

# Cataract & Refractive Surgery TODAY

**EUROPE**

## Refractive Surgery at the Cutting Edge

Maximizing outcomes with the latest-generation excimer laser systems.



### Featured Authors:

Ioannis M. Aslanides, MD, PhD, MBA, FRCOphth; and Sara Padroni, MD, MRCOphth, MSc

Diego de Ortueta, MD, FEBO

Jerry Tan, FRCS(Ed), FRCOphth

Minoru Tomita, MD, PhD

Detlef Uthoff, MD

# Wavefront Customization Strategies

There is no one-size-fits all solution.

BY JERRY TAN, FRCS(ED), FRCOPHTH



Aberrations are alterations of the optical surface that lead to deviations in the way light enters the eye. Such changes can trigger a decline in visual quality and a loss of contrast sensitivity. The root cause of aberrations is mainly due to abnormalities in two structures, the cornea and the lens, but changes in other optical structures such as vitreous condensation or uneven tear film can also contribute to the development of aberrations.

There are several points that must be considered when discussing aberrations. First, aberrations can either be of the lower order, which include spherical (myopia and hyperopia) and astigmatic defects, or of the higher order, which include spherical aberration, trefoil, and coma aberrations. Higher-order aberrations (HOAs) have the greatest impact on surgical results. Second, aberrations change with age. It is natural for spherical aberration to remain positive on the cornea, but spherical aberration on the crystalline lens is negative. As the crystalline lens ages, spherical aberration will change, thereby resulting in positive spherical aberration. In essence, a young eye is able to compensate for spherical aberration so that total spherical aberration (on the cornea and on the crystalline lens) is approximately zero; however, the total spherical aberration will increase with age due to the changes in spherical aberration on the crystalline lens. The third point is that conventional excimer laser treatments for the correction of ametropia induce corneal aberrations and therefore may cause poor visual quality and loss of contrast sensitivity.

## PRESERVING PREOPERATIVE HOAs

Refractive surgery has evolved from simple myopic ablations to the most sophisticated topography- and wavefront-guided ablations. Such custom ablations are created with wavefront measurements of the whole eye (Hartmann-Shack) or corneal topography-derived wavefront analysis. In order to avoid the induction of aberrations during corneal ablation, special patterns have been designed to preserve the preoperative level of HOAs (Figure 1). This and other recent advances in excimer laser technology, such as the use of aspheric ablation profiles, incorporation of HOA treatments, compensation for induced HOAs, and the use of high-speed eye trackers, have presumably led to better refractive outcomes and

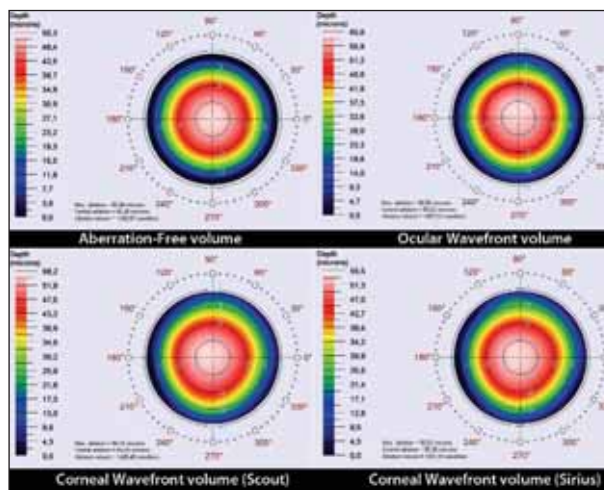


Figure 1. Comparison of ablation volumes of aberration-free, ocular wavefront (irx3), corneal wavefront (Scout), and corneal wavefront (Sirius) profiles in the same patient (-2.50 D with 7-mm optical zone).

reduced HOAs postoperatively.

However, ocular wavefront-guided and conventional LASIK treatments can still increase HOAs by 100% after surgery. A significant number of refractive surgery patients may not even benefit from ocular wavefront-guided treatment, as the induction of HOAs relates to baseline levels. Surgically induced HOAs tend to occur in patients with less than 0.30  $\mu\text{m}$  of existing HOAs but are reduced in patients with greater than 0.30  $\mu\text{m}$  of existing HOAs. In the future with improving technology, I believe that this (arbitrary) 0.30  $\mu\text{m}$  level of existing HOAs will not be the guiding factor to treat patients with HOAs. Even today, it is safe to say that no one-size-fits-all concept can be applied to every refractive surgery patient.

## CORRECTING HOAs

There are three approaches to correct HOAs: (1) objectively eliminate or reduce the eye's total aberrations, (2) correct the corneal aberrations, and (3) avoid inducing aberrations during ablation. We know that the corneal aberrations do not change with age; however we also know that corneal and internal aberrations interact to produce an aberration pattern of the total eye that is different from the aberration

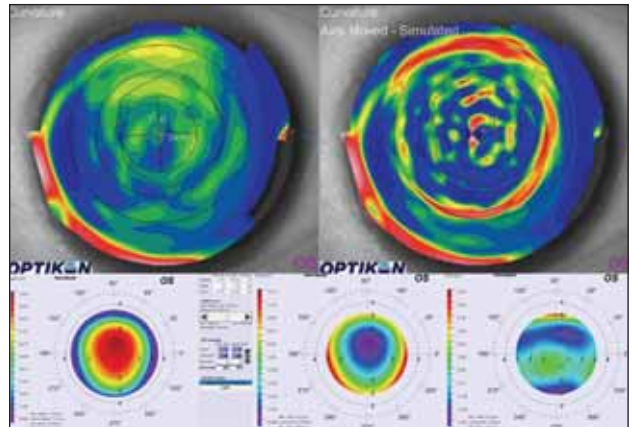
pattern of the cornea alone. For this reason, the first and second approaches to HOA correction should not be applied indiscriminately to everyone. Both can be useful approaches, but they require prior screening of corneal and internal aberrations (in a nonaccommodative state) to know identify which aberrations are balanced and which ones are not. Before either of these treatments is applied, it is also mandatory to signify if the particular type of aberration should be removed or left as is. A point to note if there is significant internal/lenticular HOAs: Consider lens surgery or else avoid laser refractive surgery until the lens needs to be removed. Applying the compensation for lenticular aberrations on the cornea can lead to a poorer resultant vision.

The third approach, which is the aberration-free ablation profile of the SCHWIND AMARIS laser systems (SCHWIND eye-tech-solutions, Kleinostheim, Germany), aims to avoid the induction of aberrations during the excimer laser treatment. The intended result is to keep the eye's HOAs as they were before the treatment while improving visual quality. This type of treatment is not as ambitious; it is a simple approach that can be applied to all patients. The profile's main effects on postoperative coma and spherical aberration occur due to decentration and edge effects, the strong local curvature change from optical zone to transition zone, and the changes from the transition zone to the untreated cornea. When using an aberration-free ablation profile, it is necessary to emphasize the use of huge optical zones that cover the scotopic pupil size and well-defined smooth transition zones. The profile must also include some tolerance for possible decentrations.

## MAINTAIN PREOPERATIVE PROFILE

Based on the random nature of HOA induction and current research in this area, it maybe beneficial to maintain the preoperative wavefront profile for a significant number of refractive surgery candidates. I am not postulating that customized ablation algorithms are not useful; rather, I am saying that only specific populations with specific demands deserve customized treatment solutions. For example, aspheric treatments that aim to preserve preoperative HOAs are beneficial in patients with preoperative BCVA of 20/20 or better or in patients whose visual degradation cannot be attributed to the presence of clinically relevant HOAs.

As part of the corneal wavefront analysis, the type and size of any optical error on the anterior corneal surface is registered, thus allowing selective HOA correction. The defects are corrected exactly at their origin—the anterior corneal surface. In this context, the precise localization of defects is crucial to successfully achieving optimal results in laser surgery. The unique corneal wavefront profile developed by SCHWIND eye-tech-solutions (Figure 2) allows precise diagnosis, thus providing an individual corneal ablation pattern to obtain optimal results. The treatment zone is not limited by pupil size, and accommodation does not influence the measuring results.



**Figure 2.** Concept of corneal wavefront-guided correction. Top left: Preoperative corneal topography. Top right: postoperative corneal topography. Bottom left: ablation map. Bottom center: corneal wavefront aberration. Bottom right: Higher-order corneal aberrations.

This corneal wavefront approach is especially useful in cases with asymmetrical corneas and all corneas previously treated with refractive surgery from radial keratotomy, PRK, and LASIK. Apart from minimal additional ablation of corneal tissue, a systematic corneal wavefront-customized ablation profile is safe and beneficial. The corneal wavefront also is useful when the patient is pseudophakic as many aberrometers have difficulty in achieving an accurate wavefront measurement in the presence of a less-than-perfect posterior capsule. Finally, the corneal wavefront will affect the optics of a cataract patient after IOL insertion.

In Singapore, a coma corneal aberration with mild inferior corneal bulging is often observed. Therefore, the vast majority of my patients are treated using a corneal wavefront-based ablation with excellent results in reducing coma and providing large prolate corneal areas postoperatively.

## CONCLUSION

Ocular wavefront treatments have the advantage of being based on objective refraction of the complete human eye system whereas corneal wavefront treatments have the advantage of independence from accommodation effects or light/pupil conditions as well as in treating previously refractive surgery treated corneas. Aspheric treatments have the advantage of saving tissue, time, and—due to their simplicity—they offer better predictability. When evaluating the outcomes of wavefront-customization strategies, wavefront aberration analysis (both total and corneal) is mandatory to determine whether the customization aims can be achieved. ■

*Jerry Tan, FRCS(Ed), FRCOphth, is the owner and Medical Director of Jerry Tan Eye Surgery Pte Ltd., Singapore. Dr. Tan did not provide disclosure information. He may be reached at tel: + 65 6738 8122; e-mail: info@jerrytan.com.*

# 6D Eye Tracking

Compensating for pupil movements with AMARIS' built-in eye tracker.

BY MINORU TOMITA, MD, PhD



Human eyes have six degrees of freedom to move: x and y lateral shifts, z levelling, horizontal and vertical rotations, and cyclotorsion (rotations around the optical axis). To better understand this concept, think of the eyeball as a buoy at sea: When the sea is calm, the buoy shifts from side to side or forward and backward, but as the sea swells the buoy tilts to the side. The buoy can also turn around its anchorage and move upward and downward. Such movements are similar to the movements of the eye (Figure 1), which can roll, rotate around its own axis (cyclotorsion), or move up and down along the z-axis.

## POSITIONING ERRORS

The SCHWIND AMARIS laser systems (SCHWIND eye-tech-solutions, Kleinostheim, Germany) actively compensates for eye movements using a built-in eye tracker to monitor the position of the eye 1,050 times per second with a latency of 1.6 ms. The scanner mirror system positions the laser beam within less than 1 ms. Altogether, the total reaction time of the AMARIS is typically less than 3 ms.

Pulse-positioning errors can be caused by various components of the eye-tracker system. If the acquisition rate is below 100 Hz, the pulse-positioning error will typically be above 1.5 mm. Therefore, a fast-acquisition eye tracker is ideal to reduce positioning errors. Second, latency affects the pulse-positioning error, with approximately 15 ms of latency corresponding to errors up to 3.5 mm. Consequently the eye tracker should also be fast-processing. Third, long scanner positioning times can create pulse-positioning errors, with approximately 9 ms corresponding to pulse-positioning errors up to 2 mm. Fast-reacting scanners are preferable to avoid errors caused by scanner positioning. Fourth, laser firing rates that are faster than eye-tracker acquisition rates will double the pulse-positioning error, emphasizing the need for an eye tracker that completes acquisition faster than the laser's firing rate. Lastly, when placing the pulse, the latency time is more relevant than the sampling rate. There is no single parameter that alone minimizes positioning error. Rather, it is achieved with an optimal combination of these parameters.

## SIX DEGREES

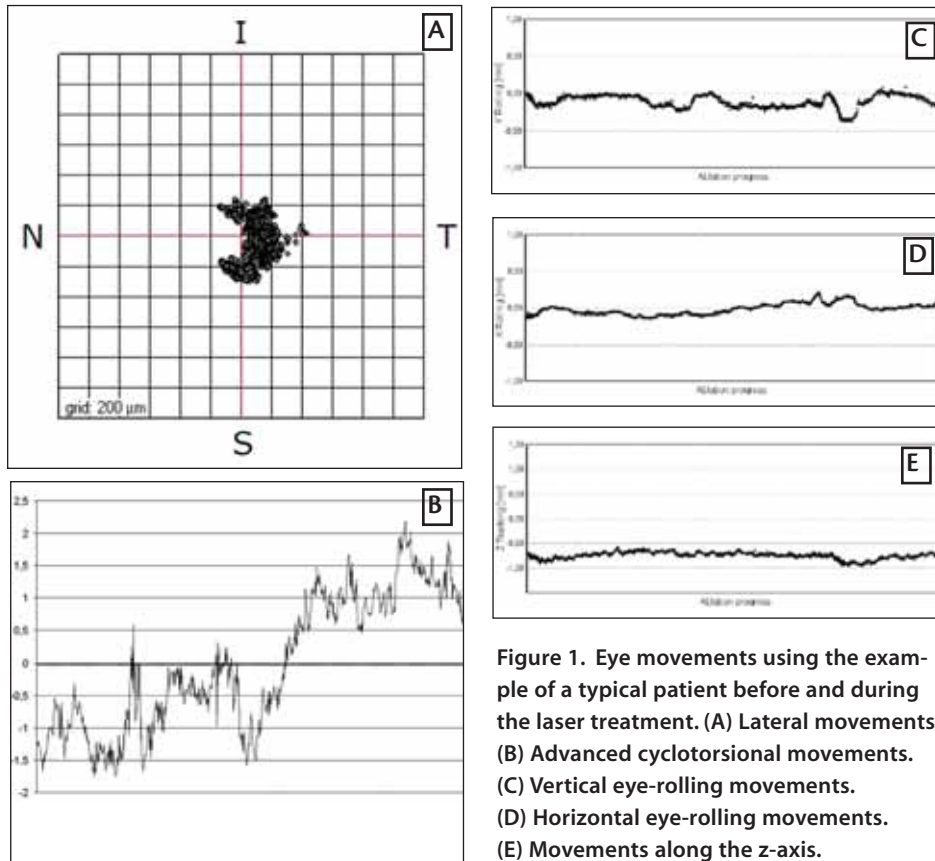
Using a 6D eye tracker, we are more likely to avoid placing a decentered ablation and thus less likely to induce

comatic aberrations, which are typical when there is no compensation for pupil (lateral) or eye-rolling movements. Uncompensated cyclotorsional movements also induce aberrations, whereas uncompensated axial movements induce asymmetrical under-corrections. Axial movements cause the laser spots to become defocused when they reach the cornea, and therefore the same energy spot produces a larger diameter, reducing the radiant exposure and the ablation depth. Axial movements can also mean that off-axis pulses hit the cornea more centrally than planned if the eye moves toward the laser system or further peripherally if the eyes moves away from the laser. Focusing on cyclotorsion should help to explain why exact centration and constant positioning of the eyes is important. Cyclotorsional movements have been analyzed since the mid-20th century, with several papers reporting the necessity for dynamic compensation to maintain the natural orientation of the retinal image.<sup>1</sup> However, other reports suggest that significant cyclotorsion can occur under monocular viewing conditions.<sup>2</sup>

Bueeler and Mrochen<sup>3</sup> used optical ray tracing in a schematic eye model to quantify the parallax error associated with localizing corneal positions. By tracking the subjacent entrance pupil center, they found that the tracking error can amount to 30% of the detected lateral shift. When the eye tracker is mounted closer than 500 mm to the eye, this error could be even higher. Thus, if the eye tracker registers a lateral shift of the entrance pupil that is 200  $\mu\text{m}$  away from the tracking reference axis, the point of interest on the cornea would be 260  $\mu\text{m}$  away from the reference axis. A laser pulse fired at that moment would be systematically displaced by 60  $\mu\text{m}$ .

Measuring rotation with the patient in the upright position may lead to ocular cyclotorsion<sup>4,5</sup> and result in mismatched applied and intended ablation profiles.<sup>6,7</sup> Recent developments facilitate the measurement of and potential compensation for static cyclotorsion. Such programs quantify the ocular cyclorotation that occurs between wavefront measurement and laser refractive surgery and in turn compensate for the difference.

The pupil size and the pupil center usually vary between the initial diagnosis and the treatment time. Therefore, even excluding cyclotorsion, there is already lateral displacement between the intended and placed ablation profile if pupil



**Figure 1.** Eye movements using the example of a typical patient before and during the laser treatment. (A) Lateral movements. (B) Advanced cyclotorsional movements. (C) Vertical eye-rolling movements. (D) Horizontal eye-rolling movements. (E) Movements along the z-axis.

a study on 445 myopic eyes treated with the AMARIS and 6D eye tracking. Static and dynamic cyclotorsion compensation was used and the rotational amplitudes registered in all cases. The mean preoperative spherical equivalent (SEQ) was  $-5.19 \pm 1.76$  D with a mean cylinder of  $-2.19 \pm 0.56$  D. Three months after surgery, the mean SEQ was  $-0.07 \pm 0.29$  D, and the mean cylinder was  $-0.12 \pm 0.30$  D. Additionally, 24% of eyes gained 1 or more lines of visual acuity and almost 70% remained unchanged. The average distance BCVA improved from  $-0.16$  logMAR (20/12.5) preoperatively to  $-0.18$  LogMAR (20/12.5) postoperatively. Static cyclotorsion con-

movements are not compensated for. Furthermore, cyclotorsion around any position other than the ablation center results in additional lateral displacement, and the cyclotorsion angle will remain at the same value. The SCHWIND AMARIS laser systems compensate for pupil centroid shift to consider this behavior actively.

## EYE REGISTRATION

The AMARIS' eye-registration technology provides an accuracy of approximately  $\pm 1.5^\circ$ . Therefore, it is possible to achieve a visual benefit up to the triacontafold (30-fold) angular frequencies and an optical benefit even beyond these angular frequencies. Using our limit of absolute residual dioptic error (less than 0.50 defocus equivalent [DEQ]), up to 19.10 DEQ coma, 9.55 DEQ astigmatism, and 6.37 DEQ trefoil can be corrected. This opens a new era in corneal laser refractive surgery, because we can now treat patients for a wider range of refractive problems with enhanced success ratios.

The Shinagawa LASIK Center in Tokyo is a leading clinic with one of the largest treatment volumes worldwide. Currently we perform an average of 10,000 treatments with the SCHWIND AMARIS each month. The active 6D eye tracker is one of the main benefits compared with other laser systems. We recently performed

control compensated for torsional movements of  $23.3^\circ$  between an angle of  $-11.1^\circ$  to  $12.2^\circ$  (mean value,  $-0.8^\circ$ ), and dynamic cyclotorsion control was applied during the laser treatment to compensate for torsional movements from  $-5.8^\circ$  to  $6.9^\circ$  (mean value,  $1.6^\circ$ ). Knowing that  $5^\circ$  of rotational misalignment for a preoperative cylinder of  $-2.00$  D will result in a mismatch of  $-0.35$  D (approximately 17%), we concluded that safety, predictability, efficacy, and stability exceeded currently accepted standards. ■

*Minoru Tomita, MD, PhD, is an Executive Director of the Shinagawa LASIK Center. Dr. Tomita states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: [tomita@shinagawa.com](mailto:tomita@shinagawa.com).*

1. Taylor NM, Eikelboom RH, van Sarloos PP, Reid PG. Determining the accuracy of an eye tracking system for laser refractive surgery. *J Refract Surg.* 2000;16(5):S643-646.
2. Bueeler M, Mrochen M, Seiler T. Effect of eye movements during refractive surgery with a scanning spot laser. 2003; DOI:10.1117/12.488628.
3. Bueeler M, Mrochen M. Limitations of pupil tracking in refractive surgery: systematic error in determination of corneal locations. *J Refract Surg.* 2004;20(4):371-378.
4. Smith EM Jr, Talamo JH, Assil KK, Petashnick DE. Comparison of astigmatic axis in the seated and supine positions. *J Refract Corneal Surg.* 1994;10:615-620.
5. Smith EM Jr, Talamo JH. Cyclotorsion in the seated and the supine patient. *J Cataract Refract Surg.* 1995;21:402-403.
6. Bueeler M, Mrochen M, Seiler T. Maximum permissible torsional misalignment in aberration-sensing and wavefront-guided corneal ablation. *J Cataract Refract Surg.* 2004;30(1):17-25.
7. Arba-Mosquera S, Merayo-Llodes J, de Ortueta D. Clinical effects of pure cyclotorsional errors during refractive surgery. *Invest Ophthalmol Vis Sci.* 2008;49:4828-4836.

# Intelligent Thermal Effect Control

ITEC ensures a thermally optimized distribution of laser pulses and minimizes corneal damage, even at high ablation speeds.

BY DIEGO DE ORTUETA, MD, FEBO



Refractive surgery procedures induce an increase in corneal temperature (Figure 1), which has been demonstrated clinically as well as in the laboratory.<sup>1-3</sup> The thermal load of a single laser pulse depends on the applied energy profile of the laser beam, the reflectivity, the thermal conductivity, the density, and the heat capacity. As the energy increases, the thermal load of a single pulse increases.

The cumulative thermal load of a refractive treatment increases during irradiation and depends on the effective local repetition rate of the system; once the cooling temperature between two pulses is equivalent to the temperature rise of a single pulse, the limit of the thermal load has been reached. The temperature in the cornea continues to rise during treatment, increasing from 0.7° C at 5-Hz irradiation to 2.8° C at 40-Hz and 32° C at 500-Hz irradiation. Excessive thermal load on the cornea can be avoided by using sophisticated algorithms that cover most of the possible variables.

## CONTROL THE THERMAL LOAD

If no frequency controls are established for a given system, the treatment's total thermal load will depend on the thermal load of a single pulse and the repetition rate of the system. For a system that uses a peak radiant exposure of 400 mJ/cm<sup>2</sup>, the thermal load of a single pulse is 0.5° C. If the system fires at 400 Hz without local frequency controls, the thermal load may exceed 20° C. If the same system includes local frequency controls of 40 Hz, the thermal load is confined to 2.2° C.

Ultraviolet (UV) irradiation is considered cold irradiation because the thermal relaxation time of the molecules is usually shorter than the thermal denaturation time. However, this does not mean that laser UV irradiation does not lead to local temperature increase. The thermal load of a single pulse describes the variation of temperature at a given position in the cornea immediately after having received a laser spot. The thermal load model is characterized by an immediate effect on the initial temperature in the cornea at a given position, proportionally to the beam energy density at that point.

If the thermal load of the ablation is minimized during high-speed laser corneal refractive surgery, faster wound healing and healthy cell reaction should result. The

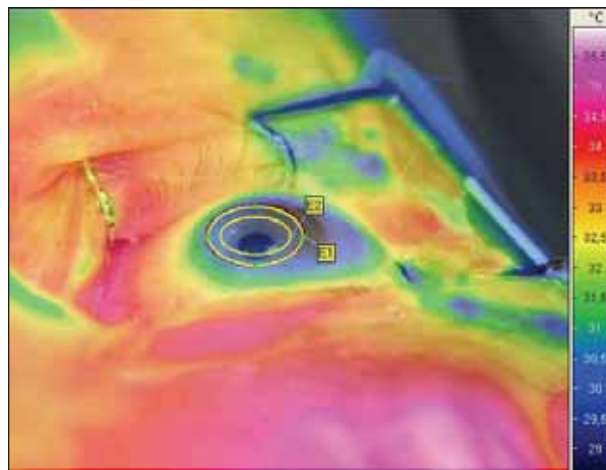


Figure 1. Thermal measurement prior to ablation.

AMARIS laser systems (SCHWIND eye-tech-solutions, Kleinostheim, Germany) use a novel approach to minimize the thermal load. The Intelligent Thermal Effect Control (ITEC) software automatically controls the local frequency during delivery of the pulse sequence to optimize refractive outcomes and visual quality after surgery. The use of defined pulse sorting creates extremely smooth surfaces and mild ablations and reduces the thermal impact of the ablation. To achieve this, laser spot energy is distributed both spatially and temporally. The control of pulse recreation time versus interspot distance minimizes the heat propagation during the ablation by dynamically limiting the local frequency.<sup>4</sup>

ITEC minimizes the thermal load on the cornea by blocking small areas around the laser spots for longer intervals and wider areas for shorter intervals. Therefore, instead of ablating the corneal tissue in layers, the pulse positions are chosen arbitrarily based on whether a position is blocked. This ensures a thermally optimized, dynamically adapted distribution of laser pulses during treatment, meaning that there is always enough time for each area on the cornea to cool between laser pulses. In this way, corneal damage due to long exposure times is avoided, even at very high ablation speeds. This method results in minimized thermal load on the cornea, fewer induced aberrations, less need for nomograms, and better visual quality after surgery.

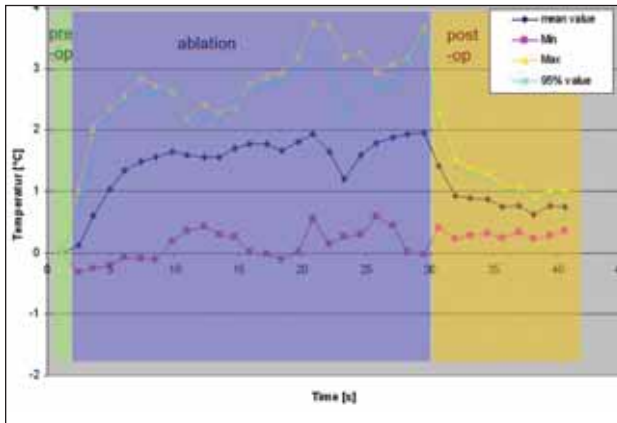


Figure 2. Intraoperative temperature rise during a myopic ablation of -7.50 D -1.75 D @ 130°.

## LASER PULSES

The repetition rate at which a laser pulse can be continuously delivered onto the same spot of corneal tissue without denaturing the proteins is defined as the maximum allowed local frequency. Given the radiant exposure of the laser pulses, firing at higher local frequencies will result in the denaturation of proteins and a suboptimal ablation.

Considering treatment geometries, thermal load depends on two things: (1) how the laser pulses are distributed across the treatment surface and (2) how dense pulse placement is. When the same amount of ablative pulses are applied over the same treatment area, thermal load is the highest for myopic treatments (Figure 2), followed by myopic astigmatism, mixed astigmatism, phototherapeutic keratectomy (PTK), hyperopic astigmatism, and hyperopic treatments.

In myopic treatments, pulses are most densely located at the center, where the laser angle is close to normal. In myopic astigmatism treatments, pulses are most dense along a central line and extend toward the peripheral cornea, where the laser incidence is oblique. In PTK treatments, pulses are evenly distributed across the corneal surface and extend toward the peripheral cornea. In hyperopic astigmatism treatments, pulses are most densely located at two symmetrical sectors of the peripheral cornea at oblique angles of incidence. In hyperopic treatments, pulses are most dense at the peripheral cornea, creating a ring-like pattern.

Pulse distribution, the density of the spots across the treatment surface, and the oblique incidence of spots at the peripheral cornea explain the results we have seen to date. Using actual pulse lists generated with the AMARIS systems, the maximum thermal load of a treatment is less than 40° C corneal temperature independent from the repetition rate of the laser. For example, if

the eye requires treatment for -10.00 D of spherical myopia, the AMARIS estimates that treatment should never exceed 3.6° C. If the treatment is for -4.00 D of cylindrical astigmatism, it estimates a thermal load of 3.5° C, and for a mixed astigmatism treatment of +3.00 D of sphere with -6.00 D of astigmatism, it estimates a thermal load of 2.9° C. The latter thermal load is also accurate for a PTK treatment with 75 µm depth. If treating +7.00 D of cylindrical astigmatism, the AMARIS estimates 2.9° C as the thermal load and 1.8° C for +5.00 D of spherical hyperopia.

## TEMPERATURE IN THE CORNEA

Scientific thermodynamic measurements carried out at the Eye Laser Clinic Recklinghausen in Germany showed that, with ITEC and the AMARIS laser system, the temperature of the cornea rose less than 4° during the laser treatment and was independent from the actual repetition rate of the laser system.

Nine eyes were investigated, and preoperative spherical equivalent (SEQ) range from +3.00 to -9.25 D. Measurements were performed with high-resolution infrared thermographic cameras that recorded thermal images of the eye from a distance of 66 cm. Corneal temperature was evaluated within the optical zone as well as in the entire ablation zone. The preoperative cornea temperature ranged from 29.3° to 31.4° C; it is not until the cornea reaches 40° C that possible damage can occur, resulting in corneal haze and negatively influencing the treatment.

In all eyes, the intraoperative corneal temperature did not rise more than 4° C, and the maximum temperature was less than 35° C. This confirms that the ITEC method efficiently preserves corneal tissue despite the very high pulse frequency of the SCHWIND AMARIS laser systems. Furthermore, this study showed that, with ITEC, the amount of the refraction and consequently the length of ablation has no influence on temperature rise. ■

*Diego de Ortueta, MD, FEBO, is a Senior Consultant at the Aurelios Augenzentrum, Recklinghausen, Germany. Dr. de Ortueta states that he is a consultant to SCHWIND eye-tech-solutions. He may be reached at e-mail: [diego.de.ortueta@augenzentrum.org](mailto:diego.de.ortueta@augenzentrum.org).*

1. Bende T, Seiler T, Wollensak J. Side effects in excimer corneal surgery; corneal thermal gradients. *Graefes Arch Clin Exp Ophthalmol.* 1988;226:277-280.
2. Ishihara M, Arai T, Sato S, Morimoto Y, Obara M, Kikuchi M. Measurement of the surface temperature of the cornea during ArF excimer laser ablation by thermal radiometry with a 15-nanosecond time response. *Lasers Surg Med.* 2002;30:54-59.
3. Betney S, Morgan PB, Doyle SJ, Efron N. Corneal temperature changes during photorefractive keratectomy. *Cornea.* 1997;16:158-161.
4. Brunsmann U, Sauer U, Dressler K, Triefenbach N, Arba Mosquera S. Minimisation of the thermal load of the ablation in high-speed laser corneal refractive surgery: the 'intelligent thermal effect control' of the AMARIS platform. *J Modern Opt.* 2010;57:466-479.

# PresbyMAX and the AMARIS Total-Tech Laser

Representing the most advanced central presby-LASIK technique.

BY DETLEF UTHOFF, MD



When we are looking at a near object, a triad of events occurs: convergence, miosis, and accommodation. As the eye ages and signs of presbyopia are recognizable, accommodation becomes more difficult but convergence and miosis still occur. The main goal of any surgical procedure that aims to correct presbyopia is to enhance not only distance and near visual acuity but to also enhance the range of relatively clear vision.

Presbyopia-correction surgery can be broadly categorized into two groups: techniques that mimic the crystalline lens and techniques that induce bifocality or multifocality. The latter are simultaneous vision techniques that enhance the depth of focus. For approximately the first 50 years of life, the eye experiences a near-linear reduction in accommodation, a reduction in pupil size, and a shift in the general pattern of ocular spherical aberration. Pupil constriction—and in some individuals the change in ocular spherical aberration—does not only offer some relief from the near vision deficiencies attributed to loss of accommodation but enhances the depth of focus. Bi- and multifocal surgical techniques tend to combat presbyopia by emulating and enhancing these natural phenomena.

## PRESBY-LASIK AND PRESBYMAX

Presbyopia-correcting LASIK techniques, or presby-LASIK, aim to create a multifocal surface on the cornea to correct defocus and astigmatism and simultaneously reduce or in some cases eliminate near spectacle dependence. This treatment constitutes the next step in the correction of presbyopia after monovision LASIK. More specifically, central presby-LASIK techniques increase curvature (smaller radius) in the central pupil to produce more refractive power in the corneal vertex than at the periphery. The aim of the treatment is to improve near vision with miosis, and Alió et al<sup>1</sup> demonstrated the efficiency, predictability, stability, safety, and visual quality of this technique for treating presbyopic patients with hyperopia. In another study, Ortiz et al<sup>2</sup> found that, with complete characterization of the eye and a propagation algorithm that simultaneously accounts for all refractive surfaces in the eye, it is possi-

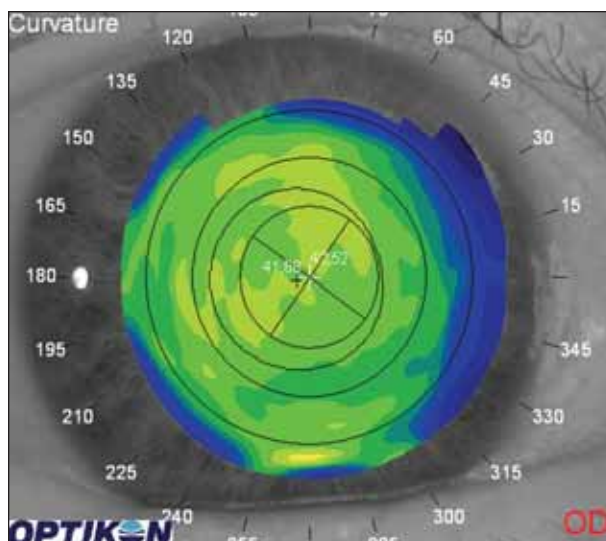


Figure 1. Presbyopia treatment in combination with hyperopia (preoperative).

ble to evaluate the optical quality of patients who have undergone central presby-LASIK treatment.

SCHWIND's (Kleinostheim, Germany) presby-LASIK module, PresbyMAX, is the most advanced central presby-LASIK technique available today. It integrates biaspheric multifocal ablation profiles into two focus-shifted aspheric profiles with different asphericities. This compensates for the peripheral energy loss due to an increased angle of incidence on the cornea and for biomechanical changes induced during LASIK. PresbyMAX uses wavefront diagnostic data as well as presbyopic compensation, thereby combining the advantages of both techniques—improved visual outcomes and enhanced pseudoaccommodation. Finally, controlled multifocal vision is achievable with PresbyMAX, and the profile meets the following requirements: multifocality (the center is corrected for near and the periphery for far vision), optimized biaspheric profile, and addition of a precalculated amount of higher-order spherical aberrations.

## CLINICAL EXPERIENCE AND RESULTS

In our cohort of 60 eyes of 30 patients, 100% of hyperopic patients, 80% of emmetropic patients, and 70% of



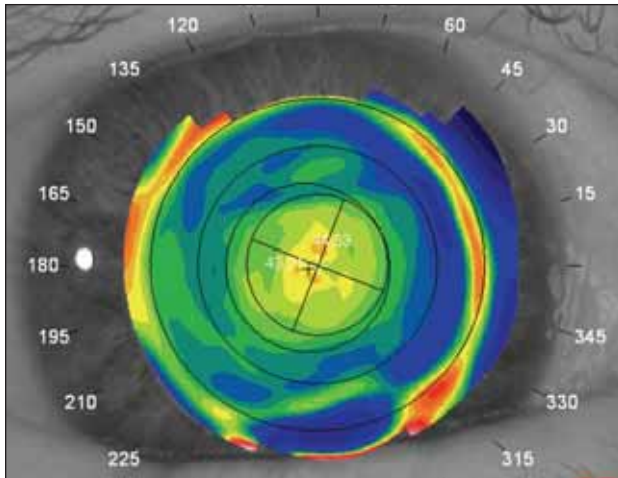


Figure 2. Presbyopia treatment in combination with hyperopia (6 months postoperative).

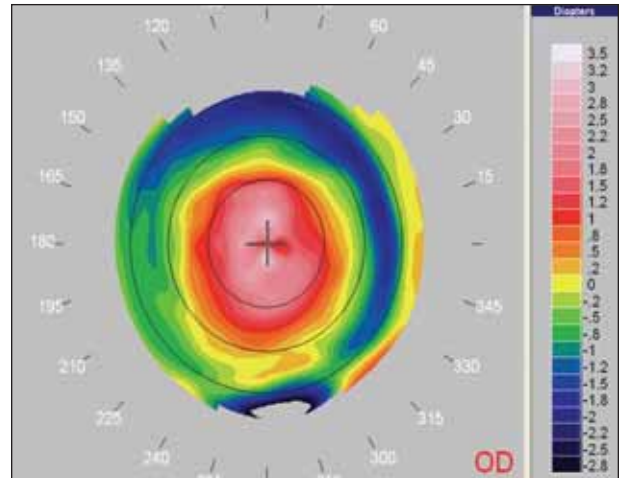


Figure 3. Difference map pre- versus postoperative (treatment of +1.50 D of sphere with +2.50 D addition).

myopic patients achieved good objective and subjective distance vision (logMAR 0.1), very good intermediate vision, and good near vision at 6 months (hyperopic and emmetropic patients, 80% with 0.3 logRAD or better; myopic patients, 90% with 0.3 logRAD or better). We have found that PresbyMAX offers a possible compromise for the whole distance range.

Of the treated eyes, 20 underwent emmetropic PresbyMAX, 20 underwent myopic PresbyMAX, and 20 underwent hyperopic PresbyMAX (Figures 1 through 3). Mean patient age was 52 years (range, 45–57 years) for the emmetropic presbyopic group, 54 years (range, 39–69 years) for the hyperopic presbyopic group, and 51 years (range, 46–60 years) for the myopic presbyopic group. Mean binocular distance UCVA improved from  $0.28 \pm 0.25$  logMAR preoperatively to  $-0.04 \pm 0.07$  logMAR, from  $-0.05 \pm 0.07$  logMAR to  $0.03 \pm 0.11$  logMAR, and from  $0.78 \pm 0.27$  logMAR to  $0.09 \pm 0.08$  logMAR at 6 months in the hyperopic, emmetropic, and myopic groups, respectively.

Mean binocular near UCVA improved from  $0.86 \pm 0.62$  logRAD to  $0.24 \pm 0.23$  logRAD and from  $0.48 \pm 0.14$  logRAD to  $0.18 \pm 0.11$  logRAD, respectively, in the hyperopic and emmetropic groups at 6 months. In the myopic presbyopic group, the mean binocular near UCVA changed from  $0.04 \pm 0.19$  logRAD to  $0.12 \pm 0.18$  logRAD 6 months postoperatively. The mean postoperative refractive outcome was  $-0.21$  D of sphere and  $-0.41$  D of cylinder. Spherical equivalent was  $-0.42$  D, which was close to the expected outcome of  $-0.50$  D defocus.

Patient satisfaction was high, and we feel that the principles of PresbyMAX help us to increase the quality of life of our patients, offering spectacle-free vision for almost every patient. However, not every patient is well suited for this technique, and the first considera-

tion is to individually check the patient's tolerance for PresbyMAX. The patient's profession, hobbies, and visual expectations must be identified before deciding whether the postoperative visual performance provided by the ablation profile will comply with patient's needs. A trial with multifocal contact lenses or trial frames should simulate postoperative visual impressions to verify patient acceptance of the final outcome. Furthermore, the patient should understand that the aim of PresbyMAX is spectacle-free vision for daily life but that there is the possible need for correction in cases that demand great focus. Well-lit conditions allow the best near performance, and dim conditions are optimal for distance vision. Therefore, patients will benefit from wearing sunglasses for distance vision.

## CONCLUSION

Centering the ablation on the corneal vertex helps to reduce unwanted higher-order aberrations, especially disturbing asymmetrical aberrations like coma. Good visual results, a high level of predictability and accuracy, and safety have been achieved with PresbyMAX. ■

*Detlef Uthoff, MD, is the Medical Director of the Eye Clinic Bellevue, Kiel, Germany. Dr. Uthoff states that he no financial interest in the products or companies mentioned. He may be reached at tel: +49 431 30108 0; fax: +49 431 30108 40; e-mail: D.Uthoff@Augenlinik-Bellevue.de.*

1. Illueca C, Alió JL, Mas D, Ortiz D, Pérez J, Espinosa J, Esperanza S. Pseudoaccommodation and visual acuity with Technovision presbyLASIK and a theoretical simulated Array multifocal intraocular lens. *J Refract Surg.* 2008;24(4):344-349.
2. Ortiz D, Alió JL, Illueca C, Mas D, Sala E, Pérez J, Espinosa J. Optical analysis of presbyLASIK treatment by a light propagation algorithm. *J Refract Surg.* 2007;23(1):39-44.

# Advanced Surface Laser Ablation: A True No-Touch Technique

This single-step ablation is the best choice for surface correction of refractive errors.

BY IOANNIS M. ASLANIDES, MD, PhD, MBA, FRCOPHTH; AND SARA PADRONI, MD, MRCOPHTH, MSc



TransPRK by SCHWIND (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany) is the only transepithelial single-step treatment that avoids the eye coming into contact with any instrument. The clinical application of TransPRK, an advanced surface laser ablation (ASLA) treatment, uses the excimer laser to remove the epithelium, resulting in a more precise and more uniform treatment than what is achieved with either manual or alcohol-assisted debridement. TransPRK was introduced in September 2009, and since then this treatment has gone through various evolutions. TransPRK-ASLA, performed with the SCHWIND AMARIS laser system, applies an epithelial thickness profile that resembles a slight hyperopic treatment (less than 0.75 D). The resultant epithelium is thinner in the center, thereby avoiding or at least reducing hyperopic shift. Because ASLA applies the laser beam directly over the epithelium, it acts as a smoothing agent for the residual stromal bed. Treating refractive errors with ASLA has several advantages.

The single-step approach allows simultaneous ablation of the epithelium and the stroma to shorten the overall treatment time and minimize the risk of corneal dehydration. Beside a faster surgical time, epithelial tissue removal has been optimized to avoid myopic-like corrections (approximately -0.75 D). This new approach treats refractive errors by superimposing a defined epithelial thickness profile of approximately 55  $\mu\text{m}$  at the center and 65  $\mu\text{m}$  at the periphery (4 mm radially from center) with a corneal aspheric ablation profile. Additionally, the diameter of epithelial removal is calculated to match the ablation zone, thus decreasing the wound surface and speeding up the healing process.

## ABLATION PROFILE AND OPTICAL ZONES

Transepithelial approaches allow maximum correspondence between the corneal topography and the ablation profile. Despite the slight difference in photoablative rates of the stroma and the epithelial tissue (approximately 20% higher in the epithelium), the

AMARIS software is set up to compensate for this. TransPRK profiles on the AMARIS system are safe and effective, and the high-speed laser reduces variability from stromal hydration effects. ASLA yields good visual, optical, and refractive results and has the potential to replace other surface ablation procedures.

Transepithelial ASLA with the AMARIS offers additional safety, because there is no corneal flap and thus no enduring weakening of the cornea. ASLA patients have lower pain scores, functional visual outcomes are achieved earlier than with alcohol-assisted epithelial ablation, and patients remain stable. Additionally, the AMARIS creates large optical zones and smart blend zones to avoid edge effects, especially in eyes with coma and spherical aberration. The size of the optical zone should generally be at least the size of the scotopic pupil diameter.<sup>1</sup> In hyperopic eyes, an optical zone of 7.0 mm is preferred because it minimizes the risk for regression and halos.

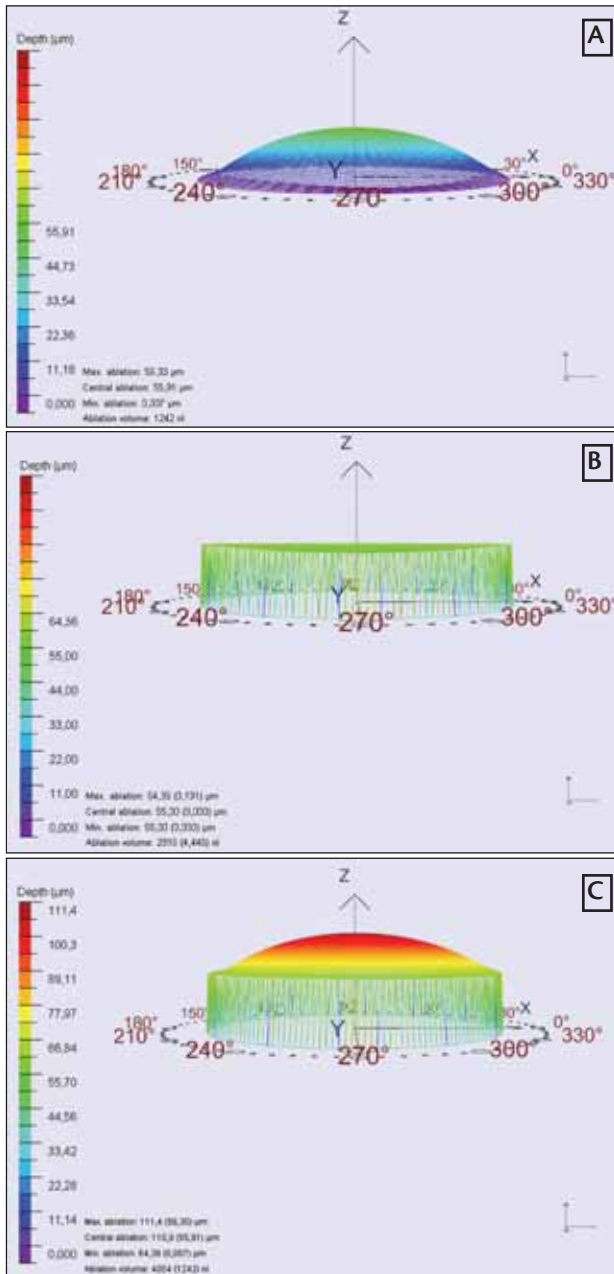
## CASES FOR ASLA

ASLA in combination with corneal wavefront is preferable for patients who need retreatment after radial keratotomy or corneal transplantation.<sup>2</sup> Moreover, it can be used to treat haze, scarred corneal tissue, and keratoconus before corneal collagen crosslinking (CXL). When used as a keratoconus treatment, we aim to minimize the ablation and smooth the existing astigmatism. Compatibility with the preoperative initial corneal thickness is important.

The ASLA technique is useful in all cases where a difficult epithelial flap is expected or when the epithelium covers corneal irregularities of the stromal tissue. Our approach is treating refractive errors sequentially with a corneal wavefront-guided aspheric ablation followed by a defined epithelial thickness profile, without masking fluid, to remove residual epithelium from the center or in the periphery of the treated area.

## VERSATILITY

We performed a study comparing ASLA with alcohol-assisted PRK. The resulting outcomes were com-



**Figure 1. Composition of a ASLA myopic profile. (A) PRK component; (B) epithelial component; and (C) resulting ASLA profile.**

parable UCVA and BCVA. In terms of aberrations, pre-operative and 1 and 3 months postoperatively, the results are comparable across the spherical, coma, and trefoil groups. In terms of intra- and postoperative pain, the ASLA patients have a lower score and the difference in pain between an alcohol-assisted PRK and an ASLA patient is more marked on the third postoperative day, when ASLA-treated eyes show better heal-

ing and epithelialization. This is also demonstrated by a higher percentage of alcohol-treated patients requiring replacement of bandage contact lens on day 3 as compared to the ASLA-treated group, where only a very small percentage (less than 10%) required replacing the bandage contact lens because of residual epithelial defect.

Furthermore, the levels of haze (measured on the Fantes scale) in the ASLA group are about 60% lower than in the alcohol group. It has not exceeded grade 2 in any case at 6-month follow-up.

## CONCLUSION

ASLA is a versatile approach, allowing treatment of pathologic corneas as well as combined therapies such as CXL plus ASLA. Results are at least comparable to, if not even better than, alcohol-debrided PRK. With ASLA, pain scores and days to contact lens removal are lower and the healing process (haze and visual acuity recovery) is conveniently shorter.

In addition to the study, we have performed ASLA on more than 150 patients with at least 6 months' follow-up. All patients have excellent results thus far, with all ASLA outcomes are comparable to alcohol-assisted PRK outcomes in terms of final BCVA and UCVA, stability and long term safety.

When ASLA profiles are applied to regular corneas using the AMARIS system, the outcome is efficacious, safe, stable, and reliable results. ASLA preserves the eye's natural aberrations just as well as alcohol-assisted PRK does. ■

*Ioannis M. Aslanides, MD, PhD, MBA, FRCOphth, is an Assistant Professor at Weil-Cornell N.Y. Hospital and Medical Director at Emmetropia Mediterranean Eye Clinic in Greece. Dr. Aslanides states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: [i.aslanides@emmetropia.gr](mailto:i.aslanides@emmetropia.gr)*

*Sara Padroni, MD, MRCOphth, MSc, is the current Fellow at the Emmetropia Mediterranean Eye Clinic in Crete.*

1. Camellin M, Mosquera SA. Aspheric optical zones: The effective optical zone with the SCHWIND AMARIS. *J Refract Surg.* 2010;19:1-12. doi: 10.3928/1081597X-20100428-03. [Epub ahead of print].
2. Camellin M, Arba Mosquera S. Simultaneous aspheric wavefront-guided transepithelial photorefractive keratectomy and phototherapeutic keratectomy to correct aberrations and refractive errors after corneal surgery. *J Cataract Refract Surg.* 2010;36:1173-1180.

*\* Editorial Note: Personal communication: The Emmetropia data relative to our randomized control study are currently being submitted for publication and cannot be fully disclosed.*



## Welcome to the SCHWIND AMARIS Product Family

### Superior has a name: **SCHWIND AMARIS 750S**

- 750-Hz Pulse Rate
- Automatic Fluence Level Adjustment
  - 0.54-mm laser spot
- Intelligent Thermal Effect Control
- Active 6D, 1,050-Hz Turbo Eye Tracking
- A wide range of treatments with ORK-CAM, PresbyMAX, and PALK-CAM
- TransPRK: No-Touch Surface Treatment
  - Online Pachymetry
- Swivelling laser arm and patient bed

### Efficiency has a name: **SCHWIND AMARIS 500E**

- 500-Hz Pulse Rate
- Automatic Fluence Level Adjustment
  - 0.54-mm laser spot
- Intelligent Thermal Effect Control
- Active 5D, 1,050-Hz Turbo Eye Tracking
- A wide range of treatments with ORK-CAM, PresbyMAX, and PALK-CAM
- TransPRK: No-Touch Surface Treatment
  - Online Pachymetry
- Swivelling patient bed

For more information about the SCHWIND AMARIS TotalTech Lasers,  
please visit: [www.eye-tech-solutions.com](http://www.eye-tech-solutions.com)

**Cataract & Refractive Surgery**  
**TODAY!**  
**EUROPE**