Femtosecond laser–assisted technique for performing bag-in-the-lens intraocular lens implantation

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We describe a technique for femtosecond laser–assisted bag-in-the-lens (BIL) intraocular lens (IOL) implantation. Anterior capsulotomy and lens division into small pieces are performed by the laser. A fluid-filled interface makes it possible to re-dock the laser to the eye for posterior capsulotomy after the eye has been opened for lens aspiration without complications. The integrated optical coherence tomography also visualizes the posterior capsule, allowing a centered central posterior capsulotomy for uncomplicated IOL positioning. In 31 patients, no complications were observed within a 1-month follow-up. Femtosecond laser–assisted cataract surgery facilitated the BIL technique.

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The bag-in-the-lens (BIL) intraocular lens (IOL), first described by Tassignon et al. in 2002, was designed to prevent posterior capsule opacification (PCO), which is the most frequent complication of modern cataract surgery. It was approved by the Belgian Social Security in December 2004 and has been used in adult and pediatric cataract surgery. The clinical results for this IOL are excellent, with the posterior optical pathway remaining clear after surgery in all adult cases.

In the BIL technique, the anterior and posterior capsules are placed in the IOL’s flange after creation of both an anterior and a primary posterior capsulorhexis. The IOL flange is defined by the anterior and posterior oval haptics of the IOL that are oriented perpendicular to each other.

Creating appropriately sized and centered capsulorhexes relative to each other is important in BIL implantation. The IOL centration is dependent on the position of the 2 capsulorhexes. The posterior continuous curvilinear capsulorhexis (CCC) in the BIL technique has been criticized as being too difficult for routine manual performance.

Femtosecond laser systems for cataract surgery have been available since 2011. Studies have shown the possibility of creating a perfectly sized, shaped, centered, and strong anterior capsulotomy with this new technology. We describe a technique that uses a femtosecond laser to create both anterior and posterior capsulotomies for cataract surgery. Facilitating the creation of the posterior CCC with an image-guided femtosecond laser provides precise control of size and centration symmetry with the anterior capsulotomy and reproducibility that is technically difficult with traditional manual techniques. We applied the femtosecond laser-assisted technique for creating a posterior capsulotomy to BIL implantation.
SURGICAL TECHNIQUE

Step One: Planning

For this technique, 2 separate laser treatments in the same eye are necessary. The first treatment includes anterior capsulotomy, lens fragmentation (includes segmentation and softening), and corneal incisions (if desired). The second includes capsulotomy only.

For the anterior capsulotomy, a 5.0 mm diameter and pulse energy of 4 \( \mu \text{J} \) are used. The incision depth is 600 \( \mu \text{m} \). For the lens fragmentation, grid spacing of 350 \( \mu \text{m} \) or 500 \( \mu \text{m} \) and pulse energy of 9.5 to 10 \( \mu \text{J} \) are used. For the second capsulotomy treatment, a 4.6 mm diameter posterior capsulotomy with energy of 9.5 \( \mu \text{J} \) is used.

Step Two: First Docking

The suction ring (Liquid Optics interface [Optimedia Corp.]) is placed on the eye, and the first vacuum is activated to stabilize the eye. The suction ring is then filled with a balanced salt solution. A second suction is created between the suction ring and the nonapplicating disposable lens.

Step Three: Image Guidance

The 3-dimensional full-volume optical coherence tomography (OCT) image guidance system will determine the location and dimension of the cornea, the anterior chamber, the anterior capsule, and the posterior capsule, as well as the thickness of the crystalline lens. In almost all cases, the software automatically identifies the surfaces and the surgeon has to confirm only the planned treatment that was customized based on the anatomical surfaces of the eye. The anterior capsulotomy can be centered automatically on the pupil or the scanned capsule. Additionally, the high-resolution cross sections of the anterior segment displayed to the surgeon often provide visualization of Berger space and the anterior hyaloid surface, knowledge of which can be valuable in subsequent steps in the technique.

Step Four: Laser Treatment

After confirming the treatment plan, the surgeon presses the laser pedal to initiate treatment. On this first docking, the anterior capsulotomy, lens fragmentation (segmentation and softening), and corneal incisions (if desired) are performed. After finishing the laser treatment, the surgeon undocks the eye and proceeds with lens removal. After the initial laser treatment, the patient interface is stored in a sterile cup holder.

Step Five: Phacoemulsification/Lens Removal

The surgeon proceeds with removal of the softened cataract using irrigation/aspiration only or using phacoemulsification in dense cataracts.

Step Six: Preparation for Laser Creation of the Posterior Capsulotomy

After the cortex is aspirated, the posterior capsule is carefully opened with a 27-gauge self-bent needle. Sodium hyaluronate 1\% (Healon) is injected posteriorly to push back the intact anterior vitreous surface and elevate the posterior capsule. An ophthalmic visco-surgical device (OVD) is also injected into the anterior chamber to reform it. The incisions are hydrated with balanced salt solution. No sutures are necessary in adults.

Step Seven: Second Docking

The suction ring is placed on the eye and secured with vacuum under the microscope. The patient is then swiveled back to the femtosecond cataract laser for docking of the second laser treatment. The docking is done as described in step 2.

Step Eight: Image Guidance

The OCT image guidance system will scan the eye, process the full volume data, and attempt to identify the anatomical surfaces of the eye. At this time, the system will advise that modifications are required because abnormal anatomy has been detected. The surgeon is instructed by the system to confirm and adjust the surface fits for the anterior and posterior lens. In this specific situation, this message should be ignored. The high-resolution axial and sagittal OCT images will show the less than 5 \( \mu \text{m} \) thick posterior capsule in a convex shape, the anterior hyaloid in a concave shape, and a space between them, which was filled with OVD. The surfaces, from which the safety zones and the treatment are calculated, have to be customized. The convex surface in the anterior image (the posterior capsule) is customized and interpreted as the anterior capsule, the concave surface in the posterior image (the anterior hyaloid) is customized and interpreted as the posterior capsule, and the space between them is interpreted as the lens. Because the capsulotomy treatment is calculated based on what the user confirms as the correct surface, the planned capsulotomy can be delivered to the posterior capsule to create a posterior capsulotomy. The infrared camera picture is used to center the posterior capsulotomy to the anterior capsulotomy, and the intended location of the posterior capsulotomy is checked to be within the diameter of the anterior capsulotomy, usually with a 4.5 to 4.8 mm diameter.
Step Nine: Laser Treatment

After final confirmations, the laser is fired to complete the posterior capsulotomy. The laser treatment time for the posterior capsulotomy is usually 12 to 14 seconds and is monitored in real time on the video (Video, available at http://jcrsjournal.org).

Step 10: Implanting the BIL

After the vacuum is released and the patient undocked, the patient is rotated back under the operating microscope. The edges of the posterior capsulotomy are easily seen due to the created gas bubbles. The anterior chamber is filled with sodium hyaluronate 1%. Using a microforceps, the surgeon verifies that the posterior capsulotomy was completed and carefully removes it. The main incision is then enlarged to 2.8 mm.

The BIL type 89 A (Mocher GmbH), which is a foldable hydrophilic 1-piece IOL, is loaded into a 2.8 cartridge (Medicel) and injected into the anterior chamber. At the time of the injection, a spatula is placed beneath the IOL to prevent its injection into the vitreous. After the IOL is completely inserted and unfolded in the anterior chamber, the posterior haptics are placed behind the posterior capsule and the anterior haptics in front of the anterior capsule, keeping the anterior and posterior capsules in the IOL’s flange (Figure 1). After IOL placement, the OVD is aspirated. Acetylcholine chloride is injected into the anterior chamber to bring the pupil to miosis. The paracentesis and main incision are closed watertight, if necessary by stromal hydration. At the end of surgery, 1 drop of pilocarpine 2% is instilled to maintain miosis.

Results

In our cases, the Catalys Precision Laser System (Optimedica Corp.) was used. The technique was performed as an off-label use under an ethics committee-approved clinical protocol. In our clinic, the laser system is installed permanently in the operating area. To maintain sterility during the entire procedure, the touchscreen, laser control buttons, and vacuum connection port were draped with sterile transparent foil. The patient interface and the disposable lens of the laser system were supplied in a sterile condition. A cup holder (Geuder AG) was used to store the suction ring in a sterile condition.

Thirty-one cases of femtosecond laser-assisted BIL implantation have been performed. The mean age of the 6 men and 25 women was 73.5 years ± 8.0 (SD) (range 59 to 91 years). The mean intraocular pressure (IOP) was 14.5 ± 2.5 mm Hg (range 9 to 19 mm Hg) preoperatively, 13.0 ± 3.4 mm Hg (range 6 to 20 mm Hg) (P = .05) at 1 week, and 13.4 ± 2.9 mm Hg (range 8 to 18 mm Hg) (P = .6) at 1 month (Figure 2). During the 1-month follow-up, no significant increase in IOP was observed. The highest postoperative IOP was 20 mm Hg. The corrected distance visual acuity (CDVA) (logMAR) was 0.44 ± 0.17 (range 0.2 to 1.0) preoperatively and 0.08 ± 0.11 (range −0.1 to 0.3) at 1 month (Figure 3). The CDVA increased in all patients postoperatively (P < .0005). The distribution of achieved spherical equivalent (SE) refraction (diopters [D]) from the target refraction emmetropia is shown in Figure 4. The SE refraction at 1 week did not differ statistically significantly from the SE refraction at 1 month. Twenty-seven (87%) of the eyes were within 0.5 D of the target refraction at 1 month. No eye demonstrated intraoperative or postoperative
complications including fibrin reaction, cystoid macula edema, and retinal detachment during the 1-month follow-up.

In the postoperative period, the anterior and posterior capsules could be visualized in the flange formed by the anterior and posterior haptics using anterior segment spectral-domain OCT (Figure 5).

**DISCUSSION**

The femtosecond laser–assisted technique for performing BIL implantation demonstrates the potential for new applications of image-guided femtosecond laser technology. We believe the safety profile and reproducibility of anterior capsulotomies with the Catalys laser can be applied to posterior capsulotomies.

No complications occurred during the procedure. All posterior capsules were cut by the image-guided femtosecond laser without vitreous loss. During the first month, no IOP increase, glaucoma, macular edema, or retinal detachment was observed. This is similar to the low complication rate Tassigon et al.6 presented after manual BIL implantation in 807 eyes.

The most significant advantage of the BIL technique is the perfect IOL centration and absence of PCO in adults.8 Intraocular lenses with a sharp-edge haptic and optic lower the rate of PCO, but they are not able to prevent the proliferation and migration of lens epithelial cells and the resultant PCO over the long term.10 In addition to avoiding PCO, our results showed that the SE refraction at 1 week did not statistically significantly differ from the SE at 1 month, indicating early visual stability. With both anterior and posterior capsule surfaces in the IOL flange, and without the effect of capsular bag fibrosis and contraction on the effective lens position (ELP), BIL-implanted IOLs cannot increase higher-order aberrations and reduce the image quality after BIL implantation.11 The position of the anterior capsule is well known as the final optic position of BIL IOLs. Any capsular bag shrinkage would not affect the IOL position in the postoperative period. Contrary to ELP predictions for IOLs implanted in the bag, a known and stable resting position for BIL IOLs can theoretically improve ELP predictions and IOL power calculations. In our study, 87% of eyes were within 0.5 D of the target refraction. This compares favorably with published target refractive results after light-adjustable IOL implantation.12

The main advantage of the image-guided femtosecond laser–assisted technique for performing BIL implantation is the safety and reproducibility of creating perfect anterior and posterior capsulotomies with the proper size, centration, and symmetry. High-resolution imaging provides good visualization of the posterior capsule and anterior hyaloid surface. The ability to adjust the treatment based on identified surfaces allows delivery of the posterior capsulotomy with all the advantages of image guidance, such as
tilt control and precise positioning. The liquid optical interface has the advantage of being a noncontact fluid-filled interface, which does not applanate the cornea and does not induce a significant IOP increase. The low IOP increase makes it possible to perform the second laser treatment for the posterior capsulotomy after the anterior chamber has been opened without the risk for chamber collapse. Despite advantages of the femtosecond laser-assisted technique, we note that the puncture of the posterior capsule is manual and surgically demanding to carefully elevate the posterior capsule with OVD prior to the laser posterior capsulotomy.

Studies with a larger patient number and a long-term follow-up are necessary to examine the final refractive outcomes and possible adverse events. However, femtosecond laser-assisted cataract surgery with both anterior and primary posterior capsulotomies facilitated the BIL implantation technique.

WHAT WAS KNOWN
- Bag-in-the-lens IOL has the advantage of preventing PCO in the postoperative period.
- The posterior capsulotomy has been criticized as too difficult for routine manual performance. The anterior capsulotomy must be centered and a consistent size for good results.

WHAT THIS PAPER ADDS
- The femtosecond laser for cataract surgery was able to perform the anterior and posterior capsulotomies at the desired size and location and in a reproducible way without complication.
- The femtosecond laser--assisted anterior and posterior capsulotomies facilitated the BIL implantation technique for more general use.

REFERENCES