Advanced Femtosecond Laser Lens Surgery

This technology can be used with pupil-expanding devices and to perform primary posterior capsulotomy.

By H. Burkhard Dick, MD, PhD

Has it been just 5 years since the femtosecond laser, a technology first introduced into ophthalmology for corneal refractive surgery, segued into cataract surgery? It has, indeed—give or take a few months.

In 2009, laser-assisted cataract surgery (LACS) seemed like an attractive option to some of us. The new femtosecond laser was a fascinating technology bent on perfection, a tool that could conceivably complement our premium surgery techniques and boost our premium IOL conversion rates. A handful of us embarked on journeys through the learning curve with LACS and quickly learned to appreciate the potential and the versatility of the femtosecond laser in cataract surgery.

Initially, it was the exact and reproducible anterior capsulotomy that was the most impressive function of the femtosecond laser. However, the facts that surgery was safe and that the laser did no more damage to the corneal endothelium than conventional phacoemulsification—meaning it could be considered even in patients with low preoperative endothelial cell counts (eg, patients with cornea guttata or Fuchs dystrophy)—opened the door for LACS to be used in cases we have long considered difficult.

Today, the femtosecond laser has been used in lens surgeries for patients with trauma, brunescent and intumescent cataracts, congenital lens opacities, and Marfan syndrome, to name a few challenging situations.

There have been numerous small steps forward indicating that this new technology is fast approaching widespread adoption in the field of lens-based surgery. With growing experience and the right equipment, LACS can help surgeons overcome even severe intraoperative difficulties, should these arise. Several advanced applications of the femtosecond laser in cataract surgery are described in this article.

The Curse of the Small Pupil

Small pupil cases present a challenge for cataract surgeons, as the pupil must dilate sufficiently in order to make an adequately sized capsulotomy with a default diameter aimed at 5.5 mm. If necessary, the diameter of the capsulotomy can be reduced to compensate for the smaller pupil.

Poorly dilated pupils can be expected in eyes with comorbidities such as a hard lens, pseudoexfoliation glaucoma, chronic uveitis, and zonal dehiscence, as well as after earlier surgery and in eyes with intraoperative floppy iris syndrome. It is well known that cataract surgery in eyes with small pupils is associated with a higher rate of complications, but a small pupil can also be the result of the laser procedure itself, as there have been reports of sudden miosis after perfect pharmacologic dilation. Roberts et al reported an incidence of miosis of 9.5% in their first 200 LACS procedures; the rate decreased to 1.23% in the subsequent 1,300 cases when instillation of one drop of 10% phenylephrine was added immediately after laser treatment.

The phenomenon of postoperative laser miosis is under evaluation. Possible explanations are a sudden rise in the temperature of the aqueous humor immediately after the laser has been applied and the resulting release of inflammatory mediators. One thing is sure, however: It is time-dependent. The more time has elapsed since laser anterior capsulotomy and lens fragmentation, the higher the chances for laser-induced miosis—another argument for a speedy procedure and for close proximity of the laser and manual portions of the cataract procedure, a point that is further discussed below.

Whether the miosis is caused by an individual patient’s characteristics or a protracted laser procedure, a couple options exist for treatment. Additional pharmacologic intervention is one. During the manual part of the procedure, an intracameral mydriatic (eg, epinephrine 0.1% solution) and viscomydriasis with an ophthalmic viscosurgical device (OVD) are easy to administer. The success rate of these additional agents is limited, however. In one study of 850 eyes undergoing LACS, 40 had preoperative horizontal or vertical pupil diameters smaller than 5.5 mm. Epinephrine...
was sufficient to dilate three of these eyes (7.5%), and additional viscomydriasis was necessary in 10 (25%).

MECHANICAL OPTIONS IN EYES WITH SMALL PUPILS

The next step in the management of a small pupil is mechanical dilation. In our experience, there are two approaches, either of which can be performed with or without an OVD: (1) iris retraction and (2) pupil expansion.

The Malyugin Ring (Microsurgical Technology) is inserted through the main incision and expands the pupil to a diameter of 6.25 or 7 mm. Compared with iris retractors, handling the Malyugin Ring is easier, less elaborate, and faster. In eyes with narrow pupils, the Malyugin Ring has been associated with less endothelial cell loss than manual pupil stretching with iris hooks.

To insert iris hooks, up to five incisions are made with a 27-gauge needle (Smiths Medical) attached to an irrigation/aspiration device (Geuder). The liquid optics interface (LOI) of the Catalys Precision Laser System (Abbott Medical Optics) has a hollow suction ring that does not touch the cornea and induces only minimal increase in intraocular pressure during docking. Therefore, it allows two or three laterally placed iris hooks to be directly positioned inside the LOI by moving the suction ring laterally. The surgeon can then move the remaining hooks into the LOI field with tying forceps.

When all retractors are inside the LOI, the suction process can commence and the docking proceed as usual. If there is no OVD in the anterior chamber, default laser settings can be employed. If OVD is used, it is wise to use one with a refractive index close to that of aqueous humor; a major difference between these indices may require changes to laser settings for safety reasons.

PERSONAL EXPERIENCE

We have performed LACS in 73 eyes (73 patients) with small pupils using one of the four techniques described above (ie, iris retractors without OVD; iris retractors with OVD; iris expanders without OVD; iris expanders with OVD). In all cases, placement of the mechanical dilation device was achieved without complications. Additionally, neither anterior chamber flattening nor other complications occurred during docking or laser treatment, and no anterior or posterior capsule tears occurred during the procedures. With OVD in the anterior chamber (n=35), small adhesions were recognized in six cases and corrected with a central dimple-down maneuver. Uncomplicated in-the-bag implantation of a posterior chamber IOL was achieved in all cases.

Incomplete capsulotomies with tags and other irregularities were strikingly more frequent when the anterior
chamber was filled with OVD during laser treatment. Another consideration with OVD use is that, in our experience, laser shots are not dampened by a high-viscosity OVD. This has led us to prefer this variant if the situation allows.

There is no doubt in our minds that mechanical pupil dilation enables the surgeon to perform LACS safely in eyes with small pupils and comorbidities, with only a slight and temporary rise in intraocular pressure (Figure 1). Even these challenging eyes may profit from the benefits the femtosecond laser offers to cataract surgery.8

**PCO PREVENTION**

Posterior capsular opacification (PCO) is the most frequent long-term complication of modern cataract surgery, and it can lead to significantly reduced visual acuity in many patients. Several surgical techniques and IOL designs have been introduced to solve this problem, yet none have prevented PCO, only delayed its onset.

With the femtosecond laser, there is another option, which begins with redocking the LOI after the IOL is placed in the capsular bag. Femtosecond laser systems with full-volume, intraoperative, three-dimensional spectral-domain optical coherence tomography (OCT) now enable the surgeon to visualize the anatomic changes in the anterior eye after the procedure—an advantage unthinkable before the advent of these technologies.

With the laser redocked, it is possible to cut a primary posterior laser-assisted capsulotomy (PLC), keeping the anterior hyaloid membrane of the vitreous intact (https://www.youtube.com/watch?v=R5CJFOawThA; Figures 2 and 3). Although extremely thin (3 to 4 µm), the posterior capsule is almost always visible to the surgeon. Creating a PLC is a potential way to block the migration of lens epithelial cells, the most likely cause of PCO.

**KEEP THE LASER IN THE OR**

Performing a primary PLC with the femtosecond laser can be easy; our technique is described below. However, there is one logistical factor that must be considered if this technique is to be adopted: It requires returning the patient from the operating table to the laser. To enable conversion to PLC, adequate and safe positioning of the laser platform within the practice is crucial. In our practice, the laser is positioned in the operating room (OR); however, another model is to have the laser set up in a separate laser suite. In this setting, the patient must be shuttled between the OR and the laser suite. Because each room has different hygienic standards, from hygienic and ethical points of view, this patient shuttle process is questionable.

**TAKE-HOME MESSAGE**

- LACS has evolved as a precise and safe option even for complicated cases of lens removal.
- An intraoperative small pupil can be tackled first with pharmacologic agents, but in most cases mechanical dilation is necessary. The Malyugin Ring has proved to be effective and safe.
- A primary PLC can be performed by redocking the patient’s eye to the LOI before or after IOL implantation.
- The PLC procedure, which uses the Berger space between the IOL and anterior hyaloid membrane, helps to eliminate the risk of a PCO after cataract surgery.

We recently conducted a histologic study on a human eye that was scheduled for enucleation after laser treatment. High-magnification light microscopy revealed complete cuts through several corneal layers with only minimal tissue bridges remaining in place.9 This study demonstrates that after the corneal incision is made with the femtosecond laser the eye must be considered open. We therefore strongly recommend doing the laser treatment and the surgical steps of the procedure in one room—the OR—out of concern for patient safety. We expect that this model will become the standard of care.10

**EASY REDOCKING**

Primary PLC can be performed before or after IOL insertion. A round blunt cannula is used to inject a small amount of OVD homogeneously behind the IOL optic. Then, with minimal pressure on the optic, the OVD is spread evenly behind the IOL. The corneal incisions are hydrated and the eye is docked to the LOI.

Between the posterior capsule and anterior hyaloid membrane is an anatomic void known as the Berger space. After IOL implantation, this space generally is much larger than expected. This may be due to the natural lens’ replacement with an IOL, which is approximately 20% of the thickness of the crystalline lens. On the optical coherence tomography treatment screen, the inferior third of the cylindrical capsulotomy treatment zone is placed on the posterior capsule by adjusting the surface so that the anterior capsule fit is matched with the posterior capsule surface (Figure 2). Depending on the size of the Berger space, an incision depth between 400 and 800 µm is programmed to stay within this space. The pulse energy is set to 9 to 10 µJ, and the capsulotomy diameter is usually 3.5 mm or greater.

On the infrared camera view, the PLC is centered. After confirmation of the treatment zones, the laser delivers
pulses in front of the anterior hyaloid membrane first and, moving anteriorly, then to the posterior capsule (Figure 3). Because of the relatively large Berger space, the laser does not fire in potentially dangerously close proximity to the vitreous when creating the PLC; however, even if that were to happen, the damage would be minimal. Small bubble formations can be seen while the laser strikes the OVD between the posterior capsule and IOL optic. The OVD acts as a safety cushion. The extremely thin posterior capsule button forms a tiny scroll and rapidly drops out of view. After undocking, the patient is again placed under the operating microscope for inspection.

In our experience, PLC has proved to be safe in all cases, with no complications to date. This suggests that the PLC procedure is easier to adopt than manual posterior capsulorrhexis and that primary PLC has the potential to eradicate PCO, the most common long-term complication of cataract surgery.11

THE DAYS OF TEARING ARE OVER

My final thought is this: Whether posterior or anterior, we are creating a capsulotomy, not a capsulorrhexis. The femtosecond laser achieves the same results as a knife, using focal photodisruption to produce cuts (Greek: tomos). In manual capsulorrhexis creation, the surgeon shears or rips (neo-Latin/Greek: rhexis) with forceps or a bent needle. Five years into the age of advanced LACS, we are beyond that point.12

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