to dock the laser very asymmetrically or to induce tilt. If tilt does exist or the dock is not centered, the system's Integral Guidance automatically compensates using three-dimensional, full-volume optical coherence tomography (OCT) and automatic ocular surface mapping. As the surgeon, I verify this compensation when I review the treatment plan with an overlay on the OCT images. I can see the outline of the safety zones and treatment area and note that the latter is well aligned and parallel to the capsular surfaces (Figure).

The docking system has a direct impact on the quality of the capsulotomy. Creating a perfect capsular tear requires a clear optical path. The less distortion, the higher the quality of the laser cuts. I have found that the Liquid Optics Interface does not create corneal folds. In the majority of my cases, I have been able to achieve a free-floating capsulotomy.

CONCLUSION

Docking with the Catalys Precision Laser System has been a comfortable process for my staff, my patients, and me. The platform's many unique features, including the on-screen docking aids and direct visualization, make the unit very effective and easy to use. In addition, its ability to minimize rises in IOP and to treat individuals with glaucoma gives me greater confidence in using the laser for a broad group of patients. Ultimately, the docking system's reliable performance has been critical to my successful completion of laser cataract surgery.

Jason Jones, MD, is medical director of Jones Eye Clinic in Sioux City, Iowa, and Sioux Falls, South Dakota. He is a consultant to OptiMedica Corporation. Dr. Jones may be reached at (712) 239-3937; jasonjonesmd@mac.com.

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Lensar Laser System



By William B. Trattler, MD

As an ophthalmologist, I am also an investigator at heart. Recently, my explorations led me to Lima, Peru, where I joined 17 other surgeons at the Instituto de Ojos Sacro Cuore to learn more about the Lensar Laser System's Augmented Reality (Lensar, Inc.). Among us, the consensus was that a common limitation in cataract surgery today is accounting for a tilted lens. Lensar's approach is unique from that of other laser cataract systems. By means of a rotating camera, this three-dimensional (3-D) imaging system uses ray-tracing technology to produce high-quality, anatomically correct images of the entire anterior segment of the eye. The unit then creates a 3-D model of the anterior segment by combining these rotationally asymmetric "slices" of the eye (taken at multiple angles) to get a 360° view, not in two axes as other systems may allow—essentially rectifying the complications of a tilted lens.

COMPENSATION

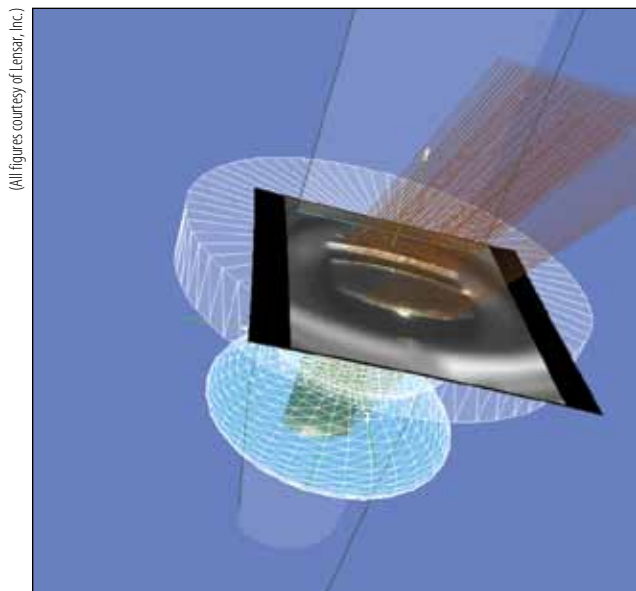
Lensar's imaging and biometry system uses the following to compensate for a tilted lens. First, a nonapplanating scleral suction skirt ensures that there is no distortion of

the corneal center in relation to the center of the lens. This is the fluid interface that does not contact the cornea.

Second, the system's Augmented Reality Camera (ARC) rotates around the eye at the Scheimpflug angle and takes 10 scans. If the surgeon chooses, the platform can obtain as many as 16 images from eight different positions. During each scan of the anterior segment, the ARC images the eye with a higher scanning rate over areas of interest. The goal of this approach is to ensure that the cornea, anterior capsule, and posterior capsule are all imaged accurately at a high resolution, which will later allow the surgeon to use the software in a fully automated fashion at his or her discretion.

Automatic image processing identifies each patient's individual ocular surface of interest on all 10 scans, thus avoiding the possibility of error introduced by the operator's attempting to make the identification him- or herself. The Lensar Laser System uses ray tracing to reconstruct the exact position of the cornea and lens, including the anterior and posterior capsules, in 3-D space.

Next, the system combines all 10 scans to form a 3-D model of the anterior segment. Biometric values are also provided for each patient. The patterns for the capsulotomy and nuclear fragmentation are then auto-



(All figures courtesy of Lensar, Inc.)

Figure 1. An example of Lensar's Augmented Reality 3-D reconstruction capabilities.

matically programmed to fit the position, geometry, and curvature of the eye's lens and anterior capsule.

WHY ACCURATELY MAPPING THE EYE MATTERS

Without question, the precision of laser cataract surgery is highly dependent on the imaging and biometric system's capabilities. Accurate reconstruction of the anterior ocular dimensions not only compensates for a tilted lens, but it also assists in the modification of the treatment pattern to maintain safety margins around the lens capsule.

Optical coherence tomography (OCT) may be able to recognize a lens tilted along the axial (x) and sagittal (y) planes of the orbit, but the curvature of the anterior and posterior lens capsules may not be symmetric between these two planes. For that reason, the multiple scans and biometric calculations that Lensar's ARC performs between the axial and sagittal planes is crucial to the accurate reconstruction of the anterior ocular apparatus. With several other laser systems, this is a manual operation that depends on the tilt's being in a plane that the surgeon can recognize and then choose that particular image as the basis for treatment.

OCT was designed to have a high resolution over a focal range of 500 to 600 μm . To produce an image of the entire anterior segment of the eye (possibly 8,000-9,000 μm), an OCT-based laser cataract platform must scan the eye multiple times at different depths. These scans are then "stitched" together to produce an image

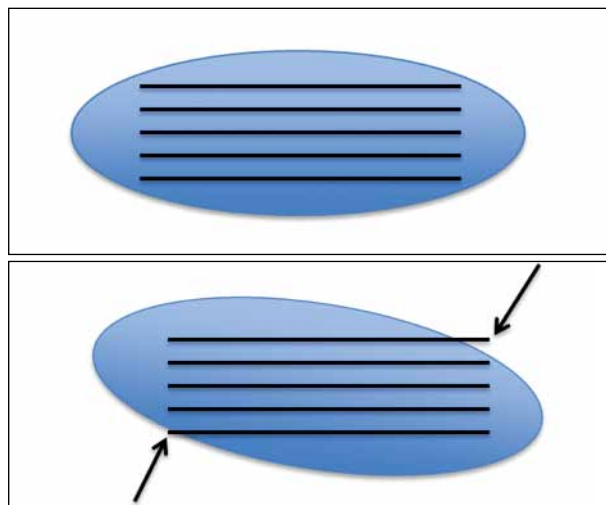


Figure 2. Treatment pattern represented by horizontal lines fits within the capsular bag and does not encroach on the capsule in this eye without a tilted lens (A). Treatment pattern of a tilted lens of the same dimensions now encroaches on the anterior and posterior capsules due to the tilt (arrows) (B).

from the corneal endothelium to the posterior capsule. Moreover, OCT is known to penetrate the posterior capsule poorly in eyes with dense (grade 3-4) nuclei, which can lead to incomplete images in these cases.

I have now seen for myself how the Lensar system's ability to produce a real-time 3-D image of the lens in its entirety increases the precision of calculations for the laser pulses' placement and profoundly affects results (Figure 1).¹

IMPACT OF A TILTED LENS OR DECENTERED SUCTION RING

When a lens is tilted relative to the center of the cornea, the laser pattern is horizontal, and the imaging system cannot compensate for the tilt (or decentered suction ring), the chances of capsular breakage rise.² Figure 2A illustrates how the treatment of a lens with standard dimensions that is not tilted maintains the prescribed capsular clearance. Figure 2B, on the other hand, shows that not accounting for tilt can result in an encroachment on the anterior and posterior capsules.²

HOW AUGMENTED REALITY AFFECTS THE BOTTOM LINE

A rotating camera on the Lensar Laser System captures the eye from the anterior cornea to the posterior lens in a single image. More importantly, the Augmented Reality imaging system helps to ensure optimal fragmentation by automatically detecting key surfaces within the ocular



Figure 3. Single video frame of a LenSx 3-D scan with the corneal and lenticular surfaces automatically located.

structure (Figure 3), placing the treatment pattern, and processing the images. As a result, the images produced

have high signal-to-noise and contrast-to-noise ratios, which expose different zones of the anterior segment of the eye at different levels, depending on the contrast.

All of this should increase safety in cases involving a tilted lens by enhancing precision and predictability. My colleagues and I performed 65 surgeries while in Peru, and we achieved consistently predictable, accurate, and reproducible results, even in eyes with a tilted crystalline lens. We found that these advantages make treatment more effective overall.

William B. Trattler, MD, is the director of cornea at the Center for Excellence in Eye Care in Miami. He is a consultant to Abbott Medical Optics Inc. and Lensar Inc., and he receives research support from Abbott Medical Optics Inc. and Bausch + Lomb. Dr. Trattler may be reached at (305) 598-2020; wtrattler@earthlink.net.

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2. Klyce S, Palanker D, Edwards K, Krueger R. Imaging systems and image-guided surgery. In: Krueger RR, Talamo JH, Lindstrom RL, eds. *Textbook of Laser Refractive Cataract Surgery*. Philadelphia, PA: Springer; 2012.

LenSx Laser



By Robert J. Cionni, MD

The LenSx Laser (Alcon Laboratories, Inc.) uses a small, single-piece patient interface to dock the patient's eye to the laser gantry. The docking mechanics are quite simple for the surgeon and the patient. The latter is positioned on the surgery center's rolling stretcher or OR chair of choice and centered under the laser gantry. A lid speculum may be used to prevent the patient from squeezing his or her eyelids closed. With the newest patient interface (SoftFit), a moistened, proprietary soft contact lens insert is placed onto the curved plastic applanation surface just before the gantry is lowered onto the corneal surface. This interface is the newest and most exciting advance that I have seen since the introduction of this family of femtosecond lasers. Its profile is quite narrow, allowing it to fit easily even into small and deep orbits (Figures 1 and 2).

IMPROVED DESIGN

In my experience, the improved SoftFit patient interface permits secure docking and lowers the likelihood of tilt, all without inducing corneal compression or causing a significant rise in IOP (16 vs approximately 30 mm Hg with the rigid patient interface [data on file with Alcon Laboratories, Inc.]). Because docking with the new interface does not require significant applanation pressure before suction is engaged, I find that the

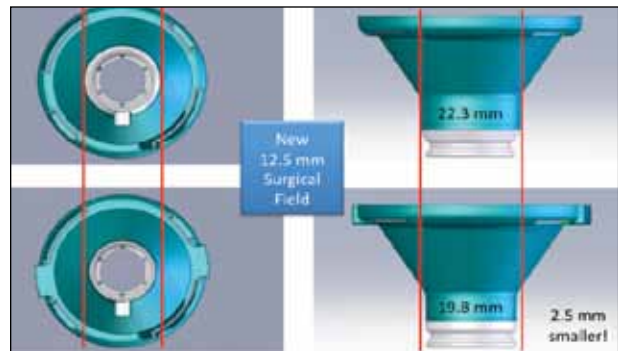


Figure 1. The narrow profile of the newly designed patient interface compared to the original interface.

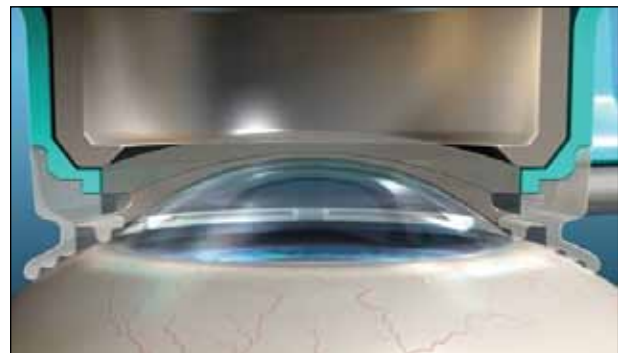


Figure 2. The SoftFit patient interface has decreased the rise in IOP and eliminated corneal compression in nearly all of Dr. Cionni's cases.

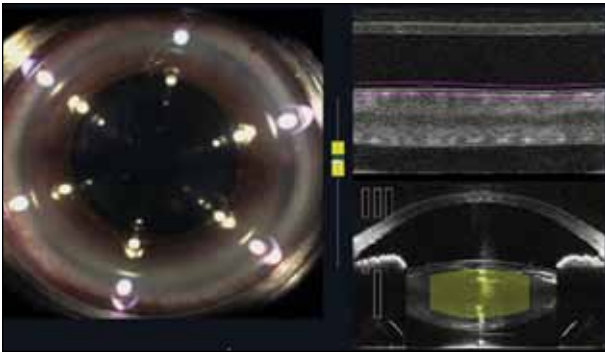


Figure 3. The SoftFit decreases the likelihood of a tilted lens and causes no corneal compression.

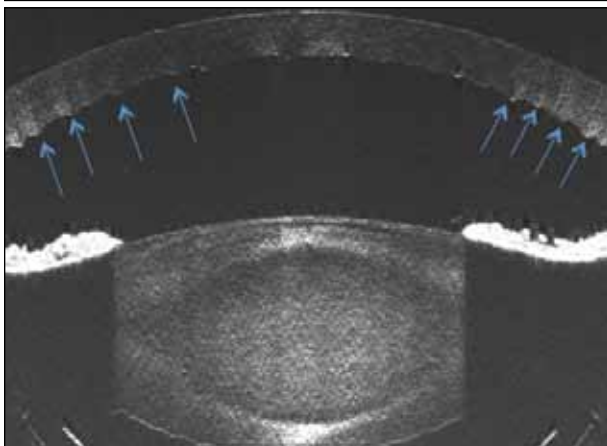
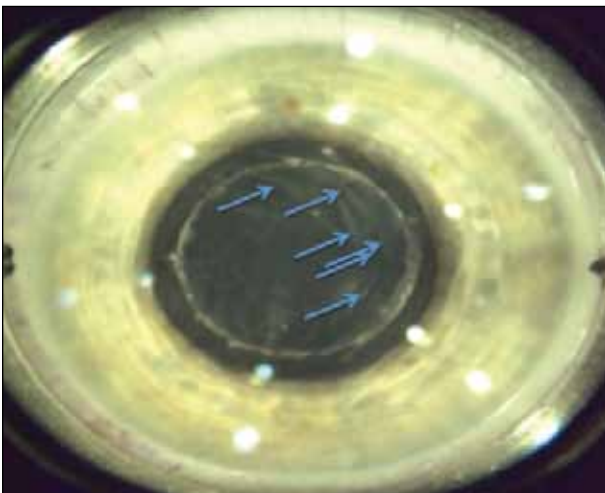


Figure 4. The previous rigid patient interface resulted in corneal compression (arrows show corneal folds induced by compression).

eye does not tend to torque, rotate, or roll, and that tilt is therefore less likely. Figure 3 demonstrates the lack of corneal compression compared with the previous rigid design seen in Figure 4. Eliminating corneal folds has rendered my capsulotomies more pristine and, in nearly

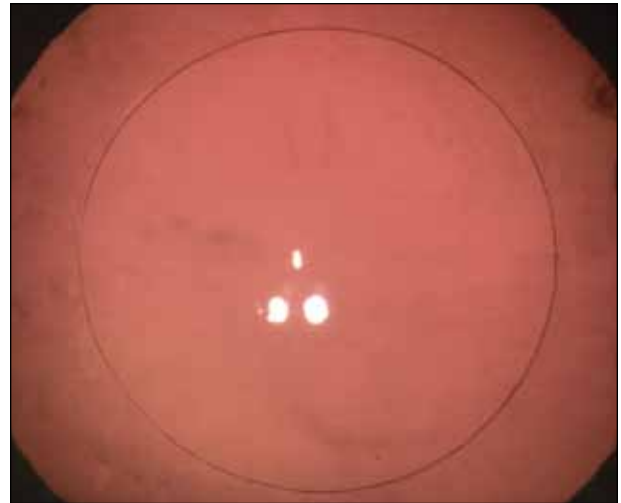


Figure 5. The SoftFit results in free-floating capsulotomies with pristine edges.



Figure 6. A nearly flat circle scan indicates little or no tilt.

all cases, free floating (Figure 5). The SoftFit has also markedly reduced how much energy is needed to complete all of the incisions, which means the laser’s speed can now be increased significantly.

I had already found the docking process with this laser system to be relatively easy and quick, but it is now even easier, quicker, and more effective. On average, it takes less than 3 minutes for me to walk into the laser room, dock the patient, perform the laser treatment, and walk out of the laser room.

COMPENSATION

Although the aforementioned improvements have reduced the incidence and degree of lens tilt I have observed, some tilting is still possible due to the extremes of orbital or facial anatomy and the level of patients’ cooperation.

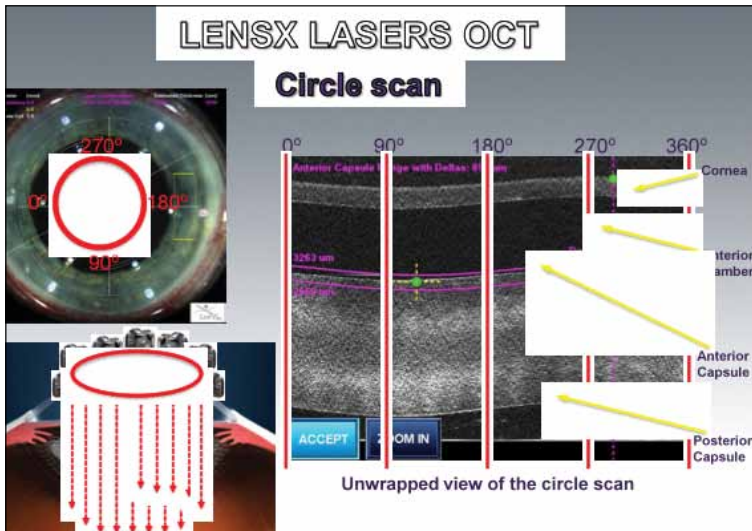


Figure 7. This wavy circle scan indicates modest tilt. The vertical dotted line is placed at the highest point along the posterior capsule. This represents the axis where the next OCT scan is performed in order to visualize and set the safety zone for lens fragmentation.

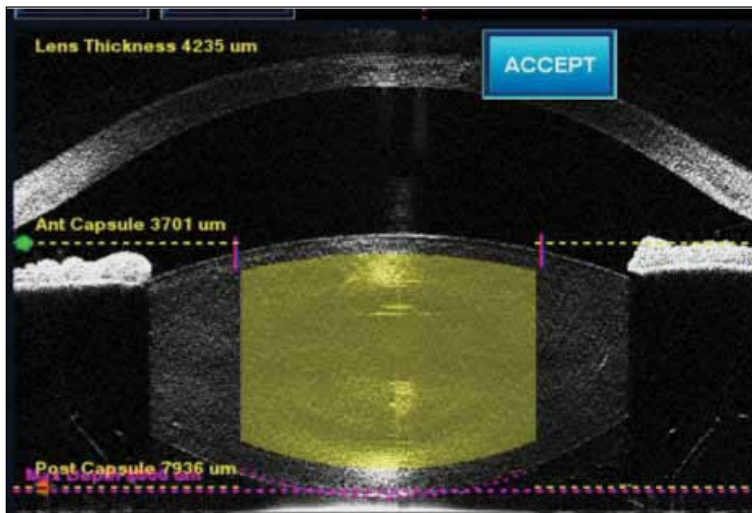


Figure 8. OCT scan of lens fragmentation taken in the axis of tilt.

My first clue that a lens is tilted occurs as I observe the real-time video monitor and optical coherence tomography (OCT) during the docking process. The former enables me to carefully center the patient interface, while live OCT monitoring allows me to ensure that the capsulotomy circle scan appears flat, indicating the desired flat dock. If the patient interface is not centered or if the circle scan is not flat, I can reapply the interface prior to obtaining suction. After applying suction, uneven scleral visibility and an offset pupil may indicate a tilted lens or simply a poorly centered dock. If the asymmetry is significant, I disengage suction and

attempt docking a second time.

If multiple attempts fail to achieve a perfectly centered, even docking as observed on the video monitor, I can proceed with aligning the capsulotomy, lens fragmentation, and corneal incisions on the video monitor. The first OCT scan is then performed along the circle of the capsulotomy and should be nearly flat if there is no tilt (Figure 6). A wavy scan occurs when tilt or significant decentration is present (Figure 7).

The vertical dotted line is placed at the most anterior portion of the posterior capsule to identify the axis of tilt. The next OCT scan is performed along this axis to provide a real-time picture of the most significant degree of lens tilt (Figure 8).

Performing sequential OCT scans in this manner identifies the most anteriorly located area of the posterior capsule and allows its avoidance during chopping of the lens. The software automatically sets the chopping with a predetermined safety zone to avoid the posterior capsule, but this zone can be modified by the surgeon if desired. Doing so ensures the integrity of the posterior capsule for laser lens fragmentation.

CONCLUSION

If unrecognized or managed improperly, a tilted dock could lead to off-centered capsulotomies and corneal incisions. Additionally, if not properly identified and managed before the laser treatment begins, significant tilt could compromise the posterior capsule. Despite the LenSx Laser's use in more than 50,000 cases, such a compromise has yet to be reported with the system. With real-time video monitoring as well as real-time and sequential OCT scans, the system is able to assure me that tilt has been avoided or identified and properly managed.

Robert J. Cionni, MD, is the medical director of The Eye Institute of Utah in Salt Lake City, and he is an adjunct clinical professor at the Moran Eye Center of the University of Utah in Salt Lake City. He is a consultant to Alcon Laboratories, Inc., and a member of the LenSx Medical Advisory Board. Dr. Cionni may be reached at (801) 266-2283.

Technolas Victus Laser



By Steven J. Dell, MD

Laser cataract surgery offers several new possibilities for the surgical correction of a cataract but, inevitably, introduces new challenges as well. Many surgical decisions previously made on the fly during a manual procedure must now be specified in advance with a laser. For example, the ophthalmologist must select the capsulotomy's size, lens fragmentation pattern, and the incision's location and shape prior to beginning the operation.

Significant considerations in laser cataract surgery include the role of orbital anatomy as well as the patient's ability to lie flat, favorably position his or her head, and cooperate. With a manual procedure, the entire event takes place in an OR, typically with established intravenous access and the assistance of anes-

thesia personnel. A patient struggling to cooperate can almost always be successfully treated with additional sedation and coaching. Similarly, patients with unusual orbital anatomy and those who are unable to position their heads optimally can typically be treated through manipulation of the orientation of the operating microscope, the surgeon, and the operating table. It is common for patients to struggle with tucking their chins, Bell phenomenon, blepharospasm, and turning their heads during surgery. When these problems occur in the context of an unsedated patient docked to a femtosecond laser in a minor procedure room, however, there can be trouble.

DIFFERENT INTERFACES

Femtosecond lasers rely upon the precise placement of spots to achieve their effects. Manufacturers have employed various strategies to achieve the requisite

physical coupling of the laser to the eye by means of a patient interface. Some units use a liquid interface, which maintains a layer of fluid between the cornea and the interface. This approach has the advantage of avoiding optical deformation of the cornea via compression, resulting in effective spot-pattern delivery inside the eye. With a layer of fluid separating the cornea and the interface, however, defining the precise location of corneal incisions is a challenge. Other systems use a curved plastic interface that employs a fixed and relatively flat base curve. The cornea is flattened to conform to the base curve, which results in good physical coupling between the two but also produces compression folds or wrinkles in the cornea that may distort the spot pattern. The clinical result is typically small tags in the capsulotomy. In the context of a pressurized, gas-filled lens, these tags can be the nidus of an extensive capsulotomy tear.

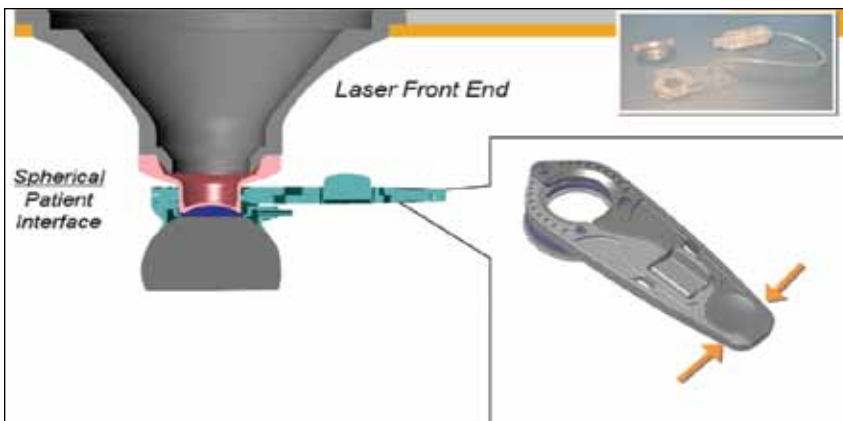


Figure 1. The Victus Femtosecond Laser Platform uses a two-piece, spherical patient interface.



Figure 2. The system features real-time optical coherence tomography to assist with docking and positioning.

THE PROBLEM OF TILT

Tilting of the eye during docking can create numerous problems, including increased discomfort for the patient. The cornea is asym-

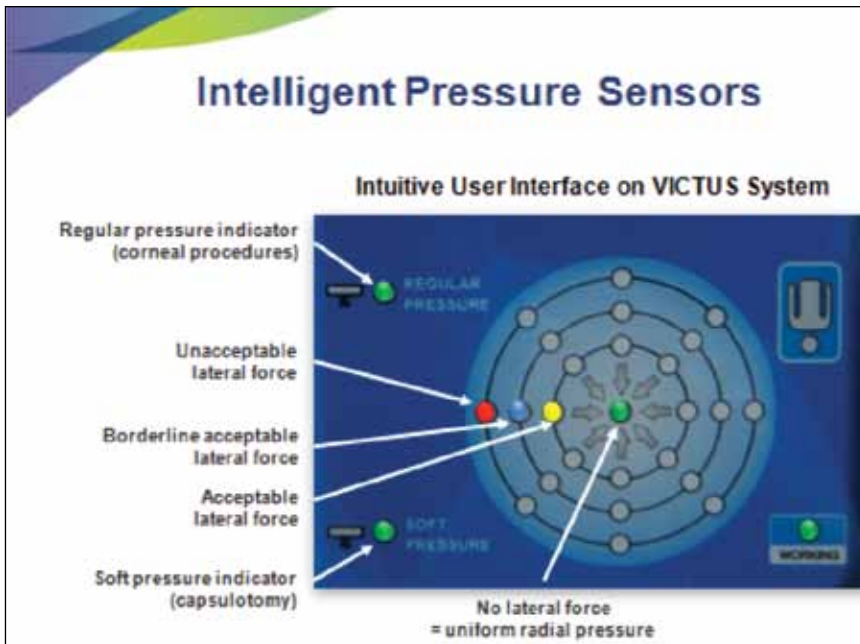


Figure 3. Multiple pressure sensors facilitate correct docking. Soft pressure is used for the capsulotomy and lens fragmentation. Regular pressure is used for corneal procedures.

metrically compressed, with possible optical distortion of the spot pattern. The plane of the treatment can also fall outside the desired range. For example, a capsulotomy might be incomplete, with some of the intended spots fired below the desired plane into the body of the lens or above, into the anterior chamber. Finally, a tilted eye hazards a loss of suction, requiring an interruption of the treatment.

COMPENSATION

Of course, the best way to address the tilting problem is to avoid it. Some laser systems use a single-piece patient interface, and the eye must be docked directly to the laser itself. This maneuver requires a lid speculum. Because the laser can only be moved to a limited degree, the eye must be brought into position and docked directly to the patient interface. In contrast, the Victus Femtosecond Laser Platform (Bausch + Lomb and Technolas Perfect Vision GmbH) has a two-piece patient interface; a suction ring is initially centered on the eye and then is docked with the laser (Figure 1). I have used both types of systems and have found the latter to be much more familiar and easy to operate. It is, in fact, directly analogous to using an Intralase FS laser (Abbott Medical Optics Inc.) to create a LASIK flap. In my experience, small manipulations of the eye's position are much simpler with the two-piece system, and I find it easier to

visually confirm proper positioning of the patient.

The Victus platform's patient interface incorporates features of both a solid and a liquid interface. For the capsulotomy and fragmentation of the lens, it uses a "soft" docking technique, where a very thin layer of saline solution is present between the cornea and the interface. In my experience, this approach produces minimal corneal distortion during docking and creates capsulotomies of superb quality. For the corneal incisions, the system uses a "regular" docking technique, where the vertical position of the interface is lowered very slightly, resulting in a firmer corneal coupling to precisely define corneal incisions. All of these positioning maneuvers are guided by real-time optical coherence tomography to assist the surgeon

during the procedure (Figure 2). Finally, multiple sensors constantly monitor the pressure in several locations throughout the docking and treatment. These sensors alert the surgeon to vertical forces to avoid corneal folds and to lateral forces that would indicate the presence of tilt (Figure 3).

If the eye tilts despite these safeguards, I can adjust the spot treatment patterns to compensate. Built-in safeguards ensure that the delivery of laser energy avoids critical structures such as the iris and posterior capsule.

CONCLUSION

I have been impressed by the engineering of the Victus Femtosecond Laser Platform. The versatility of a laser that can perform both cataract and LASIK procedures is intriguing. As ophthalmologists embark on a new chapter of femtosecond laser surgery, increased clinical experience will no doubt lead to many further improvements in this exciting technology. ■

The Victus Femtosecond Laser Platform currently has 510(k) clearance for the capsulotomy and corneal flap procedures.

Steven J. Dell, MD, is the director of refractive and corneal surgery for Texan Eye in Austin. He is a consultant to Abbott Medical Optics Inc. and Bausch + Lomb. Dr. Dell may be reached at (512) 327-7000.