CASE REPORT

Transection and explantation of intraocular lenses using femtosecond lasers

Chandra Bala, PhD, MB BS (Hons), FRANZCO, Ushasree Pattamatta, PhD, Thomas Chan, MB BS, Jeffrey Shi, PhD, FRACI CChem, Kerrie Meades, MB BS, FRANZCO (Hons)

We present 2 cases in which a femtosecond laser was used in vitro to transect hydrophilic acrylic intraocular lenses (IOLs). At 8 μJ with 3 μm spot separation and 6 μm line separation, no charring occurred and there was no increase in total organic carbon. In vivo, the IOLs were successfully transected in the capsular bag (Case 1, opaque IOL) and the sulcus (Case 2, subluxated IOL post-pneumatic displacement of submacular hemorrhage) and explanted through a clear corneal incision (∼3.0 mm). At 3 months, in Case 1, the corrected distance visual acuity (CDVA) improved from 6/24 to 6/5, astigmatism improved by 0.23 diopters, and endothelial cell density (ECD) remained unchanged (1935 to 2210 cells/mm^2); in Case 2, the CDVA was hand motion, astigmatism remained unchanged, and ECD decreased (1960 to 1600 cells/mm^2), possibly as a result of complex surgery. Femtosecond IOL transection and explantation may be a clinically safe and feasible option for surgeons.

J Cataract Refract Surg 2017; 43:420–423 © 2017 ASCRS and ESCRS

Online Video

Explanting an intraocular lens (IOL) is often a challenging procedure performed to address issues such as IOL opacification, dysphotopsia, and refractive surprise.[1–7] The ideal explant procedure would remove the IOL through a small clear corneal incision (CCI) without inducing astigmatism or damaging the capsular bag, zonular fibers, or corneal endothelium. Explantation is particularly challenging in cases with large hydrophilic plate-haptic IOLs. A variety of techniques have been used to explant opacified hydrophilic acrylic IOLs, from folding an IOL to less satisfactory options of removing the entire capsular bag–IOL complex and replacing it with an iris-clip IOL.[8] The Mplus MF30 hydrophilic acrylic IOL (Oculentis) with hydrophilic coatings (6.0 mm optic and 11.0 mm haptic) is difficult to fold due to the plate-haptic design and difficult to cut due to the thickness.

Femtosecond lasers have been used in vitro to transect IOLs[9] and showed no damage to the capsular bag; however, gases were generated based on the laser energy. At high laser energy, toxic gases, which could be carcinogenic, were generated. At minimal energy settings, no toxic gases were detected. It is possible that during the in vitro testing, gasses escaped before collection.

We investigated the appropriate laser settings for IOL fragmentation in an artificial chamber with a human donor cornea. The gasses generated were trapped in the artificial anterior chamber and analyzed for safety. The settings were then applied in 2 difficult cases.

IN VITRO INTRAOCULAR LENS FRAGMENTATION

The Mplus LU-313 MF30 hydrophilic acrylic IOL (Oculentis GmbH) was placed in a Barron artificial anterior chamber (K20-2125, Katena Products, Inc.) and overlaid with a donor corneoscleral button that was not suitable for corneal grafting. The chamber was inflated with a balanced salt solution, and the Lensx femtosecond laser (version 2.23, Alcon Laboratories, Inc.) was docked. Through trial and error, 1 of the authors (C.B.) determined the appropriate energy setting to be 8 μJ, 3 μm spot separation, and 6 μm layer separation. The volume of gas generated during a linear 6.0 mm line was too small to be analyzed. The procedure was repeated with a waffle pattern and a diameter of 6.0 mm (Figure 1). This facilitated fitting multiple lines, which added approximately 100.0 mm in length per IOL and more horizontal transection planes. No charring was observed in the IOL at these settings (Figure 1). Sufficient gas was then generated for analysis.

The gases generated by transection of an organic acrylic IOL would be expected to be organic. Therefore, total organic carbon was analyzed (Total Organic Carbon [TOC] analyzer, model: TOC-L with an auto-sampler, model, ASI-L, Shimadzu Corp.), and the results were

Submitted: October 26, 2016 | Final revision submitted: December 12, 2016 | Accepted: December 20, 2016

From the Department of Ophthalmology (Bala), Macquarie University, Analytical and Testing Laboratory (Shi), School of Chemical and Biomolecular Engineering, University of Sydney, and Personaleyes (Pattamatta, Chan, Meades), Sydney, New South Wales, Australia.

Corresponding author: Chandra Bala, PhD, MB BS (Hons), FRANZCO, Department of Ophthalmology, Macquarie University, Sydney, NSW, Australia. E-mail: chandrabala.eye@gmail.com.

0886-3350/$ - see frontmatter
http://dx.doi.org/10.1016/j.jcrs.2017.02.005

compared with those of a pre-laser control sample from the anterior chamber. The analyzer has a detection limit of 4 g/L and was set to detect nonpurgeable organic carbon of 0.5 to 900 μm. Three paired samples were analyzed, and no significant difference in total organic carbon was found between the control (23.98 ppm ± 1.42 [SD]) and the femtosecond laser samples (23.43 ± 0.1 ppm) (P = .59, Student paired t test).

CASE REPORTS

Case 1

A 59-year-old man had uneventful cataract surgery with implantation of the Mplus MF30 hydrophilic acrylic toric IOL (18.5 diopter [D], axial length [AL] 24.08 mm) in the right eye 3 years before presentation. The uncorrected distance visual acuity (UDVA) was 6/6, and the uncorrected near visual acuity (UNVA) was N5. A year later, the patient developed macula-on retinal detachment and a vitrectomy with sulphur hexafluoride gas and a scleral buckle were performed. The patient presented in January 2016 with an opacified IOL (Figure 2, *A*) and a corrected distance visual acuity (CDVA) of 6/24 (−1.00 −0.80 × 107). He had developed a refractive error because of the scleral buckle. The endothelial cell count (ECC) was 1935 cells/mm^2. An A-scan was performed with the IOLMaster (version 5.4, Carl Zeiss Meditec AG) and showed with-the-rule (WTR) astigmatism of 1.36 D (42.99 @ 173/44.35 @ 83). A non-toric 17.0 D SN60WF (Acrysof, Alcon Laboratories, Inc.) IOL was chosen to replace the opacified IOL (AL, 24.93 mm). The superior CCI was expected to correct some of the WTR astigmatism. Following extensive discussion, informed consent for explantation and replacement of the opacified IOL was obtained from the patient.

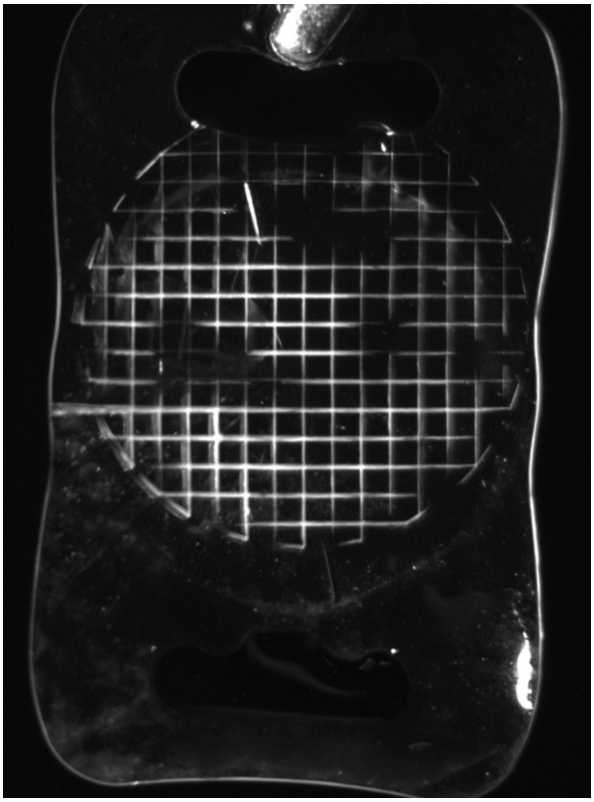

Figure 1. Waffle pattern applied to the IOL in vitro to generate gasses for analysis. There is no charring along the laser lines.

Intraoperatively, the capsular bag was inflated with a dispersive ophthalmic viscosurgical device (OVD) and the incisions were sutured. The IOL was not rotated. The femtosecond laser with a setting of 8 μJ, 3 μm spot separation, and 6 μm layer separation was used. A cross ablation pattern was chosen as this laser does not allow a vertical incision without the horizontal incision (Figure 2, *B*; Video 1, available at http://jcrsjournal.org). The posterior capsule was visualized, and the overlay was positioned to cover the diameter of the optic. The incision was intentionally displaced inferiorly to ensure the distal end was ablated. The anterior extent of the lensotomy could tear the anterior capsule so a capsulotomy of the same dimension was superimposed to overlap the IOL transection precisely. There was significant IOL tilt, and therefore the capsulotomy did not entirely cover the anterior capsule. No anterior capsule tears were noted during surgery.

When the patient was returned to the operating room, the IOL had subluxated into the anterior chamber. The proximal haptic and the superior part of the optic (to the laser ablation line) were cut with a Vannas scissors (see irregular lines Figure 2, *B*). The optic was grasped at the center with an angled Macpherson forceps. Using a Rosen chopper, the IOL was split from the distal end to the proximal end. The 2 halves of the IOL joined by the distal haptic were pirouetted from the anterior chamber through a 3.0 mm corneal incision. The non-toric IOL was inserted in the bag, and carbachol (Myocholine) was applied. A sutureless wound closure was achieved.

One day postoperatively, the UDVA was 6/9 and remained at this level at 3 months (the CDVA was 6/5; −0.25 −0.75 × 60; Figure 1, *C* and *D*). At 3 months, the WTR keratometric astigmatism was 1.07 D and the ECC was 2210 cells/mm^2.

Case 2

An 89-year-old man had uneventful cataract surgery with implantation of a high-addition (add) asymmetric refractive IOL (Mplus MF80; 20.0 D, add +8.0 D) for age-related macular degeneration (AMD) in the right eye. Postoperatively, the UDVA was 6/9 and the UNVA, N10. Despite regular intravitreal antivascular endothelial growth factor injections, the patient developed a large submacular bleed a few months after surgery. During pneumatic displacement of the submacular blood done elsewhere, the posterior capsule was ruptured and the IOL subluxated into the vitreous (Figure 2, *A* and *B*; Video 2, available at http://jcrsjournal.org). Following extensive discussion, informed consent for explantation and replacement of the subluxated IOL was obtained from the patient.

The subluxated IOL was prolapsed into the anterior chamber and then repositioned to the ciliary sulcus. An anterior vitrectomy was performed, and a Malyugin ring (7.0 mm) was inserted to expose the optic. The main wound was sutured with 10-0 nylon suture, and the patient was placed under the femtosecond laser. As in Case 1, a cross ablation was made in the IOL with the femtosecond laser. No capsulotomy was needed. The lens capsule could be visualized during the laser and avoided. The patient was returned to the operating room, where the IOL was split and explanted in the manner previously described through an approximately 3.0 mm CCI (Figure 2, *C* and *D*; Video 2, available at http://jcrsjournal.org). The transected IOL had an irregular border, suggesting the entire depth of the IOL was not ablated. This did not impede the IOL chopping process with the Rosen chopper. A 3-piece 20.0 D MA60AC IOL (Alcon Laboratories, Inc.) was inserted in the ciliary sulcus. The 3.0 mm corneal wound was sutured for safety. The CDVA remained hand motion (Figure 2, *B*) as a result of the submacular bleed. The preoperative keratometric astigmatism was 0.59 @ 36 and has remained at 0.7 D. The ECC decreased from 1960 cells/mm^2 to 1600 cells/mm^2.

In both cases, scanning electron microscopy (SEM) of the explanted IOLs showed the cavitation produced by the laser, which was unlike the smooth edge generated by the Vannas scissors.

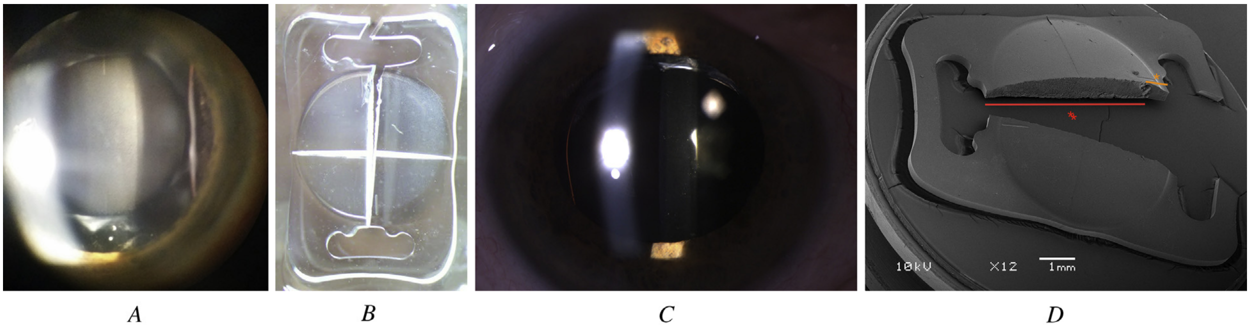

Figure 2. Case 1. *A*: Slitlamp photograph of an opacified IOL in the bag. *B*: The explanted IOL showing 2 femtosecond cuts in a cross pattern. The cut along the long axis was split to separate the 2 halves of the IOL. The superior haptic and the adjacent optic were cut with a Vannas scissors. *C*: Postoperative photograph showing the new hydrophobic IOL in the bag. *D*: Scanning electron microscopy of the laser shows the area cut by the laser (**) compared with the smooth edge generated by the Vannas scissors (*).

DISCUSSION

The transection of IOLs with the femtosecond laser is a new technique. An earlier in vitro study suggested that IOLs could be transected at 1 μJ without generating toxic gasses.[9] However, the study highlighted that at higher energy levels of 12 μJ, it was possible to generate carcinogens. The femtosecond laser pulses are spatially separated from each other, and it is likely that the generation of breakdown products is the direct result of the high energy and manifests as charring on the IOL at the point of laser application. The charring could lead to particulate breakdown products, which could affect the trabecular meshwork. The presence of the cornea in the laser path raises the need for more energy. By trial and error, we determined that 8 μJ was the appropriate energy level for transecting a hydrophilic acrylic plate-haptic IOL. At this energy setting, there was no increase in total organic carbon and no charring of the IOL (Figures 1 to 3). It is also reassuring that an IOL, which is harder than a crystalline lens, can be transected at the energy setting used in routine femtosecond laser–assisted cataract surgery. The ease of transection and the number of IOL cleavage planes desired by the surgeon may vary and will be determined by the spot and layer separation and the number of lines. Although this would prolong the duration of treatment, the spot energy would be unchanged. For example, in our investigation, the waffle pattern was used for gas generation and testing (Figure 1), generating a total laser ablation length of approximately 100.0 mm. This length is much longer than the two 6.0 mm lines used in the clinical setting. This offers further reassurance that even if more ablation lines or less spot separation were required, it would not generate toxic gasses.

Case 1 represents a large opacified plate-haptic hydrophilic multifocal IOL. Such opacifications are a well-recognized complication following intravitreal gas injection and anterior chamber air injection after Descemet-stripping automated endothelial keratoplasty surgery.[7] It is noteworthy that the IOL was explanted 3 years after implantation, at which stage there was capsule phimosis and adhesions that make such surgery challenging (Figure 1, *A*). In this case, the hydrophilic IOL with hydrophobic coating could not be rotated easily but could be displaced into the anterior chamber. The IOL was left in the bag as it was considered too large (11.0 mm) to be lasered in the anterior chamber where the iris and endothelium could be traumatized. Leaving the IOL in the bag prevented the IOL from being moved excessively by the generated gas. Caution must be exercised in filling the bag excessively with an OVD as the additional gas would move the IOL during ablation, resulting in irregular ablation or capsular block syndrome. If future lasers were manufactured to allow surgeons to alter the ablation profile, a profile could be customized to overlap the IOL precisely, reducing the number of laser pulses applied, the amount of energy used, the

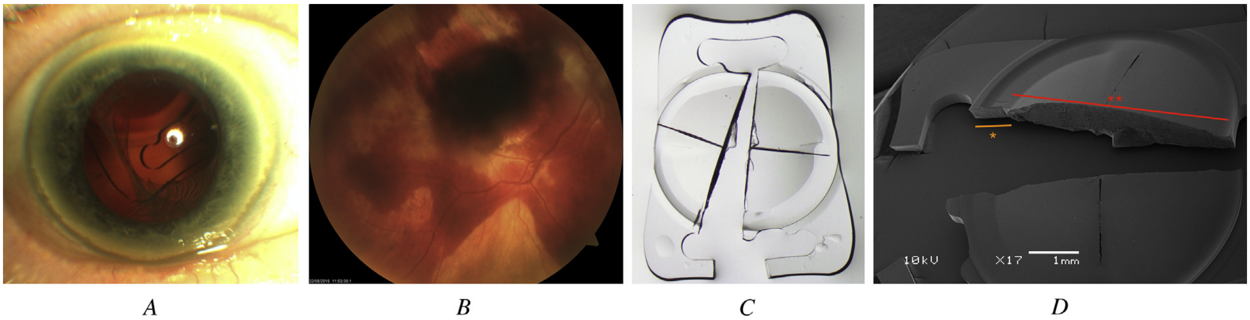

Figure 3. Case 2. *A*: Photograph of the subluxated IOL with the superior haptic protruding into the vitreous cavity through a posterior capsule tear. The anterior capsule is intact. *B*: Fundus photograph showing an extensive submacular hemorrhage following pneumatic displacement with gas. *C*: The cut along the long axis was split to separate the 2 halves of the IOL. The proximal haptic and the adjacent optic were cut with a Vannas scissors. *D*: Scanning electron microscopy of the laser shows the area cut by the laser (**) compared with the smooth edge generated by the Vannas scissors (*). The posterior portion of the lasered edge shows imperfect transection by the laser.

duration of treatment, and the amount of gas generated and minimizing the risk for posterior capsule tear. In our case, a new toric IOL could have been placed in the bag but the team was not confident of the postoperative keratometry. The largely unchanged keratometric astigmatism, rapid visual recovery, and unchanged ECD demonstrate that femtosecond IOL transection and explanation was a better procedure than manually cutting such a large IOL.

Case 2 was more challenging as the IOL had a higher add power of +8.0 D and had partly subluxated into the vitreous. Although thicker, the IOL was easier to explant because the posterior capsule was already ruptured. The procedure was prolonged by the need for vitrectomy, repositioning of the IOL, and insertion of a Malyugin ring. This may explain the reduction in endothelial cell density. It is important to note that the laser did not cause an anterior capsule tear.

In both cases, the IOL was explanted with the same technique. A Rosen chopper is ideally suited for splitting the IOL as it is thin and can enter the laser crack easily. Furthermore, it does not traumatize the underlying structures as it passes through the IOL. Holding the IOL in the middle with a forceps prevents the IOL from rocking against the force exerted by the chopper. In Case 1, the ECC was unaffected; in Case 2, the ECC decreased, which could be attributed to the prolonged surgery. In both cases, there was no longstanding corneal edema and no significant change in astigmatism. All these benefits suggest that femtosecond laser IOL transection may be a useful tool in the ophthalmic surgeon's armamentarium.

The SEM images highlight the need for further optimization of the laser settings. The areas cut by the laser show pitting consistent with the gaseous vacuoles generated by the laser compared with the smooth edge created by a scissors. In Case 2, the transection did not pass through the entire thickness of the IOL, which could be corrected with changes in the laser software.

Our investigation is a preliminary study but raises the possibility of applying this technique to IOLs of both hydrophobic and hydrophilic material. The technique has been applied in vitro to hydrophobic acrylic IOLs.[9] However, energy settings are likely to vary particularly for poly(methyl methacrylate) IOLs, which are harder (personal in vitro experience). The by-products of such lasers should be determined prior to applying the laser to new IOLs. We do not propose that femtosecond lasers be applied to all IOLs that have to be explanted. This technique is an off-label use of the technology and has not been customized by the laser manufacturers to enable its application for this purpose. Several techniques for explanting IOLs can provide equally good results. However, large IOLs and more complicated IOL designs may benefit from improving this technology. The 2 videos we present demonstrate the same IOL chopping technique, which can be applied by surgeons with existing instruments. This simplified technique holds promise for managing difficult cases and more complex IOLs in the future.

In conclusion, we found that low-energy femtosecond laser transection of IOLs is possible in the clinical setting. It can be performed safely in difficult cases and achieve quick healing.

REFERENCES

1. Werner L, Apple DJ, Kaskaloglu M, Pandey SK. Dense opacification of the optical component of a hydrophilic acrylic intraocular lens; a clinicopathological analysis of 9 explanted lenses. J Cataract Refract Surg 2001; 27:1485–1492
2. Yu AKF, Ng ASY. Complications and clinical outcomes of intraocular lens exchange in patients with calcified hydrogel lenses. J Cataract Refract Surg 2002; 28:1217–1222
3. Espandar L, Mukherjee N, Werner L, Mamalis N, Kim T. Diagnosis and management of opacified silicone intraocular lenses in patients with asteroid hyalosis. J Cataract Refract Surg 2015; 41:222–225
4. Mamalis N, Brubaker J, Davis D, Espandar L, Werner L. Complications of foldable intraocular lenses requiring explantation or secondary intervention—2007 survey update. J Cataract Refract Surg 2008; 34:1584–1591
5. Saffra N, Agarwal S, Enin J, Werner L, Mamalis N. Glare secondary to damaged IOL [letter]. Ophthalmology 2011; 118:2304.e1–2304.e2. Available at: http://www.aaojournal.org/article/S0161-6420(11)00696-8/pdf. Accessed February 2, 2017
6. Stringham J, Werner L, Monson B, Theodosis R, Mamalis N. Calcification of different designs of silicone intraocular lenses in eyes with asteroid hyalosis. Ophthalmology 2010; 117:1486–1492
7. Werner L, Wilbanks G, Nieuwendaal CP, Dhital A, Waite A, Schmidinger G, Lee WB, Mamalis N. Localized opacification of hydrophilic acrylic intraocular lenses after procedures using intracameral injection of air or gas. J Cataract Refract Surg 2015; 41:199–207
8. Bompastor-Ramos P, Póvoa J, Lobo C, Rodriguez AE, Alió JL, Werner L, Murta JN. Late postoperative opacification of a hydrophilic–hydrophobic acrylic intraocular lens. J Cataract Refract Surg 2016; 42:1324–1331
9. Bala C, Shi J, Meades K. Intraocular lens fragmentation using femtosecond laser; an in-vitro study. Transl Vis Sci Technol 2015; 4:8. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4473720/pdf/i2164-2591-4-3-8.pdf. Accessed February 2, 2017

Disclosure: *None of the authors has a financial or proprietary interest in any material or method mentioned.*

First author:
Chandra Bala, PhD, MB BS (Hons), FRANZCO

Department of Ophthalmology, Macquarie University, Sydney, NSW, Australia