Solid-State Laser Platforms: Two Reviews

The benefits of using the Pulzar Z1 and LaserSoft technologies.

BY SUNIL SHAH, MBBS, FRCOPHTH, FRCS(ED), FBCLA; AND MATTEO PIOVELLA, MD

An Attractive Proposition for Refractive Surgery

The ablation profiles of the Pulzar Z1 laser ensure low levels of tissue removal.

By Sunil Shah, MBBS, FRCOphth, FRCS(Ed), FBCLA

Solid-state lasers for refractive surgery have been an attractive proposition for many years. Early in their development, crystal temperature stability was an issue; however, since this has been overcome, the benefits of newer solid-state laser platforms, compared with excimer lasers for refractive surgery, are well established.[1-4] Solid-state lasers allow high pulse-to-pulse energy stability, small spot size, and a high repetition rate. The surgeon user, however, is more interested in how good the results are, the advantages of needing no dangerous gases for the laser, and the low maintenance costs and noise levels during operation.

Figure 1. The Pulzar Z1 solid-state laser.

ATTRIBUTES

I became aware of solid-state technologies for refractive surgery about 15 years ago.[1] I also kept a watch on the development of the Pulzar Z1 (CustomVis; Figure 1) and its results. Two specific attributes of the solid-state laser that caught my attention: wavelength and usability and results.

Wavelength. What originally attracted me to solid-state laser application in refractive surgery is the use of the 213-nm wavelength, as opposed to the 193-nm wavelength of ophthalmic excimer lasers. At this longer wavelength, the ablation rate is not significantly affected by the hydration of the cornea, unlike at the excimer wavelength. The importance of this is obvious: Tissue hydration becomes less of an issue to maintain consistency of results. With an excimer laser, the surgeon has to maintain exactly the same amount of fluid on the corneal surface and degree of corneal hydration to achieve the same results. With a 213-nm solid-state laser, however, the temperature and humidity in the laser room become less important; the surgeon can even flood the cornea with water and then use the laser, as some surgeons prefer to do.

Usability and results. As a physician, I am interested primarily in the ease of use and the results achieved with a given surgical device. Although several studies have demonstrated that PRK and LASIK procedures performed with the Pulzar Z1 are predictable, effective, and safe for a range of refractive errors,[2-7] the number of publications to date is limited. For this reason, I talked to several active and loyal CustomVis users before deciding to purchase my own system. Their responses were unanimous: They achieved excellent clinical results, and all were reluctant to look at other systems. Some of these surgeons reported using the Pulzar Z1 for very high volumes of treatments without any issues.

TAKING THE PLUNGE

I have experience with many laser platforms, and based on my research I decided to take the plunge into solid-state laser technology for refractive surgery. After acquiring and gaining experience with the Pulzar Z1, I had an opportunity to invest in the company and become its medical director, which I undertook wholeheartedly.

Why was I so keen on this laser compared with other platforms? Primarily, it was the results, and I have already published initial results of a case series using LASEK[2] for a wide range of preoperative spherical equivalent (SE) refractive errors (-9.50 to 6.50 D). In 245 eyes, 10% had more than 2.50 D of astigmatism preoperatively. After LASEK performed with the Pulzar Z1, 89.4% were within ±0.50 D of intended correction, and 97.9% were within ±1.00 D.

Comparing these raw results to those with any excimer laser is impressive, but when one considers the range of SE treated and the large percentage of highly astigmatic eyes, these results look even better.

In eyes with at least 1.50 D of preoperative astigmatism (mean, 2.49 ±0.94 D; range, 1.50–5.50 D), the mean residual astigmatism was 0.34 ±0.46 D (range, 0.00–2.00 D) postoperatively. These results are, once again, comparable with the best of any excimer laser treatments and better than most.

I believe that my results using this solid-state laser for LASEK are due to a combination of its ablation profile and the accuracy of torsion control. The Pulzar Z1, used in conjunction with the iTrace (Tracey Technologies, Corp.), can identify up to 0.01° of torsion. This combination is also good for treating irregular astigmatism.[4]

For the surgeon, the user interface of the Pulzar Z1 is no different from an excimer laser. The treatments possible are also the same, and the laser's ablation profiles ensure low levels of tissue ablation and maintain good optical and transition zones. Topography- and wavefront-guided treatments are designed through proprietary software and, because of the precise torsion control, are accurate when applied. For a video demonstration of treatments with the Pulzar Z1, visit eyetube.net?v=leron and eyetube.net?v=gukad.

eyetube.net
eyetube.net/?v=leron

eyetube.net
eyetube.net/?v=gukad

CONCLUSION

Using solid-state laser technology, I can treat a large range of refractive errors with confidence, including cross-cylinder and pure astigmatic corrections. I recently treated a group of patients with high visual requirements for their work, some of whom had preoperative prescriptions such as 0.00 -1.25 X 155° with a UCVA of 6/7.5 (20/25). In this population, UCVA results varied from 6/4 (20/12) to 6/5 (20/16). With many systems that I have previously used, I would not have considered undertaking this sort of treatment because of the risk of making them worse. With the CustomVis, however, I was happy to treat them.

I am pleased with my choice of laser platform. When medical colleagues now ask to undergo treatment, I am more amenable to the thought. None so far have regretted their decision, nor have I.

Sunil Shah, MBBS, FRCOphth, FRCS(Ed), FBCLA, practices at the Midland Eye, West Midlands, United Kingdom; and Birmingham Midland Eye Centre, Birmingham, United Kingdom. Professor Shah states that he is a director and stockholder of CustomVis. He may be reached at tel: +44 121 711 2020; e-mail: sunilshah@doctors.net.uk.

1. Roszkowska AM, Korn G, Lenzer M, et al. Experimental and clinical investigation of efficiency and ablation profiles of new solid-state deep-ultraviolet laser for vision correction. *J Cataract Refract Surg*. 2004;30:2536-2542.
2. Shah S, Sheppard AL, Castle J, et al. Refractive outcomes of laser-assisted subepithelial keratectomy for myopia, hyperopia, and astigmatism using a 213 nm wavelength solid-state laser. *J Cataract Refract Surg*. 2012;38:746-751.
3. Tsiklis NS, Kymionis GD, Kounis GA, et al. One-year results of photorefractive keratectomy and laser in situ keratomileusis for myopia using a 213 nm wavelength solid state laser. *J Cataract Refract Surgery*. 2007;33:971-977.
4. Anderson I, Sanders DR, van Saarloos P, Ardrey WJ 4th. Treatment of irregular astigmatism with a 213 nm solid-state, diode-pumped neodymium:YAG ablative laser. *J Cataract Refract Surg*. 2004;30:2145-2151.
5. Tsiklis NS, Kymionis GD, Pallikaris AI, et al. Endothelial cell density after photorefractive keratectomy for moderate myopia using a 213 nm solid-state laser system. *J Cataract Refract Surg*. 2007;33:1866-1870.
6. Piñero DP, Pérez-Cambrodí RJ, Gómez-Hurtado A, Blanes-Mompó FJ, Alzamora-Rodríguez A. Results of laser in situ keratomileusis performed using solid-state laser technology. *J Cataract Refract Surg*. 2012;38(3):437-444.
7. Piñero DP, Blanes-Mompó FJ, Ruiz-Fortes P, Pérez-Cambrodí RJ, Alzamora-Rodríguez A. Pilot study of hyperopic LASIK using the solid-state laser technology. *Graefes Arch Clin Exp Ophthalmol*. 2013;251(3):977-984.

Improving Refractive Surgery With a Solid-State Laser Platform

The LaserSoft offers advanced ablation profiles.

By Matteo Piovella, MD

Excimer lasers have dominated corneal refractive surgery for many years. The advances in refractive surgery in the past few years can be compared with those in cataract surgery between 1975 and 2013. In this sense, the solid-state laser can help refractive surgeons take a step forward much like femtosecond laser technologies for cataract surgery are doing for cataract surgeons today. Solid-state lasers provide all the principal benefits of excimer laser technologies with several additional advantages.

The LaserSoft (Katana Technologies; Figure 2) is a tunable, short-pulse, 210-nm wavelength, Q-switched, diode-pumped, solid-state laser with a 0.20-mm flying spot size, a repetition rate of up to 4 kHz, and an ablation zone variable from 1.00 to 10.00 mm. The laser is

Figure 2. The LaserSoft system.

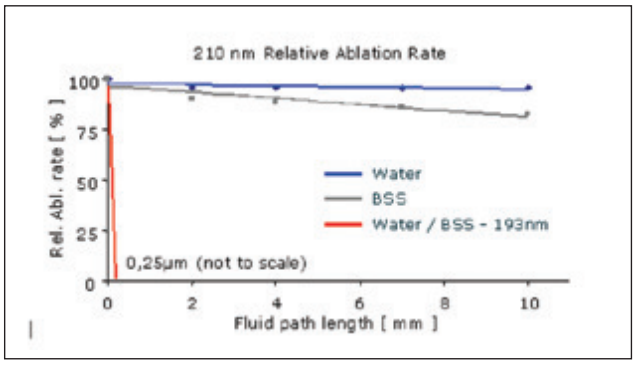

Figure 3. Ablation rate of solid-state lasers.

fitted with an eye tracker, working at a speed of more than 1 kHz, that maintains fixation with a reaction time of less than 1.0 ms. The eye tracker provides automatic centration of ablation, compensates for pupil centroid shift, and accurately determines cyclorotation and tilt on the horizontal and vertical axes. It does not require pupil dilation.

DIFFERENCES BETWEEN PLATFORMS

According to the literature, corneal ablation rates with 213-nm wavelength solid-state lasers are comparable with those of excimer lasers that operate at a 193-nm wavelength for similar repetition rates and pulse duration.[1-4] However, as excimer lasers operate at a wavelength of 193 nm and water absorbs a significant amount of the ablation at this wavelength, there is a level of unpredictability in clinical results, and complex nomograms are therefore required to achieve the desired refractive correction. Additionally, due to the aggressive action of the 193-nm radiation onto optical surfaces, service and operation costs are high with excimer laser technology.

Unlike ophthalmic excimer lasers, the LaserSoft solid-state laser operates at a wavelength of 210 nm. This wavelength is not only less aggressive on the optical surface, but it also passes through water without absorption, allowing more laser energy to pass through any aqueous fluid, tear fluid, or balanced saline solution on the eye. Thus, as fluid on the corneal surface or stroma has little or no effect on the refractive outcome, the complex nomograms required to achieve the desired refractive correction with excimer lasers are not required with the LaserSoft (Figure 3).[5]

Solid-state lasers have other advantages. First, because corneal drying is not required during transepithelial treatments with solid-state lasers, there is no risk of producing an irregular ablated surface.[6] Second, maintenance costs are lower because no toxic gas or gas storage is required to operate the system. Third, due to the absence of gas discharge, the noise level during the laser's operation is significantly lower. Fourth, the LaserSoft is a mobile unit with a small footprint.

IMPROVING REFRACTIVE SURGERY

Rapid development of laser diodes as pump sources over the past several years has given surgeons an improved option for refractive surgery. Using a solid-state source for laser ablation provides excellent shot-to-shot stability and reproducibility.

Other operating advantages are related to the spot size characteristics, repetition rate, and thermal effect of the LaserSoft. Its spot size (0.2 mm) is approximately one-fourth the size of excimer laser spots (0.80 to 1.00 mm), affording the surgeon accurate and precise ablations. The effect of a smaller spot size is akin to that of an artisan forging pewter using a fine hammer rather than a large one. The precise structuring capability of the LaserSoft system allows correction of corneal microirregularities, thereby reducing higher-order aberrations (HOAs). The result is a smooth, homogeneous corneal surface.

A further benefit of the small spot diameter is a reduction of the mechanical stress caused by the acoustic shock waves generated during ablation. Larger spot sizes produce larger acoustic shock waves and, therefore, more mechanical stress; this mechanical stress can produce cellular alterations and damage the collagen structure.[4,7] Likewise, due to the high repetition rate (up to 4 kHz) of the LaserSoft, the energy per pulse is lower than with excimer laser treatments, generating greatly reduced shock waves and less collateral damage.

Clinical results show that the temperature rise in the corneal stroma is 0.8° C during treatment with the

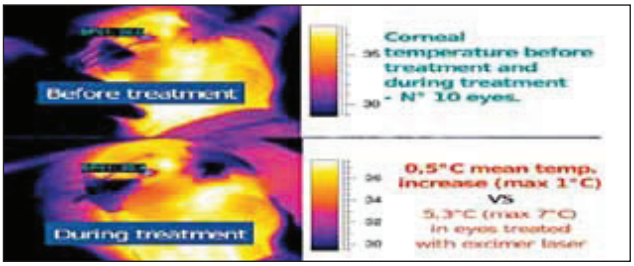

Figure 4. Corneal temperature rise before and during treatment with the LaserSoft.

LaserSoft, compared with 7° C during treatment with an excimer laser (Figure 4). This reduction in thermal effect can decrease postoperative pain and inflammation, especially after PRK, as evidenced by less stromal damage on confocal microscopy.[8] A reduced thermal effect is also associated with better and faster visual recovery and less postoperative corneal haze.[9] Additionally, reepithelization is faster after ablation with the LaserSoft.

ABLATION PROFILES

LaserSoft software offers advanced ablation profiles, including aspheric ablation and Q-value–adjusted treatments. Topography data collected with a Placido-disc topographer or Scheimpflug imaging device can be imported into the LaserSoft planning software to calculate the ablation profile, eliminating even small corneal irregularities and creating a smooth and regular corneal anterior surface.

Total ocular aberrations measured by wavefront aberrometry can also be imported into the LaserSoft, creating a customized ablation profile for correction of spherical and cylindrical refractive errors and HOAs. Software for central and peripheral presbyopic LASIK (presby-LASIK) treatments is also available. The laser's small spot size allows adequate treatment of the fine structures described by higher-order Zernike polynomials and of a small central optical zone to produce accurate multifocal patterns and smooth transition zones for intermediate vision.

CLINICAL RESULTS

PRK. In an analysis of long-term results in 680 eyes that underwent PRK in one of two centers, solid-state laser ablations achieved good efficacy, safety, and predictability. In particular, UCVA was 1.0 or better in 77.8% to 86.0% of eyes, 0.8 or better in 88.9%, and 0.5 or better in 97.0% to 100.0%. Additionally, 89.0% to 93.0% of eyes were within ±0.50 D of intended correction, and 100.0% were within ±1.00 D. No eye lost 2 or more lines of BCVA.[9,10] Corneal maps showed regular patterns with wide ablation zones (Figure 5), all treatments were well centered, and complete epithelial resurfacing was achieved between the third and

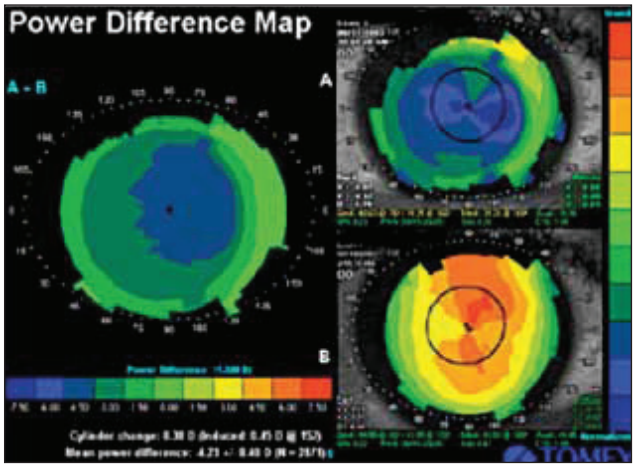

Figure 5. Power difference map showing the corneal profile modifications after PRK for myopic compound astigmatism utilizing the LaserSoft.

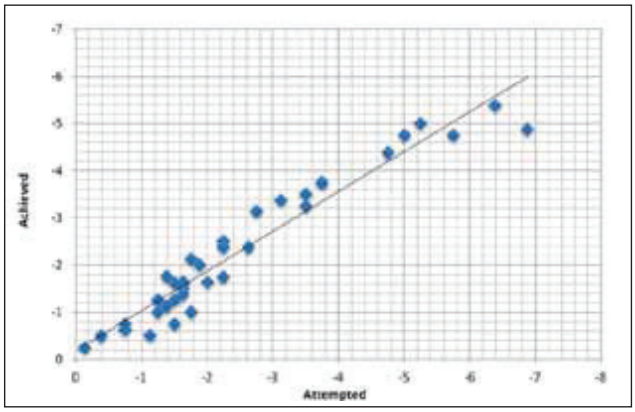

Figure 6. Three-month results: Attempted versus achieved correction in 37 patients treated with the LaserSoft at the Memira Centre in Malmö, Sweden.

fifth postoperative day. No corneal opacity was observed during follow-up.

LASIK. Good efficacy was demonstrated in clinical results obtained in 37 eyes treated for myopia and myopic compound astigmatism (average preoperative SE, -2.49 ±1.68 D; range, -6.88 to -0.13 D) at the Memira Centre in Malmö, Sweden (personal communication). In this population, UCVA was 1.0 or better in 83.8% of eyes, 0.8 or better in 89.2%, and 0.65 or better in 100.0% of eyes 3 months after treatment. Additionally, 81.1% of eyes were within ±0.50 D and 94.6% were within ±1.00 D of intended correction (Figure 6). In this study, 2.7% of eyes gained 2 lines of BCVA, 18.9% gained 1 line, BCVA was unchanged in 67.6% of eyes, 2.7% of eyes lost 2 lines, and 8.1% lost 1 line.

I presented 12-month refractive outcomes of LASIK treatments administered with the LaserSoft.[11,12] In 30 eyes with a preoperative mean SE of -1.71 ±3.71 D (range,

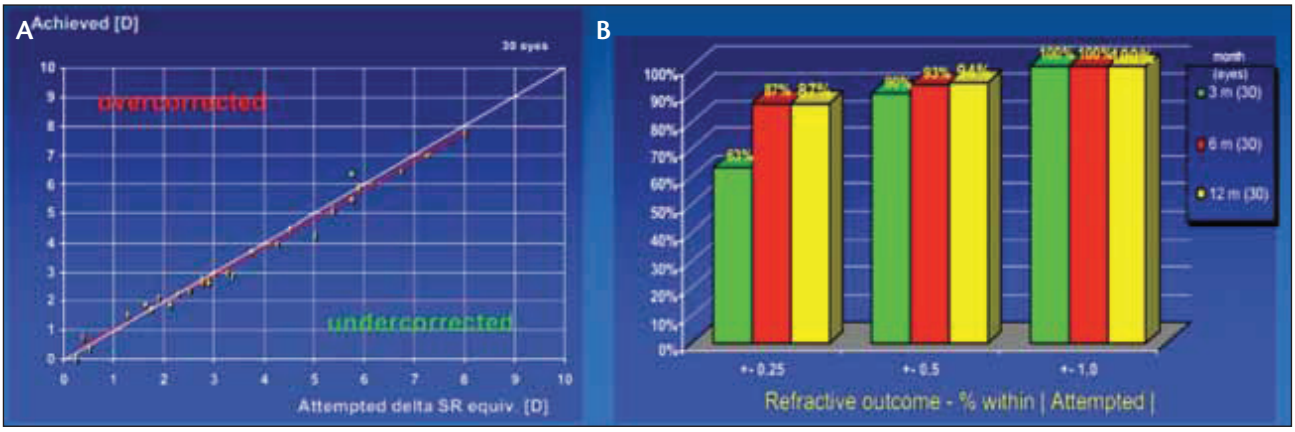

Figure 7. Attempted versus achieved correction in 30 eyes treated with the LaserSoft (A and B).

-8.00 to 6.75; Figure 7), 94% were within ±0.50 D of intended correction. All eyes were within ±1.00 D.

MERGING REFRACTIVE AND CATARACT SURGERIES

The LaserSoft Dual laser platform (available soon), which combines UV-ablation laser with a femtosecond laser, is capable of the following surgical procedures: corneal ablation, laser microkeratome flap creation, corneal pocket creation, lamellar and penetrating keratoplasty, and cataract surgery.

CONCLUSION

The LaserSoft system presents an alternative to excimer-based surgery and, in my experience and the experiences of others, has shown excellent results in term of efficacy, safety, stability, and predictability. LaserSoft solid-state laser technology for corneal refractive surgery has several potential advantages over currently available excimer laser systems, including its small spot size (0.2 mm), high repetition rate, silent operation, and no use of toxic gases. The Gaussian beam profile of the LaserSoft induces a smooth corneal surface after treatment, with well-defined transition zones. With less energy applied to the cornea compared with excimer laser treatments, there is reduced scarring and faster postoperative visual recovery.

Because the 210-nm wavelength is closer to the absorption peak of corneal collagen, thermal effects from the ablation and the amount of collateral damage are reduced. Unlike the excimer laser's 193-nm wavelength, the wavelength of this solid-state laser is not absorbed by air, water, or tear fluid. Thus, even if the stromal bed is wet, the ablation rate remains stable. ■

TAKE-HOME MESSAGE

- Because the Pulzar Z1 laser operates at a wavelength of 213 nm, it is not significantly affected by hydration of the cornea.
- The user interface of the Pulzar is no different from that of an excimer laser, and possible treatment types are also the same, including treatments for cross-cylinder and pure astigmatism.
- The 210-nm wavelength of the LaserSoft is less aggressive on the optical surface than the 193-nm wavelenth of ophthalmic excimer lasers and is not absorbed by water.
- With less energy applied to the cornea compared with excimer laser treatments, there is reduced scarring and faster postoperative visual recovery with the LaserSoft.

Matteo Piovella, MD, is President of the Italian Ophthalmological Society and Medical Director of the Centro di Microchirurgia Ambulatoriale, Monza, Italy. Dr. Piovella is a member of the CRST Europe *Editorial Board and states that he is a consultant to Abbott Medical Optics Inc. and Beaver Visitec International. He may be reached at tel: +39 039 389 498; e-mail: piovella@piovella.com.*

1. Ren Q, Simon G, Parel JM. Ultraviolet solid-state laser (213-nm) photorefractive keratectomy; in vitro study. *Ophthalmology*. 1993;100:1828-1834.
2. Ren Q, Simon G, Legeais JM, et al. Ultraviolet solidstate laser (213-nm) photorefractive keratectomy; in vivo study. *Ophthalmology*. 1994;101:883-889.
3. MacRae SM, Krueger RR, Applegate RA, eds. Customized Corneal Ablation: The Quest for SuperVision. Thorofare, New Jersey: Slack, Inc.; 2001.
4. Krueger RR, Seiler T, Gruchman T, et al. Stress wave amplitudes during laser surgery of the cornea. *Ophthalmology*. 2001;108:1070-1074.
5. Dair GT, Ashman RA, Eikelboom RH, Reinholz F, van Saarloos PP. Absorption of 193- and 213-nm laser wavelengths in sodium chloride solution and balanced salt solution. *Arch Ophthalmol*. 2001;119:533-537.
6. Allan BD, Hassan H. Topography-guided transepithelial photorefractive keratectomy for irregular astigmatism using a 213 nm solid-state laser. *J Cataract Refract Surg*. 2013;39:97-104.
7. Kermani O, Lubatschowski H. Struktur und dynamik photoakustischer shockwellen bei der 193 nm excimer laser photoablation der hornhaut. *Fortschr Ophthalmol*. 1991;88:748-753. [In German.]
8. Rossi M, Garimoldi P, Schmidt M. Clinical investigation of laser vision correction using an all-solid state deep-UV laser: Two years experience. Paper presented at: the ESCRS annual meeting; Lisbon; September 10-14, 2005.
9. Roszkowska A, De Grazia L, Ferreri P, Ferreri G. One-year clinical results of photorefractive keratectomy with a solid-state laser for refractive surgery. *J Refract Surg*. 2006;22:611-613.
10. Rossi M, Schmidt M, Garimoldi P, et al. PRK with a solid-state laser: 2-year experience. Paper presented at: the 85th Congresso Nazionale SOI; Milan; November 23-26, 2005.
11. Piovella M, Camesasca F, Kusa B, Laurelli MF, Roszkowska AM, Ferreri G. Laser vision correction with the all-solid-state deep UV LaserSoft: clinical results. Paper presented at: the ESCRS Annual Meeting; 2004; Paris.