Combination Workstations

Authors give an overview on four diagnostic workstations for the excimer laser.

BY DIEGO DE ORTUETA, MD, FEBO; DAMIEN GATINEL, MD, PHD; ERIK L. MERTENS, MD, FEBOPHTH; AND PATRICK VERSACE, MD

The Combi Wavefront Analyzer

BY DIEGO DE ORTUETA, MD, FEBO

The Combi Wavefront Analyzer (Schwind eye-tech-solutions, Kleinostheim, Germany) allows me to integrate all the data needed to plan refractive surgery. The device combines ocular wavefront and corneal wavefront measurements, allowing me to determine the best treatment for each patient.

The comparison feature of this diagnostic device allows the user to load two wavefront aberration files: two corneal wavefront maps, two ocular wavefront maps, or one corneal and one ocular wavefront map. This direct comparison provides information about the location of the patient's visual deficiency. From the comparison, I can determine whether the problem resides on the corneal surface. The Combi Wavefront Analyzer thus helps the refractive surgeon decide which diagnostic data should be used for optimal treatment results.[1] It combines comprehensive analysis of higher-order aberrations (HOAs) and refraction results in an efficient one-step treatment.

Ocular wavefront. The Ocular Wavefront Analyzer is a high-resolution Shack-Hartmann aberrometer that measures 1,024 points with a resolution of 230 µm. Each eye is measured three times to ensure good repeatability. The ocular wavefront componenent of the Combi Wavefront Analyzer determines total HOAs and root-mean-square (RMS) error. An integrated infrared pupillometer allows us to determine scotopic pupil size and calculate mesopic pupil size based on aberrometry. The device also measures accommodation and keratometry (K) and calculates the Seidel refraction. In my experience, the Seidel measurement with a 4-mm pupil is close to the manifest subjective refraction and can be used in place of it. The Seidel refraction incorporates HOAs into the spherocylindrical refractive error and allows us to check our data against the patient's glasses prescription.

Corneal wavefront. Corneal wavefront measurements on the Combi device are done with the Keratron Scout Topographer (Optikon 2000 Industrie, Rome). This Placido-disc–based system measures more than 80,000 points and provides Zernike components up to the eighth order. Ray tracing and a sophisticated eye model calculate corneal topography, which provides K readings at 3, 5, and 7 mm as well as the Maloney Index and simulated K-reading. We have found that the Maloney Index is more reliable than standard K readings in describing the cornea because it better reflects the actual flattest and steepest meridians, rather than measuring only the flattest meridian and automatically placing the steepest axis 90° away.[2] The topography system also includes a repeatability test. Five topographies per eye are measured, and data from the best test can be extracted.

Images taken during corneal wavefront measurement can be used for detection of cyclorotation of the eye when the patient is at the laser.

The infrared pupilometer calculates the mesopic pupil diameter, which is useful for determining the size of the optical zone to be treated. These data can be exported to create a customized corneal wavefront treatment. In this case, the HOAs determined by corneal wavefront analysis can be incorporated into the patient's manifest refraction.

Elevation, tangential, and axial maps are generated. I normally use the tangential map because it provides the most information, applying the arc-step algorithm to compute corneal curvature and identify abnormalities of the cornea, such as keratoconus. There is also a software program that calculates a patient's likliehood of developing keratoconus based on asymmetry of the cornea. We use the difference map to track the changes in topography over time.

Application. Once the refraction, ocular aberrometry, topography, and corneal wavefront data are calculated, they can be exported to the Optimized Refractive Keratectomy-Custom Ablation Manager (ORK-CAM; Schwind eye-tech-solutions) to plan treatment on Schwind's Esiris or Amaris laser platforms. For the Amaris, I export corneal wavefront data, including K readings, pupil center, corneal vertex, and an infrared photo for cyclotorsion recognition. I can then decide if I want to treat individual HOAs or proceed with an aberration-free treatment. In general, virgin eyes have good visual acuity; I tend to choose an aberration-free protocol to treat the lower-order aberrations (sphere and cylinder) without inducing new HOAs. An aspheric, aberration-neutral ablation profile induces no clinically relevant corneal wavefront aberration in myopic and hyperopic eyes.[3,4] In eyes in which the cornea already exhibits symptomatic aberrations, as is sometimes found after refractive treatments, HOAs can be addressed with a customized laser treatment based on corneal wavefront analysis. In other cases, ocular wavefront data can be exported to treat the total aberrations of the eye. I typically treat with an aberration-free profile; however, in the case of retreatments, I use the corneal wavefront treatment profile or, more rarely, the ocular wavefront treatment profile.

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The OPD-Scan II

BY DAMIEN GATINEL, MD, PHD

The Optical Path Difference Scanning System (OPD-Scan II; Nidek, Gamagori, Japan) is a dual machine that combines Placido-disc–based corneal topography and an aberrometer in one instrument. In addition to determining accurate manifest refraction, the OPD-Scan II sofware provides the clinician a complete set of maps, including corneal topography in various curvature modes, refraction within the pupil locations expressed in diopters, and total wavefront aberration maps of the examined eye. By computing the corneal wave aberration and registrating it with regard to the total wavefront map, the OPD-Scan II can provide physicians with an estimation of the contribution of internal optics to the eye's optical quality. The extracted data is presented through the OPD-Scan II software, but can be further exploited with the OPD Station software to compute useful metrics of optical quality such as the modulation transfer function (MTF), or maximum contrast visual acuity chart simulation.

The Nidek Advanced Vision Excimer laser platform (NAVEX) system consists of the multifunction OPD-Scan II aberrometer and corneal topographer, the Final Fit ablation planning software, and the EC-CX3 excimer laser that uses both scanning slit and spot ablation capabilities to deliver the ablation to the cornea.

FEATURES

The OPD-Scan II is a multifunction diagnostic unit that measures aberrometry, corneal topography, autorefraction, wavefront refraction, keratometry, and pupillometry.

Unlike traditional Hartmann-Shack and Tscherning aberrometers, the OPD-Scan II uses the time differences of stimulation of a photodiode array instead of positional differences on a lenslet array to map the aberrations of the eye. In my experience, this sequential acquisition and difference in measuring principles allows the OPD-Scan II to measure highly aberrated eyes and eyes with large refractive gradients. Additionally, this allows a comparatively wide measuring range of -20.00 to 22.00 D of sphere and up to 12.00 D of cylinder. Such large optical distortions can be encountered in various clinical conditions such as high myopia, keratoconus, ectopia lentis (Marfan syndrome), decentered photoablations and IOLs, corneal dystrophies, and trauma.

This large dynamic range makes the instrument easy to use as an autorefractometer for the acquisition of the wavefront data. No manual entry of refraction, sphere, cylinder, or axis is necessary prior to measuring an eye, allowing extensive use with little technician time. As multiple functions such as aberrometry and corneal topography are performed on the same instrument simultaneously, the axis of alignment is the same and the wavefront and topography maps can be directly correlated.

Corneal topography is measured by employing a Placido-ring method. Clinically, the ODP-Scan II provides standard corneal topography and wavefront information. The wavefront data plots wavefront total maps, higher-order maps, and Zernike graphs cataloging the aberration profile along with the associated RMS values. The point spread function (PSF) allows the simulation of the optical effects of the aberrations. The PSF can be simulated for the total wavefront profile, the higher-order profile, and the effects of individual types of aberrations such as coma or trefoil. This can be used as a patient teaching tool to simulate the effects of the aberrations and to explain them in laymans terms. Additionally, the Strehl ratio serves as a global index of visual quality. The use of the various indices of optical and visual quality allow the surgeon to determine if a patient is a candidate for wavefront or conventional ablation.

The refractive wavefront maps, called OPD and Internal OPD maps, are the primary output of the aberrometry function of the OPD-Scan II (Figure 1). The OPD map presents the refractive status of the entire optical path of the eye. The Internal OPD map displays the refractive status of eye due to the internal aberrations of the eye by subtracting the effects of the corneal front surface. This map determines if the source of the aberrations is corneal, internal, or a combination. For intraocular surgery, the Internal OPD Map determines the centration of the IOL and the optical effect of the surgery. Additionally, corneal and/or lenticular astigmatism can be determined and quantified. This feature can also be quite useful in assessing the proper alignment of a toric IOL. Traditional Zernike-based maps, showing the wavefront phase distortions in microns to the eighth order can aslo be derived.

For refractive surgery procedures there are various indices that determine the corneal vertex, pupil center, or line of sight and visual axis for laser centering procedures. Photopic and mesopic pupil centers and mesopic pupils are acquired to determine pupil size and the location of the visual axis under these illumination conditions.

OPD STATION SOFTWARE

The OPD Station software includes tools such as the Corneal Navigator and calculates additional diagnostic maps. The Corneal Navigator uses 25 indices derived from the shape of the cornea to calculate a percentage of similarity with several corneal conditions. This device is particularly useful to detect conditions such as forme fruste keratoconus. Additional optical maps include MTF maps.

The MTF is a quantitative measure of image quality that is far superior to any classic resolution criteria. The OPD Station software determines the MTF of an eye and for each of its main optical components such as the cornea and lens.

The simulations of the retinal image of Snellen charts optotypes (visual acuity) is also provided. These are useful in situations such as complex contact lens adaptation, as they objectively compare the quality of vision obtained with different contact lens designs and parameters.

FINAL FIT SOFTWARE

The Final Fit software for customized ablations uses both aberrometry and topography to develop the ablation algorithms. This interface software allows the modification and simulation of a host of parameters including optical and transition zones, target refraction, effective optical zone, and treatment based on only corneal and/or wavefront data. This ablation planning software allows the surgeon to simulate the effects of the ablation and visualize its effect on corneal topography maps. Designed for primary and therapeutic treatments, the Final Fit software is used to plan treatments for primary cases, central island retreatments, primary or laser-induced irregular astigmatism, decentered ablations and a variety of other complicated cases.

In the topography-guided mode of ablation (CATz; Customized Aspherical Transistion zones), surgeons may adjust specific parameters allowing users to select or exclude specific aberrations in the ablation profile.

The precise qualitative and quantitative assessment of the main components of the eye's optical system allows better understanding of the patient's symptoms in various clinical conditions not restricted to the domain of customized laser refractive surgery. Modern cataract surgery and complex contact lens adaptation represent wide fields for the use of devices like the OPD-Scan that enable precise corneal and internal optical quality assessment. ■

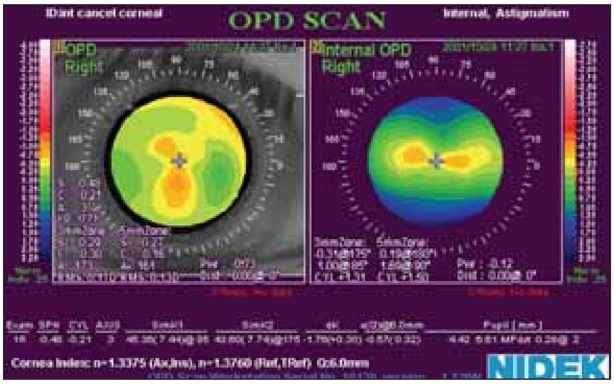

Figure 1. The OPD and Internal OPD maps are the primary outputs of the aberrometry function of the OPD-Scan II.

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The Zyoptix Workstation

BY ERIK L. MERTENS, MD, FEBOphth

The Zyoptix Diagnostic Workstation (Technolas Perfect Vision, Munich, Germany) is a modular workstation that integrates a variety of diagnostics for customized refractive treatments. This diagnostic device was launched in 2002 as a result of the merger between the Orbscan II topographer and the Zywave aberrometer (both by Bausch & Lomb, Rochester, New York) . The Zyoptix Diagnostic Workstation combines these technologies into a single device.

Topography. The Orbscan II corneal topographer has been the gold standard for detection of forme fruste keratoconus (Figure 2) and keratoconus.[1] The Orbscan uses a combination of Placido-disc–based technology for direct curvature measurement plus slit-lamp technology for direct elevation measurement. The slits are created with Scheimpflug imaging. The device provides a wealth of data, including pachymetry, anterior chamber depth, elevation

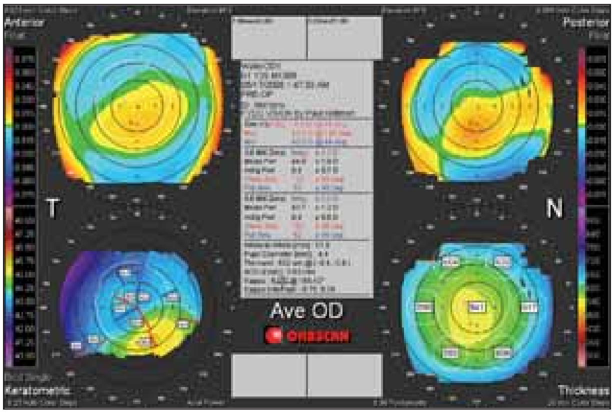

Figure 2. Orbscan II quad map with inferior steeping visible on the keratometric map depicting a forme fruste keratoconus.

maps, corneal curvature and power maps, and Q value. For me, the Orbscan II it is the ideal guide for the best and safest treatment choice.

Aberrometry. Bausch & Lomb pioneered wavefront technology with the the Zywave standalone device in 2000. The Zywave, a Shack-Hartmann aberrometer, uses 625 lenslets.[2] It measures and analyzes the presence of higher- and lower-order aberrations and uses iris recognition for safe and secure patient identification as well as compensation for pupil center shift and cyclotorsion. An automated alarm sounds in the case of decentering or movement.

In 2003, Bausch & Lomb introduced iris recognition on the Zyoptix diagnostic system and laser platform and combined the topographic and aberrometric diagnostic instruments into one device, the Zyoptix Diagnostic Workstation. The iris-recognition technology uses an iris code of 3,992 points and allows static compensation of cyclotorsion and pupil shift under the laser. This feature, which makes it impossible to treat the wrong eye or cylindrical axis, is important for the success of the Zyoptix wavefront technology.[3,4] To correct HOAs, the aberrations must be corrected at the exact location at which they are situated.

Advanced Personalized Technologies. A bundle of hardware and software upgrades called Advanced Personal Technologies were introduced 3 years ago to assist surgeons with patient selection. This upgrade included No Dilation ZyWave (NoDiZy), an algorithm that extrapolates lower- and higher-order aberrations in myopes and allows programming of an optical zone 10% larger than the patient's maximum low mesopic pupil. This algorithm has almost eliminated the use of dilating drops, speeding up acquisition time considerably. Another benefit is the increased signal-to-noise ratio of the measurements due to the unaltered tear film, which otherwise can create artifacts in HOA measurements.

Advanced Personal Technologies connects the diagnostic system directly with the laser, even over the Internet, eliminating the need for USB sticks or floppy disks for data transfer. Treatment calculation software is typically also located on the diagnostic system. Topographic files and wavefront files come together in this software; subjective refraction is introduced; the advanced nomogram is applied; and after the choice of optical zone and treatment profile, the treatment parameters are directly exported to the laser.

Advanced Nomogram for Personalized Treatments. The introduction of the Advanced Nomogram for Personalized Treatments[5] in 2007 is another key to the Zyoptix Diagnostic Workstation's success. This nomogram takes into account all possible coupling effects between cylinder, HOAs, and defocus (second-order aberrations). However, the subjective refraction still remains the basis for the treatment algorithm. This eliminates surprises and adjusts the patient's accommodation during the treatment. My retreatment rate is below 1% because of this nomogram.

With each upgrade, my results became better and more predictable. According to Lapid-Gortzak et al,[5] the new algorithm with the advanced nomogram showed a standard deviation after 3 months of only 0.11 D.

Personalized Treatment Advanced. Personalized Treatment Advanced corrects HOAs, but at the same time does not induce spherical aberrations due to excimer laser ablation. The aspheric component it uses is based on the Z200 and Z400 as measured by the Zywave. This means that the total preoperative aspheric component of the eye is taken into account. This could be the ultimate algorithm because it will eliminate preexisting HOAs while not introducing new HOAs during excimer laser ablation. Although I just recently started using the algorithm, my outcomes are excellent thus far.

Advanced Control Eyetracking. The latest hardware upgrade is Advanced Control Eyetracking, which uses a rotational tracker for alignment of the pupil through the end of the ablation.

Ease of use and speed have greatly been enhanced with the upgrades described above. It now takes only approximately 3 to 5 minutes to run the diagnostics on the Zyoptix Diagnostic Workstation. Data are automatically uploaded on the Zyoptix laser platform.

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The CRS-Master

BY PATRICK VERSACE, MD

The Zeiss Customized Refractive Surgery Master (CRS-Master; Carl Zeiss Meditec, Jena, Germany) is a powerful tool that facilitates the integration of diagnostic data with patient parameters and generates a customized ablation profile for the individual patient. The CRS-Master imports diagnostic and patient data, allowing the surgeon to plan and generate a customized treatment that may be based on spherocylindric refraction, wavefront, or topography, or asphericity-modulated to create blended vision.

The CRS-Master is locally networked with the Humphrey Atlas corneal topographer and the WASCA Analyzer (both by Carl Zeiss Meditec) for direct importation of topographic and wavefront data. Other patient information that can be entered by the user includes corneal pachymetry; K values, used to optimize peripheral energy correction and ablation profile; flap parameters, including standard deviation of thickness; refraction; ocular dominance; and monovision blur tolerance.

Diagnostic capture of topography and wavefront data allows eye tracking based on pupil features and a fixed limbal reference, ablation registration utilizing scotopic pupil center for wavefront-based treatments, and angle-Kappa compensation for topographic treatments. The CRS-Master allows user input to adjust pupil fit where needed. K values may be input manually or imported directly from the Atlas topographer. These values are used in the calculation of aspheric ablation profiles.

ABLATION PROFILES

Aspheric spherocylindric refractive ablations are generated using refraction and K values. Two aspheric profiles are offered: one designed to reduce ablation depth in borderline corneas and the other optimized for asphericity. Cyclotorsion compensation using iris and limbal registration is available for this and other treatment options.

Wavefront-guided treatments use manually entered refractive data and offer a choice of asphericity. The ablation is automatically centered on the pupil, referenced to the center used for the expression of the Zernicke terms. The WASCA is a high-resolution Shack-Hartmann aberrometer using 800 measured points over a 7-mm aperture. Wavefront treatments correct up to sixth-order Zernicke abberations. On-screen modeling demonstrates the PSF and MTF and simulates change in image quality with aberrations present and corrected.

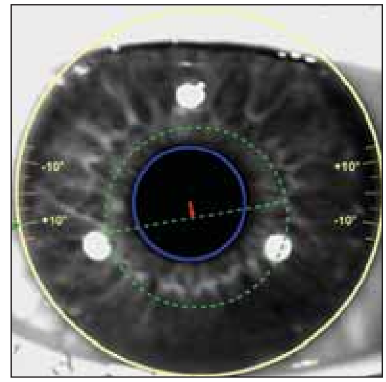

Figure 3. Cyclorotational, pupil center shift, and angle-Kappa compensation.

Topography-guided treatments may be purely topographic smoothing to correct corneal irregularity or topographic-refractive, in which refractive error is corrected at the same time that corneal irregularities are smoothed. Topographic treatments offer a good example of how the CRS-Master aids the surgeon in treatment planning and minimizes the risk of error. A topographic refractive treatment presents complexity in planning, as the refractive correction will modify the topography and vice versa. Centration of the topographic component of the ablation is aligned with topography (pupil center, which is the reference for the topography map) while the refractive component of the ablation is centered on the visual axis, which is automatically angle-Kappa–compensated to minimize induced coma (Figure 3). These two distinct ablations are mathematically integrated into one with reference to the interaction of the refractive and topographic components and the different requirements for ablation centration and overlap. Topographic treatments also target a final corneal shape optimized for asphericity.

Once a topographic treatment is created, the on-screen display models the target topography and ablation pattern. Tools are incorporated into the software to allow optimization of ablation depth. Z clip shifts the top layer of the ablation down so that some surface irregularities may be left in return for reduced ablation depth. Z shift reduces the ablation depth by raising the bottom layer of the ablation. Topographic treatments are appropriate in eyes with irregular astigmatism, reduced or decentered optical zone from prior surgery, and when an enhancement is required for a patient with reduced visual quality thought to be caused by surgically induced corneal aberrations.

Laser blended vision offers a bilateral ablation profile that corrects both refractive error and addresses presbyopia. The controlled induction of spherical aberration increases depth of focus in each eye, so that a small amount of monovision will provide functional near vision while retaining fusion and binocular function. The CRS-Master facilitates planning laser blended vision ablations. A default target refraction of 1.50 D for the near preference eye may be altered based on the patient's acceptance of monovision blur.

Diagnostic evaluation can be performed at any time prior to surgery. Wavefront and topography data are entered into the CRS-Master, and the treatment is generated. As pupil dilatation is not necessary for these measurements, same-day consultation and surgery is not compromised. If laser blended vision is to be performed, wavefront analysis is performed with a pupil size of at least 6 mm (using dilatation if needed) to give a reading for Z4,0 at 6 mm. Treatments are saved on a USB memory stick for uploading to the laser. The surgeon can review and regenerate any treatment at the CRS-Master if needed. A remote module allows extension of the CRS-Master so that diagnostic data may be uploaded to a remote computer, where installed software allows the surgeon to generate treatments or review diagnostic information such as topography and aberrometry and staff to have free access to the CRS workstation for patient measurements while the surgeon is simultaneously reviewing data and generating treatments.

Treatments can also be generated at the laser. Data input is less comprehensive than at the CRS Master, but for a simple spherocylindric treatment this may be adequate.

The integration of various diagnostic data sets into the one workspace facilitates cross-referencing and safety checks. On-screen warnings appear if an inappropriate parameter is set for a treatment—for example, if a treatment exceeds the recommended range for astigmatism, or if the calculated residual stromal thickness falls below the preset minimum value. Once a treatment is generated, no changes can be made without going back to the source data. This prevents inadvertent changes and ensures that the treatment delivered by the laser is as planned.

The CRS-Master is central to the Zeiss refractive surgery system. It allows true integration of disparate data sets and gives the flexibility required to adapt to new nomograms, treatment profiles, and surgical modalities. Generating customized laser refractive treatments is the key role of the CRS-Master. The device is also useful as an investigative diagnostic workspace for reviewing patient measurements. ■

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