A Review of Excimer Lasers

Refractive surgeons anonymously discuss the pros and cons of different refractive excimer lasers.

LADARVISION 4000

I primarily use the Ladarvision 4000 excimer laser (Alcon Laboratories, Inc., Fort Worth, TX) for wavefront-guided LASIK as well as surface ablation. The algorithm also adds more pulses in the ablation to counteract spherical aberrations. For me, the Ladarvision 4000 has proven to be a terrific flower in what can be a confusing garden of technology. The smooth corneal shape achieved by ablating with the system's flying-spot laser beam is well documented in the literature.[1] Additionally, the system's wavefront-guided corneal sculpting is highly accurate. Its eye tracker, which scans the eye's position 4,000 times per second and adjusts its mirrors 100 times per second, is very robust and locks on the target with tenacity. One under-recognized benefit of the Ladarvision 4000 excimer laser is the system's registration process for aligning the wavefront map to the eye of a patient who is in the supine position. This feature compensates for cyclorotation and ensures an accurately oriented wavefront ablation.

The outcomes achieved with the system's wavefront-guided treatments are superb. The latest algorithm, called *myopic astigmatism*, is wavefront guided (by definition), but it also places additional pulses in the periphery of the cornea to compensate for UV light reflection and decreased laser efficiency. Moreover, dilation of the pupil for treatment is advantageous because it saves an extra preoperative visit (refractive surgeons now perform the dilated fundus examination on the day of the surgery).

One drawback to the Ladarvision 4000 excimer laser is that it operates at 60Hz, meaning more time is needed to complete ablations on patients with high myopia. Also, the laser needs to be calibrated frequently to maintain a proper energy level prior to ablation. Although the internal changes of the laser's components have decreased the frequency for gas-bottle exchanges, the rate could be improved. Furthermore, although I have adapted to the working space under the laser (distance from the patient's head to the bottom of the laser head above him), it could be enhanced. Currently, a floppy disk is used to transfer the wavefront maps to the laser. In my opinion, a USB drive is preferable, and wireless transmission is ideal for this function. Although registration with the Ladarvision 4000 is excellent, it is a little labor intensive. Automating the limbal registration marking process would be an improvement.

Fortunately, the new Ladar 6000 (not FDA approved; Alcon Laboratories, Inc.) addresses all of the aforementioned drawbacks. The Ladar 6000 operates at 100Hz, thus cutting ablation time in half compared with the 4000 version. It has an extremely stable Tuilaser cavity (Coherent, Inc., Santa Clara, CA) that only needs to be calibrated once per day and requires significantly fewer changes of the gas bottle. Also, this laser has more working space under its head. The new system incorporates a USB drive, which is also upgradeable to wireless, for transferring wavefront data. Last, the Ladar 6000 is equipped with an automated limbal blood vessel registration, so surgeons will not need to mark the limbus.

1. Thomas JW, Mitra S, Chuang AZ, Yee RW. Electron microscopy of surface smoothness of porcine corneas and acrylic plates with four brands of excimer laser. *J Refract Surg*. 2003;19:623-628.

MEL 80

The MEL 80 (not FDA approved; Carl Zeiss Meditec Inc., Dublin, CA) has been an outstanding tool for my colleagues and me.

The MEL 80 has three important advantages that make it extremely effective. It is extraordinarily fast at 250Hz. The eye tracker is equally quick and maintains perfect centration throughout the ablation by means of an ultrarapid iris registration camera. Also, the laser's Gaussian flying spot provides a smooth ablation with prolate optimization, which maintains the natural outer curvature of the corneal surface and thereby minimizes induced spherical aberration. My patients are extremely pleased with their results.

The most pleasant surprise with the MEL 80 is its ability to treat hyperopia. I decided that LASIK was not ideal for patients with hyperopia because of the slower healing and aggravation of dry eye. However, even higher degrees of hyperopia are amenable to correction with the MEL 80. I have treated up to 6.00D of hyperopia with astigmatism.

This therapy range for the MEL 80 changes the landscape for hyperopes by providing a viable option for patients who want excellent uncorrected distance vision but do not mind wearing reading glasses. The effectiveness of the MEL 80 makes LASIK a reasonable alternative to refractive lens exchange in the older-than-45 population.

The ergonomics of operating the MEL 80 is different from that of other lasers I have used. The patient's head is closer to the surgeon's lap. Also, the illumination needs to be a bit lower in order for the tracker to capture the pupillary image.

We have not yet had the opportunity to use the WASCA Analyzer (Carl Zeiss Meditec, Inc.) with the MEL 80, but we have had a great deal of experience with it in the context of other clinical investigations and in our practice. It is a reliable Hartmann-Shack sensor with great sensitivity.

If I were in the market for an excimer laser today, I would give very strong consideration to the MEL 80. It represents the latest generation of excimer lasers and reproducibly delivers optimal results, even in the higher ranges of hyperopia.

NIDEK EC-5000

The EC-5000 laser (Nidek, Inc., Fremont, CA) is a reliable and robust excimer laser that produces excellent postoperative results. The biggest problem with this technology is its current lack of FDA approval. That said, treating myopia and myopic astigmatism is easy with this user-friendly device. The opportunity for the surgeon to select whatever optical and transitional zone desired is a big advantage and allows him to tailor the procedure to a variety of patient parameters. Currently, the optical zone can be set as wide as 6.5mm, and the transition zone can be set at up to 10mm if desired. However, a transition zone greater than 8mm is excessive in my opinion. Wide transition zones on the Nidek laser seem to mitigate nighttime visual symptoms for all but the highest myopic treatments.[1] Nidek engineers understood this concept early and did not try to unnecessarily create ultrawide optical zones for patients with large pupils that would waste precious corneal tissue. The utilization of optical and transitional zone adjustments allows the delivery of treatments that optimize the postoperative wavefront characteristics by reducing the induction of spherical aberration. For astigmatic treatments, the optical zone is not truncated, which produces great visual results with a full optical zone diameter.

The 200-Hz eye tracker centers easily and follows patients' eye movements well. The EC-5000 is equipped with a combination of active and passive tracking. The laser will shut down if there is eye movement of more than 0.50mm during the procedure to allow for realignment, thus avoiding a cosine effect secondary to nonaxial treatment. Furthermore, the laser's cross-hair aiming system demonstrably indicates the proper alignment of the eye with the laser for the surgeon. In my experience, when the laser is placed in a room with efficient air filtration and humidity control, the optical lenses and mirrors are long lasting, and the laser needs very little maintenance.

Hyperopia and hyperopic astigmatism should be FDA approved soon, with excellent results from the clinical trials. The hyperopic treatments will have an optical zone of 7mm and a transition zone of 9mm. Nidek leads in corrections of mixed astigmatism outside the US, thanks to the excellent work by Arturo Chayet, MD, of Tijuana, Mexico, and Paulo Vinciguerra, MD, of Milan, Italy. Once the laser is approved in the US to treat hyperopia, surgeons may take advantage of this modality. Nidek OATz (optimized aspheric treament zones) and Nidek CATz (customized aspheric treatment zones) are available outside the US by utilizing the data from the OPD Scan (Nidek, Inc.)—the system's combined wavefront analyzer/topographer/autorefractor. This instrument is a wonderful device for diagnostic applications and will allow integration for optimized aspheric treament zones and customized aspheric treatment zones. FDA trials for the customized treatments should begin very soon, although far too late for many users.

The economic advantages of the Nidek laser are obvious; there are no click fees, and that is a great benefit for any surgeon, particularly those with smaller surgical volumes who cannot negotiate volume-based lower rates with the other excimer laser manufacturers. Enhancements without fees are another plus.

In my experience, the Nidek EC-5000 is a reliable instrument that delivers unsurpassed results, especially for a surgeon willing to develop his own nomograms. This laser does not currently offer enough FDA-approved treatments in the US, however.

1. Pop M. Variables affecting the incidence of glare symptoms. Paper presented at: The Fall ISRS Symposium; November 2000; Dallas, TX.

TECHNOLAS

I have performed refractive surgery with the Technolas laser (Bausch & Lomb, Rochester, NY) for more than 4 years. The platform is an absolute workhorse and is highly reliable. Its broad range of features offers ease of use as well as excellent results. After using other platforms, I particularly like the fact that the Technolas does not require a complicated nomogram for conventional Planoscan (Bausch & Lomb); surgeons just program the desired correction with little or no adjustment. An additional advantage of the Planoscan

software is that, for astigmatic treatments, the specified treatment zone defines the short, rather than long, axis of treatment. This specification provides for a larger effective optical zone and better results when coupled with the laser's generous blend zones. Unfortunately, this benefit has been misunderstood and the laser misrepresented as a tissue-hungry device. In fact, other systems have now adopted this same strategy in their customized treatment algorithms.

The Zyoptix's wavefront (Bausch & Lomb) integration is efficient and relatively easy. It incorporates the Orbscan (Bausch & Lomb) and Zywave (Bausch & Lomb) at one workstation, with information from both blended into the treatment file calculation. This integration means that at least 50% of my patients no longer need to be dilated to receive customized ablations. The potential for topography-linked as well as wavefront treatments is obvious.

In addition, the Bausch & Lomb tracker is dependable and reliable. I have neither experienced any difficulty tracking pseudophakic patients, nor have I heard of tracking problems with the Intralase (Intralase Corp., Irvine, CA) bubbles.

Perhaps the most significant criticism I have about this laser is its inability to treat mixed astigmatism without a multicard solution. I wish that the platform had a phototherapeutic keratectomy modality and laser-scrape option to facilitate surface ablations. Other shortcomings such as iris registration and customized hyperopic treatments are already being addressed.

The ultrafast 100-Hz head has received FDA approval. Further refinements to the Technolas, such as customized hyperopic ablations and aspheric treatments, are anticipated for the end of this year. In addition, Bausch & Lomb's European platform includes not only iris recognition with tracking but also active cyclotorsional tracking and pupil-center–shift compensation during the surgical process. Both of these technological improvements are needed. Because not everyone is a candidate for customized treatments, aspheric ablation is another part of a series of advances launching later this year. The package will replace Planoscan and integrate aspheric ablation into customized and standard treatment algorithms. Results with aspheric ablation in other countres outside of the US suggest that this procedure is ideal for patients who are not candidates for existing customized treatments. Although perhaps not as good as truly customized treatments, these aspheric, wavefront-enhanced ablations will be superior to current conventional laser treatments, in my opinion.

A remote diagnostics package will also be offered soon in the US for the maintenance of the Zywave and Technolas systems. Using an Internet-based diagnostic tool, which constantly collects data on the system, Bausch & Lomb can foresee potential laser variations and pre-empt service calls to keep the system running smoothly and precisely.

Overall, Technolas is a solid performer, and I am very satisfied with the tool, its capabilities and features, and, most importantly, its results.

VISX S4

The Visx S4 excimer laser with Customvue (Advanced Medical Optics, Inc., Santa Ana, CA) has become my preferred laser system. It is reliable. When a rare systems problem occurs, such as an internal motor failure, the Visx customer service has always been outstanding, which is somewhat out of the ordinary in the laser business in my opinion. Most importantly, the Visx S4 produces consistently good results without the refractive surprises that can cause many problems for a refractive practice, such as the unexplained overcorrection. The ease of use of the Customvue system has made this the leading customized laser system in North America.

Nevertheless, in refractive surgery, we surgeons have been spoiled by the constant improvements and upgrades made to our laser systems. It seems like there is a new piece of software or hardware added every 3 months, and I am always hearing about future upgrades. I dream of faster systems, better results, and fewer complications. Amazingly, we are getting all this.

My review includes many improvements for LASIK in general and the Visx system specifically in some cases. Some of these improvements are already in the design process and should be implemented within the year, but others may be years off.

Clinical Improvements to the Visx S4

Brighter fixation light: some patients have difficulty with fixation because they cannot see the light clearly.

Auto-calibration: the calibration system for the Visx is cumbersome. Auto-calibration should save time and improve results.

Sterile controls: although LASIK may not need to be a completely clean procedure, it would not be difficult to have emaculate drapes over the microscope's controls so that sterility is not compromised as soon as the controls are touched.

Automatic mirror splash protection: drops of fluid can splash up onto the mirrors of the laser and can eventually degrade the quality of the beam. Although these splashes are detected by the laser's testing procedures and rarely result in any clinical issues, an automated method of splash protection would potentially eliminate this problem.

Suggested Technological Improvements

Visibility and lighting: the visibility and the lighting of the Visx laser are the best of the three main US systems, but, they could be more adjustable as there are few dim options.

Increased working distance: although not a huge issue, a greater distance between the laser output and the eye would allow easier manipulation of the instruments and the exhaust tube.

Increased resolution/dynamic range of the Wavescan: the wavefront data are currently derived from a relatively small number of points. Added data points should further increase accuracy and improve results.

New vacuum nozzle: the vacuum's nozzle is cumbersome and should be eliminated or improved. The nozzle could be automated so no movement of it is required and it is less intrusive.

Smaller spot scanning: the maximum size of the variable spot scanning should be reduced to 4mm. My colleagues and I know that the imperfections of the broad beam are more evident.

Faster repetition: the variable repetition rate should be increased to reduce all treatment times to less than 30 seconds. Although most treatments with the Visx are fast, if all could be decreased to less than 30 seconds, it would improve clinical results by reducing the variables of hydration/dehydration of the bed and thus enhance the patient's experience.

Faster tracker: although my colleagues and I have been assured that a 120-Hz tracker is sufficient, a 250-Hz tracker would be better, because we use smaller spots and faster scanning.

Real-time iris tracking: iris registration has been a great addition to the laser, but real-time iris registration that automatically captures eye movement and adjusts throughout the procedure would be ideal.

Real-time wavefront analysis: intraoperative wavefront analysis and adjustments could allow the ultimate in wavefront accuracy.

Combined femtosecond technology: this capability inside the excimer laser would allow the complete procedure to be performed without moving the patient.

Suggested Software Improvements

Topographic data should be added to the wavefront data to produce the ideal postoperative corneal shape and result.

Presbyopic ablations would offer an exciting alternative to presbyopic implants.

Lifestyle algorithms would allow the wavefront correction to be adjusted for each patient's specific needs/requests.

Suggested Practical Improvements

Online card purchasing

Remote/online diagnostics and service

Better looking laser box (the current Visx box has not changed in 10 years)

Recorded video output of the tracker, customized data, and the iris registration so these can be shown to those family members or friends viewing the procedure.

ALLEGRETTO WAVE

I have used the Allegretto Wave laser (Wavelight AG, Erlangen, Germany) almost exclusively for 25 months and for approximately 3,000 eyes. I also have a Visx Star S4 laser, and I have performed Customvue treatments on approximately 800 eyes. With Customvue, I have been very pleased with the results for myopia, but such positive outcomes are not often rendered in hyperopic treatments. In addition, my enhancement rate was not what I expected it to be with the Customvue upgrade.

The immediate benefits of the Allegretto Wave were demonstrated in cases of high hyperopia where I comfortably treated patients for up to +5.00D and they achieved excellent UCVA. In addition, my enhancement rate diminished to less than 2% versus 4% for my Customvue system. I have experienced no downtime with the Allegretto Wave during the 25 months I have been using it, except for routine maintenance such as changing of the gas, which occurs approximately every 8 months in my practice.

The biggest negative I associate with the laser is the fact that it does not identify the eye at the time of treatment. For instance, if I am about to treat the right eye of a patient who is positioned under the laser, I can also see his left eye, so there is the potential to treat the left eye with the right eye's data. It is my understanding that an upgrade is coming to address this possible problem.

An additional downside to the Allegretto in my opinion is its software interface for data entry. It is more time consuming to enter data compared with the Visx laser (eg, instead of typing in the number, surgeons must use the up and down keys on the keyboard). An upgrade is expected this summer to rectify this problem. Also, the Allegretto takes my technicians longer to calibrate.

Nevertheless, I gladly accept the downsides of the Allegretto for the results I achieve and the low enhancement rate in my practice. Because the Allegretto utilizes wavefront-optimized ablation profiles, surgeons do not have to spend a lot of time on diagnostics and aberrometry readings. My patients have virtually no complaints about night vision, halos, or glare with the Allegretto. Also, its speed of ablation, especially in hyperopes, is four times faster than the Visx system for the same condition. ■