Optimizing Visual Results With a Femtosecond Laser

The precision of the femtosecond laser and its subsequent software developments has expanded the application of this technology.

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Femtosecond lasers emit ultrashort optical pulses that are measured in femtoseconds (1 fs = 10-15 s). Shorter pulses translate as less energy expended overall for a given dimension and cause less damage to ocular structures, particularly the cornea, as the energy passes through the cornea until it reaches its focus. The precise focus of laser energy creates an expanding bubble that separates the tissue at distinct locations within the cornea, anterior chamber, or crystalline lens.

BACKGROUND ON FEMTOSECOND LASERS

Femtosecond lasers were first introduced for creating flaps in LASIK surgery. Soon thereafter, they were approved to create corneal incisions for implanting intracorneal ring segments and for corneal transplants. Most recently, femtosecond lasers have been used to create intracorneal pockets for the implantation of corneal inlays, to create arcuate incisions and clear corneal incisions, to create a continuous circular capsulorhexis, and even to debulk/fragment the crystalline lens. Laboratory and surgical experience have led to a new understanding of the architecture of incisions created at different depths in the cornea and anterior chamber, and new technological developments are refining these results.

In Budapest in 1999, Dr. Imola Ratkay-Traub used the first femtosecond laser in a sighted eye in ophthalmic surgery, and it had a laser engine speed of only 2 kHz. Lasers' engine speeds have improved dramatically during the years, with the current speed of the IntraLase femtosecond laser (iFS; Abbott Medical Optics Inc.) at 150 kHz. The engine speed allows the surgeon to place spots closer together without taking excessive time to create the incision(s). The closer the spots are placed together, the smoother the ablation and resulting lamellar roof and bed will be.

EXPANDED USES

Kamra Inlay

The precision of the femtosecond laser and its subsequent software developments have expanded the application of this technology and made it possible for devices such as the Kamra corneal inlay (AcuFocus, Inc. [not available in the United States]) to be successfully implanted into the cornea. The inlay treats presbyopia by increasing the eye's depth of focus using the principles of small-aperture optics. The first inlays were implanted under flaps created with a microkeratome. Numerous clinical trials with the inlay implanted under LASIK flaps have led to the conclusion that it should be implanted at a depth of 200 to 220 µm to ensure corneal health, increase the speed of visual recovery, and minimize healing times. Until recently, these mechanical devices' use was limited to creating flaps, however, and compared with a laser, they have a much higher standard deviation and range of flap thickness, resulting in a more unpredictable depth for the inlay's implantation. As a result of the increased incision predictability, the use of a femtosecond laser for the implantation of corneal inlays is a requirement.

Creating the Pocket

The Kamra corneal inlay was originally intended for emmetropic presbyopes who do not require any other visual correction. Initially for these patients, a LASIK flap was created, and the inlay was implanted underneath the flap without a refractive treatment. Subsequent advances in femtosecond laser hardware and software allowed for the creation of a lamellar pocket or channel for the insertion of the inlay. With this type of lamellar dissection, fewer corneal nerves are cut, and the first Purkinje image, used for the inlay's centration, is still visible.

Dr. Sanchez Leon in Mexico City created the first pockets in 2008 with the FS60 IntraLase laser by placing a piece

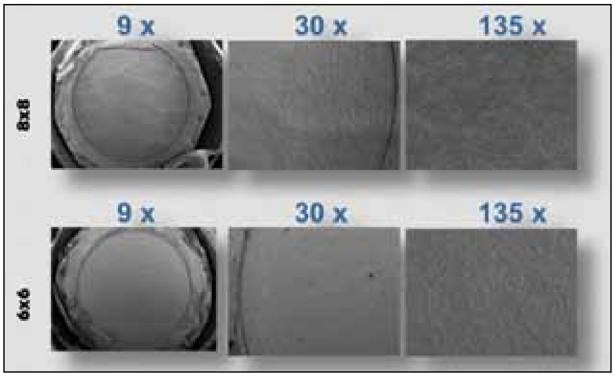

Figure. Adjusting laser settings, such as spot and line separation, results in a smoother lamellar bed.

of plastic shaped like a keyhole on top of the patient interface to block the laser energy. Although a short-term solution until software was created, the "mask approach," worked well but lacked the customization that is now possible. The pocket software for the iFS laser was completed in 2009 but was not CE Marked until 2011. The Femto LDV laser (Ziemer Ophthalmic Systems AG) was the second laser with software developed especially for the Kamra inlay. Both lasers allow users to customize parameters like the pocket's length, width, and depth; the side cut's location; and especially the laser parameters to create the smoothest beds and interfaces. Pocket software for the Wavelight FS200 femtosecond laser (Alcon Laboratories, Inc.) is in development.

COMBINING THE INLAY AND LASIK

Physicians have also successfully implanted the inlay at the time of the primary LASIK surgery. The surgeon creates a LASIK flap at a depth of 200 µm in the patient's nondominant eye, performs a LASIK treatment to correct the patient's refractive error with a targeted postoperative refraction of -0.75 D (which provides the greatest postoperative depth of focus), places the Kamra inlay on the stromal bed in the ablated area, and then replaces the flap. The fellow eye is treated with a traditional LASIK procedure with a targeted refraction of plano. At the 2012 International Society of Presbyopia Conference in Milan, Italy, Dr. Tomita reported results from 3,105 eyes of 3,105 patients who underwent a combined LASIK-Kamra procedure.[1] The mean uncorrected distance visual acuity in the inlay eye improved 8 lines from a preoperative level of 20/125 to 20/20 at 1 year, and 74% of patients achieved 20/20 uncorrected distance visual acuity or better at 1 year. The mean uncorrected near visual acuity in the implanted eye improved 3 lines from a preoperative level of J6 to J2 at 1 year, with a total of 77% of patients achieving monocular (implanted eye) J2 or better and 56% achieving J1 or better. At 1 year, 93% of patients were satisfied with their vision without reading glasses.

POST-LASIK PATIENTS

As the number of post-LASIK patients now developing presbyopia rises, the femtosecond laser makes it possible to implant a corneal inlay for the correction of presbyopia in this population. Because previously created LASIK flaps are much thinner than the recommended 200-µm depth for the corneal inlay, a pocket is created at least 100 µm below the previous LASIK interface, and the inlay is then implanted in the pocket.

Investigators evaluated 3,782 patients who had prior LASIK and later received the Kamra inlay. The device was implanted 100 µm below the prior LASIK flap interface in the nondominant eye. Results were similar to previous studies of the KAMRA inlay.[2] At 6 months, mean uncorrected near visual acuity improved 3 lines from J6 to J2, and uncorrected distance visual acuity changed only 1 line from 20/16 to 20/20. Patients also reported excellent satisfaction with their vision without reading glasses.

MORE ON FLAPS AND POCKETS

Because femtosecond lasers were primarily developed to create thin flaps, in many ways, they were not optimized to work deeper in the cornea. Superficially, the corneal lamellae are more densely packed and progressively become less tightly arranged deeper than 120 to 140 µm in the cornea. Therefore, the same cut that is smooth in a superficial layer can be rough in a deeper layer. In a study presented at the Association for Research in Vision and Ophthalmology's annual meeting,[3] Dr. Binder used the IntraLase femtosecond laser with the pocket software to create flaps between 200 and 220 µm deep. He varied the spot and line separation between 8 × 8 and 2 × 2. The results showed that a tighter spot/line separation was, in fact, correlated to a smoother lamellar bed as well as the roof over the bed. A normal flap setting for a standard LASIK procedure was initially recommended to be 8 × 8 µm of spot and line separation for the IntraLase (the spot and line separation are not selectable for the Ziemer laser, because the unit highly overlaps laser pulses to create smooth ablations). For the depth required for the Kamra inlay, however, it is necessary to set the laser to a spot-and-line separation 6 × 6 or smaller to improve the smoothness of the stromal bed (Figure); many practitioners state that 4 × 4 is ideal.

VARIABILITY AMONG PLATFORMS

All platforms vary to a certain degree. The Ziemer lasers create a lamellar resection roughly equivalent to a 5 × 5 spot/line separation setting. To make a pocket with the Ziemer Z6 laser, Dr. Tomita's recommended settings are a side-cut angle of 30º, temporal position, a pocket diameter of 6.5 mm, a tunnel 5 mm wide, and a pocket between 200 and 250 µm deep. To create a 100-µm LASIK flap, the recommended settings are a side-cut angle of 110º, a posterior diameter of 8.8 mm, a superior hinge position, resection sequence by stromal center at first then periphery, and side-cut dissection last. Because the Ziemer laser uses a low amount of energy per pulse, in cases requiring deep dissection, it is necessary to either increase the level of laser energy or to slow the scanning speed to provide sufficient ablation for the cut.

When using the IntraLase FS60, a spot/line separation of 6 × 6 µm is recommended, and for the IntraLase iFS, a 6 × 6 or 4 × 4 works well. In Dr. McGeorge's experience, the WaveLight Femtosecond Laser FS 200 provides a clean flap when set for 0.4 µJ of energy, 200 µm deep, with a spot/line separation of 4 × 4.

CONCLUSION

Huge strides have been made in femtosecond laser technology during the past decade. Not only are these lasers more precise than ever in LASIK surgery, they have been found to be advantageous for creating incisions deeper in the cornea for cataract and inlay surgery. As surgeons learn to manipulate the settings to accommodate different functions, they will certainly see even better results in the future. ■

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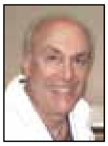

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