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The Femtosecond Laser: An Instrument to Stay

Femtosecond laser-assisted surgery is an evolving field with various applications yet to come.

BY THEO SEILER, MD, PhD

Like many refractive surgeons, I first heard about the clinical applications of a femtosecond laser when the instrument was introduced to facilitate flap formation in LASIK. At first glance, there was no good reason to use such an expensive machine—we had sophisticated mechanical microkeratomes and we believed the job that we were doing with them was great. However, when the predictability of flap thickness with the two technologies was compared, it became evident that the standard deviation in flap thickness created with the femtosecond laser was 10 times better than that created with mechanical microkeratomes. In order to avoid iatrogenic keratectasia, many of us transitioned to laser flap creation by 2007 at latest. Surgeons continue to rely on the femtosecond laser for flap creation but also for other modern LASIK applications, something that Minoru Tomita, MD, discusses in his article later in this supplement.

Two different types of femtosecond lasers are available today. The first type, which uses high-energy pulses in the order of several μJ per pulse, has a long focal length. The advantage with this is that it allows visualization of the laser application in process. The second type, a laser that uses a short focal length, produces very minimal energy, in the order of 100 nJ/pulse and less. The advantage with this is that a very high repetition frequency is achieved. Short focal lengths have the disadvantage of limited visualization of the laser process; however, they have the advantage of fewer side effects due to the production of only small cavitation bubbles. In their article, Se Ji Jung, MD, and Jodhbir S. Mehta, MD, highlight this field and present the advantages of low-energy femtosecond lasers like the Ziemer FEMTO LDV Z8 (Figure 1).

USED IN CATARACT SURGERY

About 7 years ago, when the femtosecond laser was first used to fragment the nucleus and establish a capsulorrhexis prior to phacoemulsification, it was clear that a new application for the femtosecond laser had emerged. However, scientific debates about the necessity of femtosecond lasers for modern cataract surgery continue today.

The range of applications in cataract surgery is limited because the iris is not transparent for femtosecond laser light. With that said, in his article, Boris Malyugin, MD, PhD, uncovers more about the advantages of the FEMTO LDV Z8 in complicated cataract cases.

Figure 1. The FEMTO LDV Z8.

Furthermore, with the increased safety of laser-assisted cataract surgery, some colleagues believe that this might broaden the horizon for bilateral sequential cataract surgery, an approach that Rupert Menapace, MD, FEBO, talks about in his article.

NEW HORIZONS IN CORNEAL SURGERY

One of the nice side effects of developing femtosecond laser use for cataract extraction was the introduction of online OCT with the FEMTO LDV. This technology, which is necessary to locate fragmentation, capsulotomy, clear corneal incisions, and arcuate incisions in cataract surgery, has also opened new horizons in corneal surgery. Gerald Schmidinger, MD, emphasizes the use of OCT when creating tunnels and pockets for implanting intrastromal corneal ring segments.

The online OCT of the FEMTO LDV was also a breakthrough technology for laser-assisted keratoplasty. Besides ultra-thin Descemet stripping endothelial keratoplasty lamellae that can be created with the Z8, we can use mushroom and top-hat profiles routinely.

The newest kid in town, so to speak, is laser-assisted deep anterior lamellar keratoplasty. Not only can surgeons decide online the depth of the lamella but, additionally, we can create a tunnel toward the center of the cornea—something that is helpful to create a big bubble. Currently the tunnel ends approximately 30 µm away from the Descemet membrane, which is close enough to establish a big bubble in nearly every primary case.

CONCLUSION

Comparing the current spectrum of applications of the Ziemer FEMTO LDV femtosecond laser with what was offered even a few years ago, it is obvious that femtosecond laser-assisted surgery is still an evolving field, and I would not be surprised to see femtosecond laser applications in glaucoma surgery in the near future.

The purpose of this supplement is to update you with the new applications of the Z8, and I hope you will enjoy reading. ■

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Effect of a Low-Energy Femtosecond Laser in Cataract and Corneal Surgeries

Understanding the effect of energy on tissue reactions and postoperative outcomes.

BY SE JI JUNG, MD; AND JODHBIR S. MEHTA, MD


First used in corneal and refractive surgeries, femtosecond lasers were traditionally used for flap creation. Other indications manifested over the years, including corneal transplantation and lenticule extraction. More recently, femtosecond lasers have been used in cataract surgery to refine and standardize the procedure and to allow astigmatic keratotomy.

A variety of different femtosecond lasers are commercially available today, all relying on different energy levels to produce the desired effect of tissue separation. Thus, it is important to understand the effect of energy on tissue reactions and subsequently on outcomes. This article discusses the benefits of low energy and the utility in both scenarios.

SIGNIFICANCE OF LOW ENERGY IN REFRACTIVE SURGERY

LASIK is the most common refractive surgery procedure performed worldwide. During LASIK, the creation of a corneal flap is followed by stromal ablation with an excimer laser. Initially, the corneal flap was created with a microkeratome; however, it may be associated with complications such as irregular flap incision planes and buttonholes. Currently, femtosecond lasers are more frequently used for flap creation, as they have been found to be safer and more predictable with respect to flap depth.[1,2]

Riau et al[1] recently compared two femtosecond lasers with different energy levels, the VisuMax femtosecond laser (Carl Zeiss Meditec), using microjoule energy, and the FEMTO LDV femtosecond laser (Ziemer), using nanojoule energy. In an animal study, adhesion strength, stromal bed quality, and tissue responses with each laser system (VisuMax = µJ laser group; Ziemer FEMTO LDV = nJ laser group) were measured. In both groups, flap adhesion strength increased over time; yet, in the Ziemer group, extracellular matrix formation, or the wound-healing reaction (fibronectin), and apoptotic cell death (keratocytes; Figure 1) was absent at the flap incision plane. Both were present in the µJ laser group, however.

The reason why µJ lasers cause extracellular matrix formation or the death of keratocytes is that expansion of the microcavitation bubbles are the main driving force of intrastromal incisions. This may more easily be seen with other femtosecond lasers that use even higher µJ energies (eg, IntraLase; Johnson & Johnson Vision).[1]

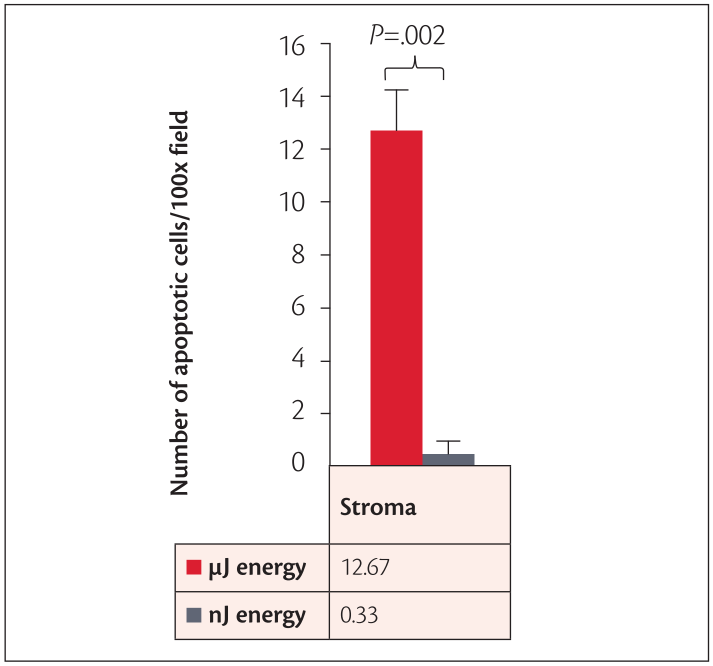

Figure 1. Apoptotic cell death was absent in the nJ group (Ziemer) but present in the µJ laser group.[1]

Our study showed that the lower-energy laser (Ziemer) produced minimal wound-healing reaction and did not cause significant tissue injury in the cornea.

SIGNIFICANCE OF LOW ENERGY IN CATARACT SURGERY

The role of femtosecond lasers in cataract surgery is multifaceted. The key functions are in producing an anterior capsulotomy, fragmenting the crystalline lens, and creating a controlled corneal incision. Manual anterior capsulotomy requires surgical skill, and many surgeons believe that the associated learning curve can be reduced when femtosecond lasers are introduced into the equation. Additionally, laser-assisted cataract surgery (LACS) could be potentially more beneficial to patients who are keen on correcting astigmatism and presbyopia, and this is because both toric and multifocal IOLs require precise centralization of the capsulotomy in order to achieve the complete benefits of the lens. The femtosecond laser has been shown to produce a more consistent, circular, and predictable capsulotomy, which is ideal for these lenses.[3,4]

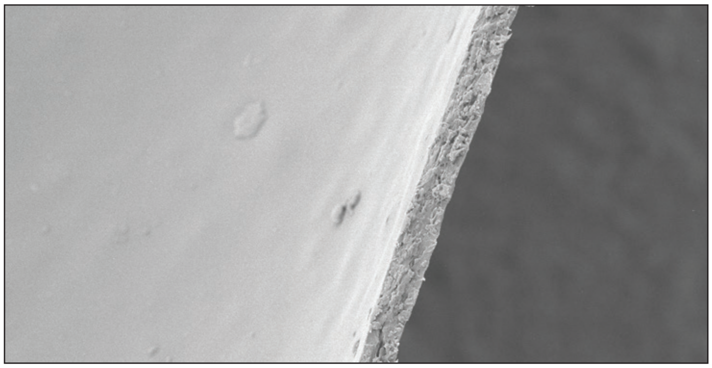

Figure 2. High-power scanning electronmicroscopy of the capsular edge created by the FEMTO LDV Z8.

Williams et al[5] found that, in porcine models, the low-energy, high-frequency laser platform of the FEMTO LDV Z8 produced consistent lens capsule circularity, regardless of the size of the capsulotomy. Furthermore, in an intact nucleus, the capsule tension strength and the stretch ratio were increased with larger capsulotomies.

When the researchers compared the FEMTO LDV Z8 with manual dissection of the capsulotomy in human cadaver eyes, the team observed that the manual technique caused an increase in capsulotomy variability, and accuracy was less predictable. Importantly, the capsule edge produced by the laser showed a smooth profile with no tags (Figure 2), similar to that of the manual techniques. These results are significant when compared with published capsulotomy edges from high-energy microjoule lasers like the Victus (Bausch + Lomb) and the LensSx (Alcon), which both have been shown to cause serrated edges following capsulotomy formation.[6] The serrated edges produced by these lasers can lead to more tags and, hence, weaker anterior capsules.

CONCLUSION

A lower-energy femtosecond laser can produce a predictable, circular, smooth, and strong anterior capsulotomy beneficial for cataract surgery. Furthermore, in laser refractive surgery, it produces minimal wound-healing reaction with a lack of apoptotic cell death along the incision plane, causing less collateral tissue damage. ■

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Complex Cases: Less Complicated With the FEMTO LDV Z8

Why I trust tough cases to a lower-energy femtosecond laser.

BY BORIS MALYUGIN, MD, PHD

I enjoy mastering surgical technique, and I spend a lot of time trying to do so as a means to provide my patients with optimal visual results. When it comes to complex cases, however, good postoperative results can sometimes be hard to accomplish—even with a trustworthy surgical technique. That is why, especially in complex cases, I have found that it is important to have instrumentation that I know I can rely on and that I am comfortable handling.

In terms of both standard and complex cataract and refractive surgery cases, one device that I have found helpful is the Ziemer FEMTO LDV Z8. What initially attracted me to this femtosecond laser is its versatility and the fact that it does not change my workflow. I do not have to set up a special room for the laser; in fact, I have integrated it seamlessly into my operating room, allowing me to perform entire procedures in one room. This has also helped to decrease the complexity of challenging cases.

Prior to using the Z8, surgical care in complex cases—such as patients with traumatic injuries and those with zonular pathologies like Marfan syndrome—was difficult to organize. I would have to perform the laser part of the procedure in one room and then the rest of the procedure in the operating room. My surgical staff had to move the bulky anesthesiology equipment between the two rooms, which is specifically cumbersome for surgery in pediatric patients. Now, with the FEMTO LDV Z8, I can perform the entire procedure in one operating room, without moving the patient or the equipment back and forth.

The other thing specific to complicated cataract surgery in patients with zonular defects is that the most significant part of the procedure is the capsulotomy. Like standard cases, a strong, circular, and centrally located capsulotomy sets the stage for a successful procedure in complex cases. When a perfect capsulotomy is achieved in these situations, I know that I have a 50% chance—maybe even higher—that the results of the complex surgery will be successful. This is yet another reason that I trust the FEMTO LDV Z8: I do not have any concerns with the capsulotomy strength, even specifically in young patients, where the capsule is very thick and elastic. On the other hand, it is well known that the elasticity of the tissue in these patients can complicate the creation of a manual capsulotomy.

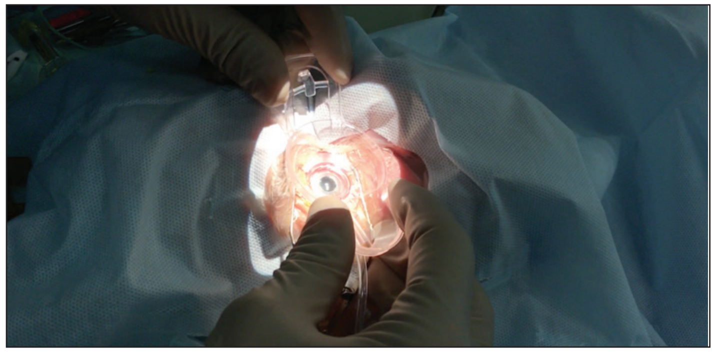

Figure 1. The patient interface is docked to the eye.

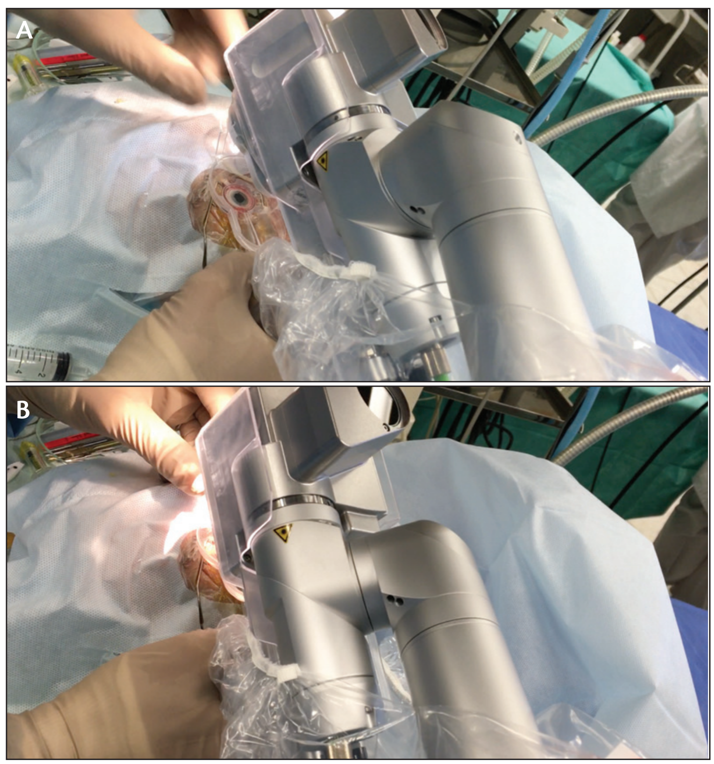

Figure 2. After filling the patient interface with balanced saline solution (A), the laser head is attached (B).

A SURGEON-CENTRIC TECHNIQUE

In many centers, the femtosecond laser is at the core of the procedure, with everything moving around it—the room, the surgeon, the surgical staff, and the patient. Until recently, that is how we had been operating, and I must say that I was never very fond of that approach. Now with the Z8, however, I am able to perform a surgeon-centric technique, meaning that everything is and should be arranged around me, the surgeon.

With a surgeon-centric technique, I am free to use any tool and instrument at any particular time during surgery, without changing the surgical environment that I am accustomed to. I think that it is important for the surgeon to be in his or her own surgical environment and that no additional steps are required, which can be cumbersome and inefficient. It is especially so for complicated cases in which the surgeon is operating under stressful conditions. Because I have been able to achieve this with the Z8, it is my first choice of the femtosecond laser systems I have experience with. These include the Victus (Bausch + Lomb) and the LenSx (Alcon).

CASE PRESENTATIONS

Two types of complex cases in which I have found the FEMTO LDV Z8 to be especially beneficial are patients with Marfan syndrome and those with small pupils. Following is one example of each.

Marfan syndrome. One of my most recent Marfan syndrome cases was in a 5-year-old who presented with a significantly displaced lens that caused myopia and astigmatism. Neither the myopia nor the astigmatism could be corrected with spectacles, and, therefore, I decided to remove the lens using a laser-assisted technique.

After administering general anesthesia and draping the patient, the FEMTO LDV Z8 was docked to the eye and a laser capsulotomy was manually positioned and created at the center of the lens. Also, the capsulotomy size was smaller than usual. Following creation of clear corneal incision, a dispersive OVD (Viscoat; Alcon) was injected into the anterior chamber, and the anterior capsular button was removed with the forceps.

In complex cases such as this, I like to use capsular retractors to catch the edges of the capsulotomy and displace the lens. This aids in replacing the capsular bag to the center of the pupil. Once this was achieved, dry aspiration was performed. Sometimes, as in this case, it becomes necessary to refill the capsule bag several times with the dispersive OVD before aspiration is completed. Because the lens is soft in pediatric cases, lens fragmentation is not required.

Once the capsular bag was cleaned, a cohesive OVD (Provisc; Alcon) was used to inflate the anterior chamber and a modified capsular tension ring (Malyugin Modified Capsular Tension Ring; Morcher) was inserted. Once the fixation element of the ring was positioned out of the capsulotomy, I sutured the eyelet to the sclera through the ciliary sulcus. Sometimes I use Gore-Tex sutures (W.L. Gore & Associates), but, in this case, I used 9-0 prolene sutures. As soon as the capsular bag was centered, I implanted the IOL and sutured my incisions. Also, it is important to add that, before injecting the capsular tension ring, I like to remove the capsular hooks in order to avoid them from becoming entangled with the capsular tension ring.

Small pupils. When a small pupil (4 mm or less) is recognized prior to surgery, the main incision is created with a 2-mm metal keratome. The anterior chamber is filled with Viscoat and then the Malyugin Ring 2.0 (MicroSurgical Technology) is injected.

When injecting the Malyugin Ring, the distal and lateral scrolls should catch the iris simultaneously. Then, to place the last scroll, the Osher/Malyugin Ring manipulator (MicroSurgical Technology) is introduced through the main incision. In these cases, I try to avoid creating additional paracentesis and manipulate the ring by introducing the instruments into the anterior chamber through the main incision. This is helpful later, when I will use the femtosecond laser in subsequent steps of the

Figure 3. On the laser screen image, the anterior segment is seen. The dark blue Malyugin Ring is attached to the iris, expanding the pupil.

procedure. By minimizing the number of incisions, there is much less chance of leakage during laser docking.

Finally, I completely fill the anterior chamber with dispersive OVD. Throughout all of these steps, it is important to avoid any air bubble formation in the anterior chamber. This is because the bubbles will block the laser transmission.

If I am not sure that the 2-mm wide corneal tunnel is long enough to be self-sealing during docking, I do not hesitate to place a single 10-0 nylon suture. This ensures that I will not loose the anterior chamber when the vacuum builds during docking.

With the OVD still in the anterior chamber, the suction ring is placed and docked and the liquid interface is engaged. Then the laser head is attached to the suction ring, and the fragmentation as well as the capsulotomy is fashioned. From the screen of the laser, the pupil edges and the Malyugin Ring are easily visible, as well as the distance in between the pupil and the laser capsulotomy.

Once the lens is fragmented, the capsulotomy is created. For fragmentation, I prefer using a pattern with six or eight radial cuts, something that I call *pizza cuts*. Once the laser is disengaged from the eye, two additional paracenteses are created with a 1.2-mm knife. This allows me to introduce additional instrumentation, like the I/A handpiece, manipulator, and chopper. Once phacoemulsification is finished, the Malyugin Ring 2.0 is removed and surgery is complete.

CONCLUSION

In addition to its use in complex cataract surgery, I also use the Z8 for corneal procedures including intrastromal corneal ring segments, deep anterior lamellar keratoplasty, Descemet stripping endothelial keratoplasty, and penetrating keratoplasty. I also have very good experience with the laser in these applications, and I believe that the technology is invaluable. Overall, I like that it is so versatile, easy to use, and extremely mobile. It has enhanced the way that I perform surgery in standard and complex cases alike. ■

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- Financial disclosure: Licensed intellectual property (MicroSurgical Technology)

A Temporal Approach to ISBCS

The Z8 femtosecond laser is an instrumental device in immediate sequential bilateral cataract surgery.

BY RUPERT MENAPACE, MD, FEBO

Over the past several years, immediate sequential bilateral cataract surgery (ISBCS) has gained increasing popularity, both with surgeons and with patients, for various reasons. Included in these is that the procedure saves money, time, and effort and accelerates visual rehabilitation. Socioeconomic savings have been calculated to amount to more than €700 per patient. For these reasons, I have been performing ISBCS for 10 years, and I have completed the procedure in more than 2,500 patients.

ISBCS requires optimum safety measures. A femtosecond laser potentially allows standardization of the cataract procedure, including incisional architecture, and, thus, helps in preventing suboptimal outliers. The Ziemer FEMTO LDV Z8 low-energy femtosecond laser creates unprecedented smooth corneal incisions. Since 2016, I have been exploring the potential of this mobile laser machine for routine ISBCS.

CCIs: LASER VERSUS MANUAL

Optimal deformation stability of the self-sealing incision is a key prerequisite for safe cataract surgery. While deformation and topographical stability are inherently greater with posterior-limbal incisions, clear corneal incisions (CCIs) have become the standard in most developed countries. In order to maximize deformation and topographical stability, today's standard 2.2- to 2.5-mm CCIs must have a square design and should be located as far from the corneal center as possible. Temporally located CCIs, therefore, are preferable to superiorly located CCIs.

Femtosecond lasers can only cut through translucent tissue, and, thus, inherently can only create CCIs. The advantage of a laser over a manual CCI is that the length of the incision is exactly defined and reproducible. Whereas a CCI incision that is too short reduces deformation stability and, thus, safety, an unnecessarily long incision reduces maneuverability of tissue and increases stress caused by the instruments during surgery. This may impair the self-sealing function of the corneal valve. Femtosecond lasers also allow any desired wound design, including internal widening of the tunnel to reduce mechanical stress on the corneal lip. In principle, manual surgery with adequate knives also allows perfect CCIs; however, laser-assisted cataract surgery (LACS) guarantees fully standardized CCIs independent of the surgeon's skill. This avoids outliers in design and length of the incision, which is particularly important with ISBCS.

FULL INTEGRATION: ESTABLISHING THE SETTING

One unique feature of the FEMTO LDV Z8 is its mobility, allowing full integration of the device into the usual workflow in the operating room. While LACS is usually performed with the surgeon sitting superior, I have been using it exclusively for temporal-approach cataract surgery for the reasons just discussed. For an

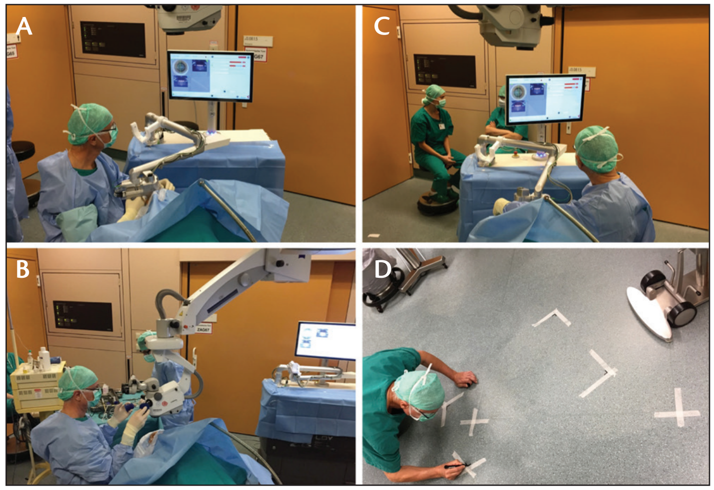

Figure 1. Schematic workflow for right-and left-eye temporal-approach ISBCS. Pretreatment in the right eye with the Z8 (A); surgery in the right eye, under the OPMI Lumera microscope (Carl Zeiss Meditec; B); pretreatment in the left eye with the Z8 (C); positional floor marks (D).

undisturbed workflow with temporal-approach ISBCS, a setting that minimized positional changes of the femtosecond laser, the phaco machine, and the instrument table and that fixed the positions of the surgical table and microscope had to be established.

To achieve this, we experimented with various settings that allowed optimum temporal-approach surgery for both right and left eyes. We found that aligning the pivot of the laser arm with the long axis of the surgical table allowed optimum access to both eyes. Also, the distance between the pivot point and the head cup had to be defined. The resulting relative positions of the patient table and the Z8 femtosecond laser were marked on the floor with four colored dots. For minimum torsion of the laser handpiece versus the laser arm, the patient table is lowered for right eye and elevated for left eye surgery.

Figures 1 and 2 depict the optimal array and workflow for temporal-approach ISBCS with the Z8. When initiating laser-assisted ISBCS in a new patient, I first operate on the same side as I had finished with the previous patient. This minimizes the need for adjusting the surgical microscope position and table height.

In clinical routine, this setting has proven to be efficient and safe, with the Z8 thus fully integrated in my standard workflow.

LASER FUNCTIONS

Incisions. As mentioned in the outset of this article, safe incisions are key to the safety of ISBCS. Compared with other femtosecond lasers on the market, the FEMTO LDV Z8 uses low-energy pulses at a very high repetition rate. Nanojoule pulses fired in megahertz

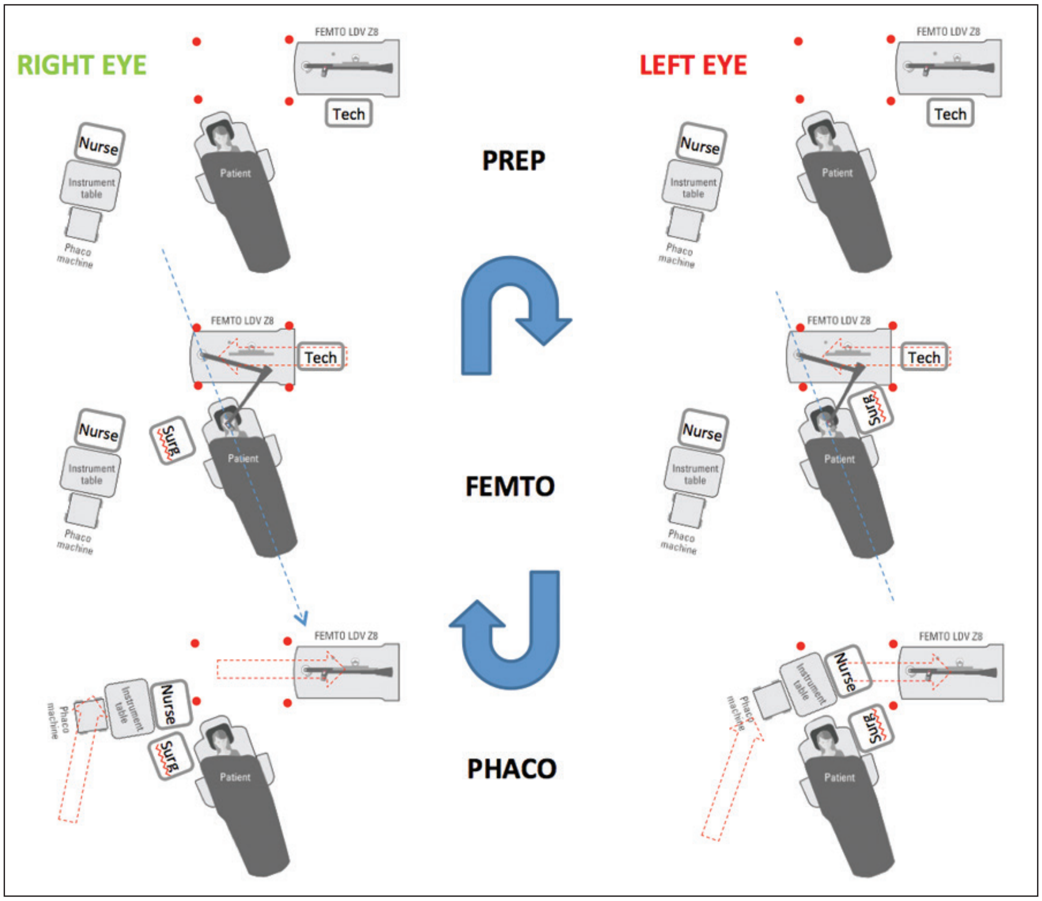

Figure 2. Setting for right- and left-eye temporal-approach handpiece docking and laser pretreatment, followed by ultrasound-assisted high-fluidic phacoaspiration and preloaded IOL injection.

intervals inherently create smoother tissue cuts compared to the microjoule pulses at a kilohertz repetition rate used by other femtosecond lasers. In fact, the cuts made by the Z8 are continuous without tissue bridges, and they are readily opened without the need and consequent trauma of mechanical separation with a sharp spatula. This may also reduce the self-sealing properties of the CCI. With the current software, the entrance of the CCI may now be placed close to the limbus. In the rare event that a CCI cannot be accessed because of inadvertent limbal encroachment, a shallow cut just inside the limbus, made with a guarded knife, easily provides access to the CCI more centrally. *(Visit www.femtoldv.com/ISBCS to see an entire procedure in time lapse.)*

Pretreatment. For pretreatment, the Z8 articulated arm is swung into place and the laser handpiece is positioned over the patient's eye. Instead of wrapping the laser arm and handpiece in plastic foil for sterility, an additional pair of sterile gloves is used by the surgeon and a sterile oversleeve is placed over the surgeon's right forearm when pretreating the patient's left eye and vice versa when pretreating the right. Both are removed after the laser-assisted pretreatment is complete, and the laser handpiece is moved away from the surgical field. Surgery is then continued immediately with the surgeon sitting in the same position. Once the Z8 is withdrawn, the phaco machine is moved toward the patient bed, and the surgical microscope is swung above the patient's head.

Continuing with manual surgery, the main incision and two paracenteses are faintly outlined due to minute gas bubble formation. With a blunt spatula, the main incision is opened first. After exchanging the aqueous for OVD, the paracenteses are checked for patency. Once the nucleus is debulked and removed with ultrasound-assisted high-fluidics phacoaspiration, the residual cortex is aspirated using special coaxial instrumentation in order to avoid mechanically traumatizing the paracenteses. At the end of surgery, the paracentesis used for the phaco spatula during lens workup is hydrated and the globe is tonisized. The 2.2-mm laser CCI is then checked for tightness, both by watching out for spontaneous leaking and by depressing the sclera peripheral to the CCI entry with the surgeon's fingertip. Gentle hydration is added to optimize sealing thereafter. In my experience, no leakage has been detected with fluorescein when reascertaining wound tightness before dismissing the patient.

CONCLUSION

The Z8 femtosecond laser has proven to allow quick, safe, and efficient ISBCS, and the CCIs created with this device have been reliably self-sealing. The mobility of the laser console and the versatility of the laser arm and handpiece allow easy temporal-access ISBCS without the need for the surgeon to change his or her habitual position.

For femtosecond laser pretreatment, the laser handpiece is easily accessed by the surgeon no matter whether operating from the patient's right or left temporal side. Immediately after laser pretreatment, the surgeon can continue with cataract surgery by swinging the surgical microscope over the patient.

With these settings, the Z8 mobile nanoJoule femtosecond laser platform is uniquely qualified for routine temporal-approach ISBCS. ■

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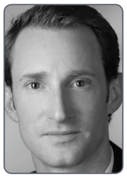
Image-Guided ICRS Implantation

Integrated OCT with the FEMTO LDV Z8 can help to enhance one's surgical plan.

BY GERALD SCHMIDINGER, MD



In patients with keratoconus, the first line of treatment for loss of visual function is indeed spectacle correction or contact lenses. Although we strive to provide these patients with a nonsurgical solution in the form of glasses or contact lenses, some will inevitably present with poor vision and even intolerance. In my practice, the second line of treatment that we offer in such cases is intrastromal corneal ring segment (ICRS) implantation.

I have considerable experience implanting ICRSs in keratoconic patients with clear corneas, and I perform an average of one to two implantations per week, up to 60 per year. What used to be a delicate and time-consuming procedure has become increasingly simpler due to the use of the femtosecond laser and, more recently, the integration of OCT into femtosecond laser technology. The combination of the femtosecond laser and OCT has enhanced my surgical planning and allowed me to customize each procedure to the patient's individual needs.

With the Ziemer FEMTO LDV Z8, I am not only able to create the tunnel incisions required for ICRS implantation, but I can also take advantage of the system's proprietary high-resolution, spectral domain OCT software to visualize the ocular surface before and after every procedure. The images provided by this state-of-the-art OCT system help me to fine-tune the resection geometry before each treatment. In fact, the software even automatically suggests the placement of the tunnel incision based on my surgical preferences.

BENEFITS OF OCT

Having the femtosecond laser available for ICRS implantation adds extra surgeon control over the procedure, in part due to the perfectly sized incisions, created at just the right depth. This helps me to prevent perforations and, even more importantly, helps me to prevent implanting the ICRS too shallow—a possible side effect of poor-quality preoperative pachymetry readings and a major cause of postoperative complications.

What has been especially useful with the Ziemer femtosecond laser in particular is its integrated OCT software, which allows me to visualize ocular structures like the epithelium and the Bowman membrane and to reach the desired depth of ICRS implantation of 70% to 80% corneal thickness (Figure 1). I am also able to visualize previous LASIK flaps and abnormalities such as corneal scarring so that I can adjust the treatment accordingly.

The OCT of the FEMTO LDV Z8 performs intraoperative adjustments of the depth of the implantation, which is a major advantage over other femtosecond laser systems as well as over manual implantation of the ICRS.

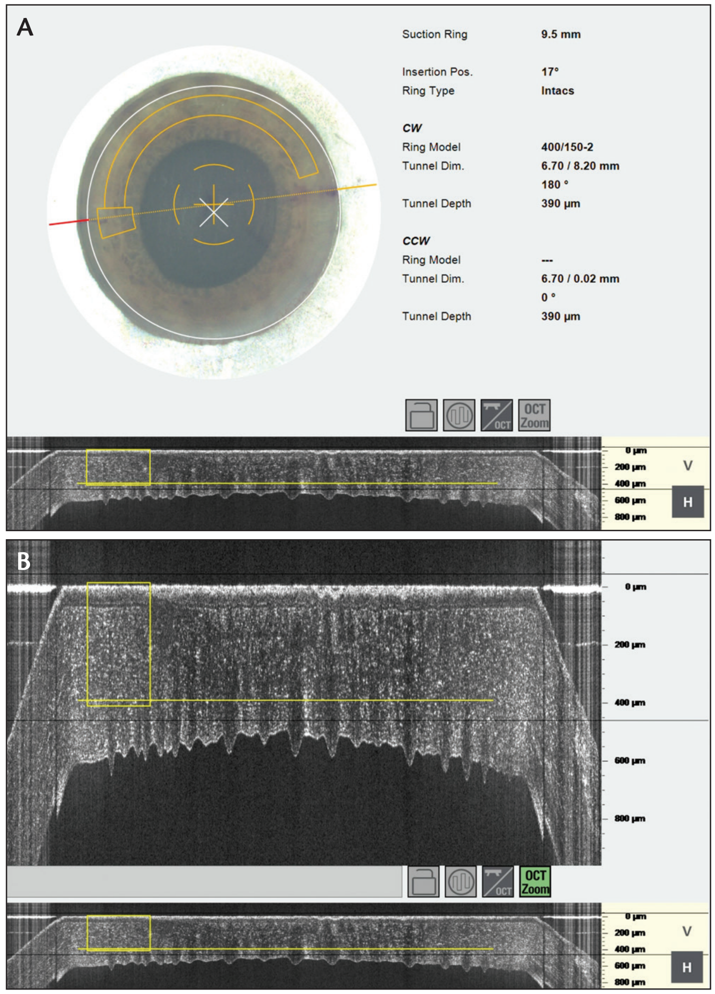


Figure 1. The FEMTO LDV Z8 screen during ICRS implantation (A,B).

IN CLINICAL PRACTICE

I use the Intacs (Addition Technology) and the Keraring (Mediphacos) ICRSs, and the FEMTO LDV Z8 provides preprogrammed trajectories for both. I simply choose from the precalibrated rings and select the thickness, the axis of incision, and the type of the ICRS. The laser then provides a preprogrammed cut for that specific ICRS. Alternatively, there is an option for manual customization of the trajectory. However, I rarely select this option. The one exception is in very advanced stages of keratoconus, in which I attempt to postpone more invasive surgical procedures like keratoplasty.

The software of the FEMTO LDV for ICRS implantation is designed to accommodate one- and two-tunnel procedures at the same or different depths, and it can also create one complete

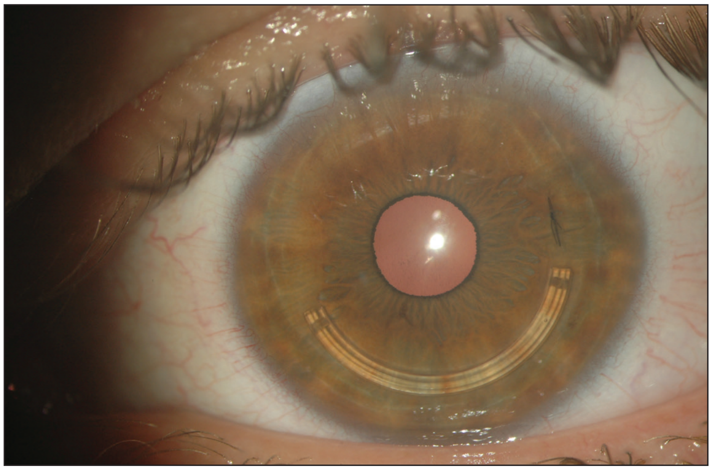


Figure 2. The ICRS in situ at 1 day postoperative.

360° tunnel. Thanks to a complete resection, insertion of an ICRS is easily accomplished (Figure 2). To date, I have not observed incomplete tunnel cuts or problems with ring insertion.

As my personal experience with laser-assisted implantation of ICRSs has been so positive and the advantages of the Ziemer femtosecond laser so plentiful, I no longer perform manual implantation. Not only does the OCT function of the laser more precisely locate the incision site and centration of the tunnel, it also allows me to adjust the incision site intraoperatively. With the FEMTO LDV Z8's integrated OCT software, I can perform an entire ICRS implantation procedure in less than 10 minutes.

Another advantage of laser-assisted implantation with the FEMTO LDV Z8 is that I have not experienced a false plane implantation. This is because the bubble layer provides a better reference for implantation of the ICRS into the corneal plane compared with manual preparation, where the ICRS can accidentally be implanted too shallow or too deep.

Lastly, implantation of ICRSs with the FEMTO LDV Z8 is faster and more precise, with a reduced risk for off-center implantation.

CONCLUSION

I am very fond of the mobility of the Ziemer femtosecond laser, as I work in different operating rooms, even on different floors in my hospital depending on the day of surgery. Because this laser is portable, I am able to perform ICRS implantation, in addition to other laser-assisted procedures, wherever I am that day. My team can have the laser up and running in about 10 minutes, without using any additional calibration. Furthermore, I can perform laser-assisted cataract and corneal surgery in the morning and ICRS implantation on a different floor or different operating room in the afternoon. ■

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Z LASIK and Z LASIK Z: Enabling 2-D and 3-D Resections

Premium laser vision correction with faster visual recovery.

BY MINORU TOMITA, MD, PhD

My experience with laser vision correction is far-reaching, spanning a total of more than 100,000 cases in just the past 9 years alone. In this time, each and every one of the LASIK procedures that I have performed has helped to provide me with a level of proficiency that is unparalleled.

Even with the variety of laser vision correction techniques available today, I continue to rely most heavily on LASIK, as I believe that the procedure is more predictable and more accurate than the existing alternatives. This is even more true today, now that I can choose between 2-D and 3-D resections made with the Ziemer FEMTO LDV.

VERSATILE PLATFORM

The FEMTO LDV line of laser systems, which includes the Z2, Z4, Z6, and Z8 models, stands out among the other available femtosecond lasers because of its versatility of applications in refractive surgery and, with the Z8, also in cataract surgery. In refractive surgery, any laser on the Ziemer platform can be used in LASIK to create corneal flaps (Figure 1), in intrastromal corneal ring segment (ICRS) implantation through tunnel creation, in corneal inlay implantation through pocket creation, and in keratoplasties to transplant corneal tissue. In cataract surgery, the Z8 performs capsulotomy, lens fragmentation, clear corneal incisions, and arcuate incisions.

In both refractive and cataract settings, I can customize my surgical templates according to my preferences and save them for later use.

PREMIUM LASER VISION CORRECTION

With regard to LASIK, the laser boasts a remarkably low complication rate. This is in large part due to the low pulse energy (nanojoules) and the high pulse repetition rate, which translates into a smooth stromal bed and incision edges. Currently I can perform either Z LASIK with a 2-D resection or Z LASIK Z with a 3-D resection, enabling me to create truly customizable flaps (Figure 2). Both procedures boast fast visual recovery[1] and reduced inflammation postoperatively.[2]

Z LASIK. Z LASIK is available on all FEMTO LDV Z models. During the procedure, the 2-D flap resection is created in a planar mode using a flap thickness of 90, 100, 110, or 140 µm and a flap diameters of 8.5, 9, 9.5, or 10 mm. No matter what specifications are selected, the hinge position is customized according to the patient's ocular status.

The Z LASIK procedure creates excellent stromal bed quality with natural corneal curvature and self-sealing flap edges. During flap creation, the vacuum levels are maintained with the laser's computer-controlled suction system.

Z LASIK Z. This procedure is available on the FEMTO LDV Z4, Z6, and Z8 models. With the Z8, intraoperative OCT is also available, further enhancing the control of the procedure. Flap thickness for Z LASIK Z is available for all values between 90 and 160 µm and flap diameters between 6.5 and 10 mm. Just as in Z LASIK, the hinge position is customizable.

Additionally, the size of the hinge is also customizable, making it possible to create each flap individually based on the desired geometry. With this procedure, I can make round and oval flaps and create angled edges; this is the major benefit of Z LASIK Z with the FEMTO LDV.

TIPS TO ENHANCE YOUR RESULTS

I have learned a few valuable tips that helped me to enhance

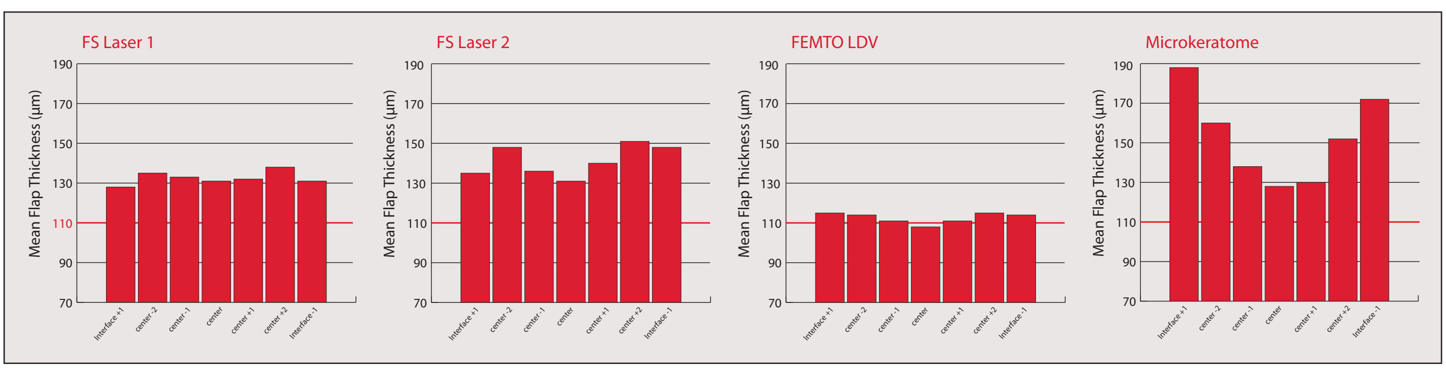

Figure 1. Inter device comparison of mean flap thickness across axial scans (1 mm from flap edge: interface ±1, mm from center: center ±x). Intended flap thickness = 110 µm.[4]

Figure 2. The 2-D and 3-D resections of Z LASIK and Z LASIK Z.

my results with Z LASIK and Z LASIK Z depending on the laser platform.

Choose your suction ring size wisely. With the Z6, I always used a 9.5-mm suction ring. When I began performing Z LASIK Z with the Z8, naturally, I used the same setup; however, I quickly noticed that the applanation was too small—approximately 80% applanation compared with the previous models of the FEMTO LDV. This was because the interface of the Z8 is slightly different from the interface of the Z6.

After using different suction rings, I found that the 10-mm suction ring worked well, and it was much easier to get a good applanation and good centration. Now when performing Z LASIK Z, I always use a 10-mm suction ring. This has given me more freedom to adapt every aspect of the procedure after docking. It should be noted, however, that I can still cut a 9.5-mm diameter flap or smaller when required. I am also able to change the settings after docking.

Use OCT. Ziemer's proprietary OCT system is of great benefit for LASIK surgeries, and I have been using the software as long as I have had the Z8, which is 3 years now. Integrated directly into the handpiece, I get a clear, high-resolution view of the cornea. As a result, I am able to more accurately and more precisely plan surgery. For instance, when creating a 90-µm flap with the FEMTO LDV Z8, I can see the Bowman layer and adjust the flap position intraoperatively with the aid of the OCT (Figure 3). I can do the same with any flap thickness.

Figure 3. Visualization of the Bowman membrane for sub-Bowman LASIK.

I also use OCT to guide the creation of pockets during corneal inlay implantation and tunnels during ICRS insertion.[3]

LASIK CONTINUES TO IMPRESS

With aid of the FEMTO LDV femtosecond laser, patients experience a "wow effect" immediately after surgery. Within a few hours postoperatively, almost all patients have 20/20 visual acuity.[1,2] They are happy with their results, and I am happy with the outcomes.

I strongly believe that LASIK is more predictable than alternative procedures such as small incision lenticule extraction, and I have no plans to switch any time soon. My patients continue to be satisfied with LASIK, thanks to the extreme accuracy I am able to achieve with the FEMTO LDV line of lasers. ■

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The Significance of OCT in Performing DALK

Built-in OCT functionality of the FEMTO LDV Z8 femtosecond laser provides added security during deep anterior lamellar keratoplasty.

BY THEO SEILER, MD, PhD

Looking back on the history of keratoplasty for the treatment of keratoconus and stromal dystrophy, about 20 years ago, surgeons had only one choice—to treat the patient nonsurgially as long as possible, until penetrating keratoplasty (PKP) was absolutely mandatory. This extremely invasive procedure was considered the last resort, mainly due to the high risk of graft rejection, which, in young patients is up to 5%, but also because of the need for subsequent keratoplasties in recurrent disease states, including herpes keratitis and granular and lattice dystrophies. The threat of surgically induced astigmatism can also be a consideration in PKP procedures.

Lucikly for us, the standard of care in keratoplasty has totally changed in the past 10 years. Not only has PKP become safer and easier to perform, but new techniques that target replacement of only the diseased layers of the cornea have been adopted. In anterior lamellar keratoplasty, the endothelium is spared, and, in endothelial keratoplasty, it is the stroma that is spared. This article discusses deep anterior lamellar keratoplasty (DALK) and describes the benefits of using femtosecond laser technology for this purpose.

OVERCOMING THE CHALLENGES

Although the newer, novel techniques in keratoplasty are obviously better than the alternative of PKP, each comes with a unique set of challenges. In DALK, for instance, the diseased stroma must be separated from the nondiseased Descemet membrane and endothelium.

This can be accomplished using the big bubble technique, in which a channel is created as close as possible to the endothelium and air is injected into it to separate the Descemet membrane from the stroma. This is not easy to accomplish, however, and the big bubble technique comes with the risk of penetrating the Descemet membrane if the tunnel is too close or the risk of air distribution formation in the stroma, with no separation of Descemet membrane, if the tunnel is too far away. As a result, the learning curve of manual DALK is relatively flat.

When I did my first DALKs in 2004, I had a conversion rate to PKP of least 50%, where every second DALK did not work out to be a DALK. Some surgeons today continue to have such high conversion rates, depending on the technology they use for the treatment. For instance, preparation of the donor button by hand can take more than 1 hour in the best hands and even longer in less-experienced ones. It goes much quicker with newer technologies (Figure 1).

Figure 1. Preparing the donor tissue with the artificial anterior chamber.

DALK has become so much easier with the use of the femtosecond laser, and now the learning curve is much steeper. In the majority of cases, it only takes the surgeon about 10 procedures to get comfortable with the technique and perform DALK with a conversion rate to PKP of less than 5%. Additionally, performing a re-keratoplasty after DALK is extremely easy, only requiring an exchange of the donor button.

THE POWER OF OCT

DALK can be performed with any of the femtosecond laser systems for refractive surgery available on the market today. Each system aids in the creation of the trephination and of the lamellar cut. The real game-changer for me, however, is the availability of online OCT with the Ziemer FEMTO LDV Z8 (Figure 2). This function allows me to create a channel going from the outside—the optic trephination—to the thinnest or near-thinnest point of the cornea.

The availability of the online OCT allows me to select the end of the channel to be 30 µm away from the Descemet membrane, ensuring that, in nearly every case, I get a big bubble separating the Descemet membrane from the stroma. In other words, the insecurity that made DALK so difficult for surgeons is no longer

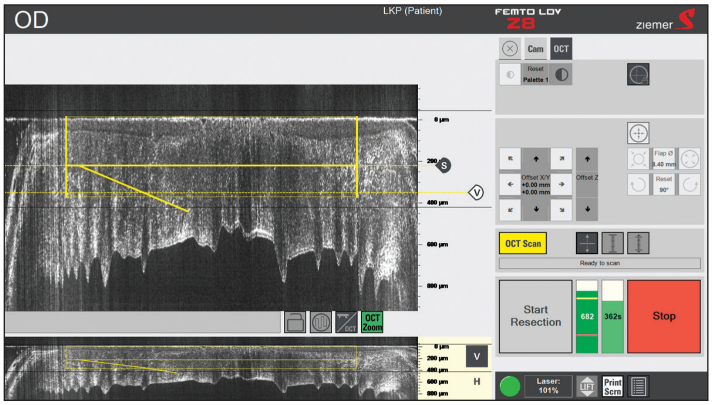

Figure 2. Intraoperative OCT of the FEMTO LDV Z8.

an issue now that we can use intraoperative OCT to visualize our progress. Not only can I cut the channel with the femtosecond laser, but I now control how close to the Descemet membrane I go with that channel. This makes life much easier for the surgeon and the procedure time much shorter. For instance, on the afternoon in which I wrote this article, I performed two DALKs and one of them took only 45 minutes.

CONCLUSION

The main advantage of the FEMTO LDV Z8 for DALK is clearly the availability of an intraoperative OCT, but a second advantage is that it cuts with a low-energy source. Therefore, the laser creates only a few cavitation bubbles inside the stroma. This is in comparison to high-energy femtosecond lasers, which create a significant amount of cavitation bubbles and shock waves within the treatment zone. When these lasers are used, it is impossible to come as close to the endothelium as I can with the Z8, which is about 20 to 30 µm away.

At the beginning, I was hesitant to use the femtosecond laser for DALK. Now, however, after improving the procedure step by step, I can create channels of varying configurations to make surgery easier for me and safer for my patients. ■

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