Combined use of an iris hook and pupil expansion ring for femtosecond laser–assisted cataract surgery in patients with cataracts complicated by insufficient mydriasis and an ectopic pupil

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We developed a surgical technique that combines use of an iris hook and a pupil expansion ring in femtosecond laser–assisted cataract surgery complicated by insufficient mydriasis and an ectopic pupil. With this technique, the surgery, including femtosecond laser assistance, phacoemulsification, and intraocular lens implantation, can be accomplished successfully prior to iris repair.

Financial Disclosure: Dr. Malyugin receives travel grants from Alcon Laboratories, Inc. and Novartis Corp.; he receives royalties from Microsurgical Technology, Inc. None of the other authors has a financial or proprietary interest in any material or method mentioned.


Modern cataract surgery is a generally successful and commonly used procedure.1 The continuous curvilinear capsulorhexis (CCC) is 1 of the most challenging steps; a long learning curve is required to perfect the technique.2 In complicated cases, creating the desired CCC, especially in patients with pupillary miosis and pupil malposition, can be an arduous task.3,4

Femtosecond laser–assisted cataract surgery is safe and effective in creating a round and precisely placed anterior capsulotomy, minimizing capsular bag damage. A growing body of evidence suggests that this produces superior refractive outcomes because it enables better prediction of the effective lens position.5,6

We describe a technique to create a precise and well-centered anterior capsulotomy in patients with decentered and insufficiently dilated pupils using the femtosecond laser. The technique has the potential to facilitate a variety of cataract cases associated with pupil abnormalities.

SURGICAL TECHNIQUE

The first step in the technique is done under the surgical microscope. After proper preparation and draping, a lid speculum is placed. A 2.0 mm clear corneal incision (CCI) is made with a single-use calibrated metal blade. The anterior chamber is filled with a highly dispersive ophthalmic viscosurgical device (OVD), facilitating placement of a Malyugin ring 2.0 (Microsurgical Technology Inc.) with the help of an injector for iris expansion. After the scrolls engage the iris pupillary margin (Figure 1, A and B), a single polymer iris hook is introduced through a clear corneal paracentesis located in the meridian opposite the displaced pupil. The hook is placed to capture the central portion of the iris expansion ring side. Pulling the silicone sleeve of the hook centers the ring and the pupil relative to the center of the cornea (Figure 1, C). The peripheral portion of the iris retractor, which protrudes from the ocular surface, is cut, leaving approximately 2.0 mm to facilitate further manipulations.

The anterior chamber is carefully watched to ensure the OVD is distributed homogenously and there are no
air bubbles and/or cells. The incision is then considered to be watertight.

The second step is performed with the femtosecond laser installed in the operating room. The draped patient with the same lid speculum in place is positioned under the laser. Using sterile powderless gloves, the surgeon manipulates the laser joystick and screen, which are covered with sterile transparent film. It is important to ensure the sterility of the entire procedure, particularly the patient interface during assembly and docking.

The surface of the cornea is covered with a highly dispersive OVD, docking is performed, and vacuum is applied. Integrated 3-dimensional spectral-domain optical coherence tomography (OCT) is activated to visualize the anterior segment of the eye in the usual manner. Using manual adjustments, the marker for anterior capsulotomy is centered relative to the limbus on the laser system screen. The femtosecond laser is activated, and anterior capsulotomy is performed and followed by lens fragmentation, with astigmatic corneal incisions if indicated. It is known that various types of OVDs have refractive indices similar to those of the aqueous. Thus, no change in standard energy parameters is required for capsulotomy and lens fragmentation.

After the laser treatment, the eye is undocked from the patient interface. The patient is moved back under the surgical microscope. A central dimple-down maneuver is performed to ensure the capsulotomy flap is free, and it is removed with a microforceps. Conventional ultrasonic phacoemulsification is performed followed by intraocular lens (IOL) implantation in the capsular bag in the usual fashion. The iris hook and Malyugin ring are removed from the anterior chamber. If necessary, pupilloplasty is performed with the Siepser slipknot technique (modified McCannel technique) to close preexisting iris defects or iris coloboma. The OVD is aspirated from the capsular bag and the anterior chamber using bimanual irrigation/aspiration (I/A) instruments. The corneal incisions are hydrated with a balanced salt solution and checked to ensure they are watertight.

Results

A 60-year-old patient was admitted to the clinic 15 years after penetrating eye trauma. Slitlamp examination and ultrasound biomicroscopy revealed a peripheral corneal opacity, extensive iridodialysis (up to 40 degrees from 13 to 17 clock hours), pupil ovalization (pupil size 4.0 mm by 2.5 mm), and downward shift accompanied by the cataract and slight phacodonesis (Figures 2 and 3). Central endothelial cell density (ECD) by specular microscopy was 2397 cells/mm². Corneal topography (Tomey Corp.) showed irregular oblique astigmatism, with 1.19 cylinder in the 3.0 mm zone (flat keratometry [K] 41.17 @ 150; steep K 42.35 @ 60). The axial length, assessed with optical biometry (IOLMaster, Carl Zeiss Meditec AG), was 24.40 mm.

The femtosecond laser procedure was done with the Lensx laser system (2.30 software, Alcon Laboratories, Inc.). After CCIs were created, an OVD (chondroitin sulfate 4%–sodium hyaluronate 3% [Viscoat]) was injected, and pupil expansion and centration were achieved with the technique described above (Figure 4). The first docking attempt was unsuccessful when a balanced salt solution was used to wet the corneal surface before vacuum was applied. After hydroxypropyl methylcellulose 2.0% was used to cover the corneal surface, docking was successful using the regular vacuum settings (Figures 5 and 6). Anterior chamber OCT of the anterior chamber structures showed the iris to be slightly elevated above the anterior lens capsule plane, with no contact between the pupil expansion ring and the cornea (Figure 7).

Conventional laser parameters were used for the laser platform: anterior capsulotomy diameter 4.8 mm
(incision depth 753 µm, pulse energy 5 µJ, tangential spot separation 4 µm, layer separation 4 µm) and lens fragmentation diameter 4.8 mm (incision depth 2383 µm, pulse energy 10 µJ, tangential spot separation 7 µm, layer separation 7 µm). The number of radial cuts to fragment the lens nucleus was set at 3.

After the anterior capsulotomy and lens fragmentation were performed, the patient was moved back to the operating microscope. The anterior chamber remained formed despite the manipulation with the laser, and therefore no additional OVD injection was necessary. The anterior capsule was removed with a microforceps (Microsurgical Technology, Inc.) with no residual capsule tags identified. The subsequent steps of the procedure, including hydrodissection, phacoemulsification, and lens cortex I/A, were performed without technical difficulties.

After IOL implantation, the iris hook and then the Malyugin ring were removed from the anterior chamber. Iridodialysis repair was performed with interrupted 10-0 polypropylene sutures (Mani, Inc.), centering the pupil. The OVD was aspirated bimanually from the posterior and anterior chambers. Corneal incisions were hydrated with a balanced salt solution and were watertight without sutures.

No intraocular pressure (IOP) elevation was observed postoperatively. After 1 month, specular microscopy showed an insignificant reduction in the ECD (up to 2105 cells/mm²). The uncorrected distance visual acuity was 20/50. The corrected distance visual acuity was 20/30, which was associated with residual irregular corneal astigmatism from the original injury (Figure 8). Ultrasound biomicroscopy showed a well-centered IOL positioned in the capsular bag (Figure 9).

Figure 2. View of the eye showing corneal scar, decentered pupil, posterior synechiae, and iridodialysis.

Figure 3. Preoperative ultrasound biomicroscopy showing iridodialysis (portion of the iris located to the right) and rounded equatorial lens surface due to the partially missed zonular fibers.

Figure 4. Pupil is enlarged and centered with the Malyugin ring—single polymer iris hook assembly.

Figure 5. Side view of the eye immediately before docking to the laser. Note the peripheral portion of the iris hook exiting the eye.
DISCUSSION

Both congenital (eg, ectopia lentis et pupillae, familial iridogoniodygenesis, Axenfeld-Reiger syndrome, idiopathic tractional corectopia, iridocorneal endothelial syndrome) and acquired (ie, iatrogenic, traumatic, and spontaneous iridodialysis) iris abnormalities result in pupil ectopia, making it extremely challenging to perform a cataract procedure.\(^3\)\(^{10}\)–\(^12\) Pupilloplasty is technically demanding; however, it is justified in many of the above-mentioned conditions. It is usually performed after IOL implantation to prevent iatrogenic lens capsule damage with the needle and to decrease the risk for intraoperative iris bleeding. Temporary suspension of a deformed and ectopic pupil with polymer iris hooks could be crucial for achieving better visualization of the lens capsule and improving the outcomes of cataract surgery. Various pupil expansion devices have proved to be effective in small-pupil cases, helping to center the pupil and maintain its dilated state.\(^13\)–\(^15\)

Currently, femtosecond laser pretreatment is gaining popularity among cataract surgeons. Laser anterior capsulotomies have been described as more geometrically perfect and reproducible than manual capsulotomies.\(^16\) An additional benefit is the ability to perform the anterior capsulotomy with a precise diameter, keeping a safe capsulotomy edge–pupillary margin distance.

A controversial advantage of the femtosecond laser capsulotomy is increased strength of the anterior capsulotomy edge to mechanical stress.\(^17\)\(^,\)\(^18\) There is also evidence of decreased resistance to tearing in a femtosecond capsulotomy; scanning electron microscopy shows a ragged postage stamp appearance to the edge.\(^19\) Friedman et al.\(^20\) showed that a femtosecond laser-assisted capsulotomy is stronger than a manual capsulotomy; however, the study was performed in porcine eyes and the results may not be the same in human eyes.

The strength of the capsule edge is particularly important in complicated cataract cases when extra surgical maneuvers could threaten capsule integrity. Conflicting evidence may be due to variable capsulotomy size and energy parameters used in the various studies and to subtle ocular movement. Also, if not done carefully, manipulation of the pupil expansion device in the anterior chamber may cause additional stress to the capsule edge and lead to iatrogenic capsule damage.

One significant disadvantage of laser capsulotomies is an increased level of intraocular prostaglandin, leading to an increased inflammatory response and pupil constriction.\(^21\)\(^,\)\(^22\) Fortunately, preoperative instillation of steroidal and nonsteroidal antiinflammatory drugs

![Figure 6. Side view of the eye during laser docking.](image)

![Figure 7. Intraoperative OCT image showing slightly elevated iris (lower right image) corresponding to the meridian of the iris hook placement but no contact between the iris/ring and posterior corneal surface.](image)
are able to reduce inflammation and decrease the risk for intraoperative miosis in femtosecond laser-assisted cataract surgery. Pupil expansion devices can be used to augment pharmacologic dilation and provide an adequate pupil aperture. Studies have shown that patients with miotic pupils can have successful sequential femtosecond laser-assisted cataract surgery after Malyugin ring placement if sterility is maintained.

Risks of laser capsulotomies include residual capsule bridges due to laser energy dissipation associated with incomplete evacuation of OVD from the anterior chamber before the laser step of the procedure. Transporting patients back and forth if the laser is not placed in the operating room as well as corneal compression during docking raise concerns of anterior chamber collapse and intraocular contamination. Theoretically, creating a longer clear corneal tunnel and filling the anterior chamber with a high-viscosity OVD may mitigate these risks.

Studies have shown that increasing external pressure on an eye with a fresh CCI might generate IOP fluctuations that result in inflow of conjunctival fluid into the eye. Biplanar and small incisions tend to be safer and more resistant to IOP fluctuations. This issue should be prioritized and positive IOP maintained to reduce the risk for infection. Laser docking is definitely not a perfectly sterile procedure and poses some risk for infection even with an intact globe and secure watertight incisions. Temporary suturing of the wound after placement of the pupil expansion ring may be beneficial.

Concerns exist that the homogeneity of the optical media with the soft-shell technique using both dispersive and cohesive OVDs may be deleterious to femtosecond laser uptake. Removing the OVD after inserting the pupil expansion ring but before docking may increase the risk for anterior chamber collapse but can be justified in cases in which the incisions are perfectly watertight due to construction architecture or suture preplacement.

Corectopia presents another set of challenges usually addressed by iris hooks. However, the hooks necessitate multiple additional corneal incisions, leading to decreased anterior chamber stability during docking and the subsequent laser procedure. Extraocular portions of multiple iris hooks with fixation elements (sleeves) located at the limbal area can interfere with suction. Additionally, the lid speculum must be left in place while moving the patient from the surgical microscope to the laser to avoid hook displacement and foreign-body sensation (as the outer portions of the hooks may scratch the inner surface of the lids if the eye is allowed to close).

In our case, we combined the advantages of the pupil expansion device; ie, sufficient pupil dilation with the single iris hook, allowing pupil centration. This permitted unobstructed access to the central portion of the lens. Using only 1 hook lowers the risk for aqueous humor and OVD egress from the anterior chamber, which threatens anterior chamber collapse, and eliminates the need for corneal sutures. We used the new Malyugin ring 2.0 specifically redesigned for injection and removal through an unenlarged 2.0 mm incision. Dispersive OVD further secured the chamber. The disparity between group refractive indices of OVDs and aqueous humor (1.336 at 1040 nm wavelength) could cause a laser focus shift. As OCT measurement is calibrated to the refractive index of aqueous humor, a change in the refractive index with OVD application could influence laser cutting depth during anterior capsulotomy in the axial direction. The calculated shift of Viscoat, with a refractive
index of 1.341 at 1040 nm that deviates by only 13 μm from that of aqueous, can be assumed to be clinically negligible.30 Although other OVDs have less disparity, with standard laser energy settings for anterior capsulotomy a focal shift greater than 100 μm would be required to affect precision. Even complete refilling of the anterior chamber with silicone oil would not lead to a clinically significant aberrant transmission of the laser beam. According to the optical model developed by de Freitas et al.,30 only a group refractive index of more than 1.417 at 1040 nm can lead to an incomplete capsulotomy.

Care should be taken to avoid air bubbles, red blood cells, and clots with a diameter proportional to the size of the laser cavitation bubbles in the anterior chamber and on the corneal surface, which can significantly affect laser beam focus.30 Any loss of optical clarity may lead to laser energy dissipation. Other possible effects due to insertion of the iris hook and pupil expansion ring such as tilt, which could contribute to an error in the capsulotomy position, can be mitigated by laser software adjustments as in more routine cases.30

Our initial concern of not achieving adequate suction with the tail of the hook protruding beyond the ocular surface was not realized as the resultant irregularity was mitigated by wetting the corneal surface with HPMC 2.0% and by the Softfit patient interface (Lensx), which includes a hydrophilic acrylic soft contact lens that contacts the ocular surface and adapts to irregularities, enabling a dependable seal. Note that we also cut the distal part of the iris hook short, leaving the sleeve in place to secure its position.

As an alternative to the iris hook, a transcorneal suction (9-0 or 10-0 polypropylene) can be used to encircle 1 of the expansion ring sides, exit the anterior chamber, and be tied on the ocular surface tensioned to center the pupil. However, this idea must be tested clinically.

The technique is also useful in patients with hereditary or acquired crystalline lens malposition in which the normal iris partially covers the paracentral portion of the lens precluding a centered circular capsulotomy. The implanted Malyugin ring–iris hook complex repositions the pupil on the subluxated lens center, enabling the ideal femtosecond laser–assisted cataract surgery capsulotomy.

The described procedure is theoretically possible with different femtosecond laser platforms. However, we believe that lasers with a bigger suction ring diameter are more suitable for the procedure. Additionally, platforms using a liquid interface that require no contact between laser cone and cornea will not compress the protruding portion of the iris hook upon docking, reducing the chance of corneal distortion.

In summary, femtosecond laser–assisted cataract surgery can be successfully used in patients with insufficiently dilated and ectopic pupils. The combined application of a pupil expansion ring and a single iris hook for centration enables the surgeon to apply laser energy effectively and to create a round, centrally located anterior capsulotomy followed by the next steps of femtosecond laser–assisted cataract surgery. The technique is simple, yields a perfect capsulotomy opening, and provides a safe and comfortable intraocular operating environment for the surgeon.

### WHAT WAS KNOWN

- Pupil expansion ring and iris hooks can be effectively used to expand the pupil during cataract extraction.
- Pupil expanders achieve and maintain sufficient mydriasis to facilitate femtosecond laser–assisted cataract surgery in patients with small pupils.
- Presence of a dispersive OVD in the anterior chamber after pupil expander implantation does not significantly affect the quality of laser anterior capsulorhexis and lens fragmentation.

### WHAT THIS PAPER ADDS

- Combined use of the Malyugin pupil expansion ring to achieve sufficient mydriasis and a single iris hook to center the ring facilitated performance of a femtosecond laser capsulotomy in patients with miotic ectopic pupils.

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