23 The NIDEK Cataract Suite: The OPD-Scan III Multifunction Diagnostic Device and the AL-Scan Optical Biometer

Farrell C. Tyson, Stefan Pieger, and Harkaran S. Bains

The NIDEK Cataract Suite includes the OPD-Scan III multifunction diagnostic device and the AL-Scan optical biometer. In this chapter, we present the use of each of these devices for diagnostics, cataract surgery, premium intraocular lens (IOL) selection, IOL calculations, and postoperative assessment.

OPD-Scan III

The OPD-Scan III is a fundamental device for cataract diagnostics (Fig. 23.1). This device measures corneal topography, wavefront aberrations, autorefraction, keratometry, pupillometry, and pupillography on the same axis. This unique combination of measurements allows comprehensive preoperative and postoperative assessment of cataract surgery patients. The measurement of topography and whole eye wavefront allows separation of corneal and internal aberrations for rapid assessment of the refractive and optical effects of the cornea, physiologic lens, or an intraocular lens (IOL) (Fig. 23.2) [1].

F. C. Tyson (✉)
Tyson Eye, Cape Coral, FL, USA

S. Pieger
Ingenieurbüro Pieger GmbH, Wendelstein, Germany
e-mail: stefan@pieger.net

H. S. Bains
Sight By Design, Edmonton, AB, Canada

The OPD-Scan III measures aberrations using a unique method called dynamic spatial skiascopy [1]. This method utilizes optically conjugate projecting and receiving systems to measure aberration data in refractive diopters. A slit of infrared light is projected into the eye and rotated at 1° increments over 360°. Simultaneously, photodetectors rotate at the same rate and meridian as the projecting system and the time difference to stimulate individual photodetectors is converted into refractive power data (OPD maps).

Fig. 23.1 OPD-Scan III

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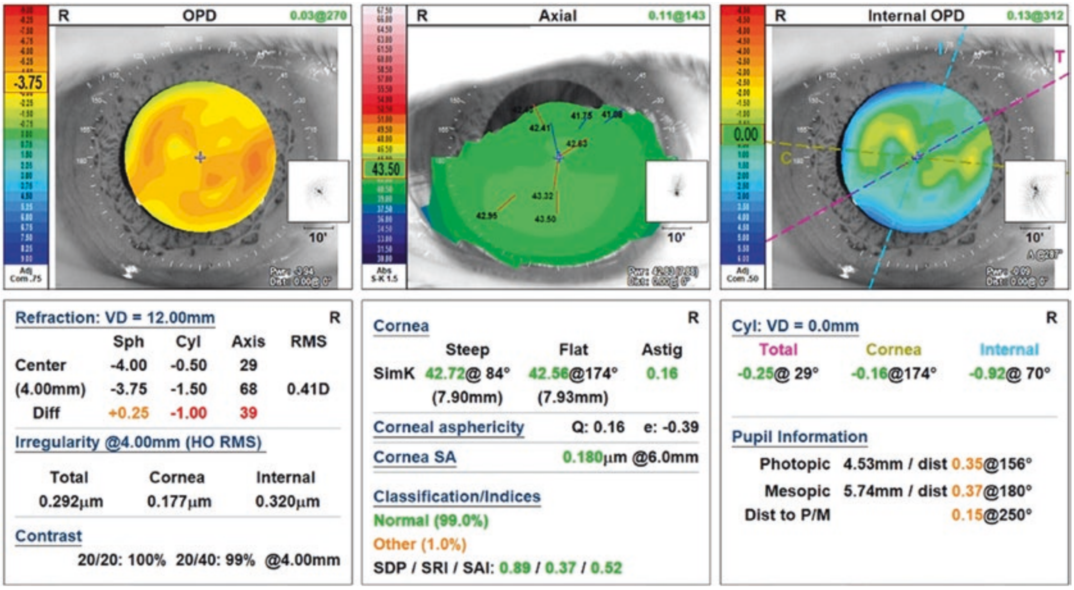

Fig. 23.2 Overview summary for preoperative evaluation of a patient with cataract. The top row presents the OPD map (top row left), axial corneal topography (top row, middle), and the Internal OPD map (top row, right). On the OPD and Internal OPD maps, cooler colors indicate hyperopia power, warmer colors indicate myopia, and green indicates emmetropia

The refractive power is then converted to traditional wavefront data (wavefront maps). The advantage of this method is a high range of measurement (−20 D to +22 D) and the ability to measure highly aberrated eyes. The OPD-Scan III measures 2520 data points and plots aberrations for pupil diameters up to 9.50 mm, out to the eighth Zernike order. The diameter and Zernike order are selectable to address the variability in physiologic pupil size. Corneal topography is measured with Placido disk technology that uses 33 rings to cover the corneal surface utilizing 11,880 data points. Multiple studies have verified the accuracy, repeatability, and reproducibly of the various functions of the OPD-Scan III [2–5].

Preoperatively, evaluation of the Placido mires during corneal topography allows the detection of subtle ocular surface abnormalities that may indicate dry eye. A pristine ocular surface is essential for accurate preoperative measurements to generate excellent postoperative outcomes. Distortions in the Placido mires can alert the surgeon to investigate for dry eye or other corneal pathology. A recent study from the US indicates that 80% of patients presenting for a cataract evaluation had objective signs of dry eye, yet only a small proportion had been previously diagnosed [6]. The OPD-Scan III includes a neural network module that screens the cornea for pathology such as keratoconus, keratoconus suspects, and pellucid marginal degeneration and classifies eyes that have undergone refractive surgery.

Corneal pathology such as anterior membrane dystrophy and Salzmann's nodules can cause irregular astigmatism that often warrants regularization of the cornea prior to IOL surgery. The combination of corneal, internal, and whole eye maps more readily facilitates patient discussion by showing the optical effects of corneal versus internal aberrations using the point spread function and Internal OPD maps. In patients with irregular corneal astigmatism undergoing IOL implantation, the PSF can be used to educate patients that there is preexisting pathology that is distorting vision and will not be corrected by cataract surgery and will prevent them from achieving optimal vision postoperatively (Fig. 23.3).

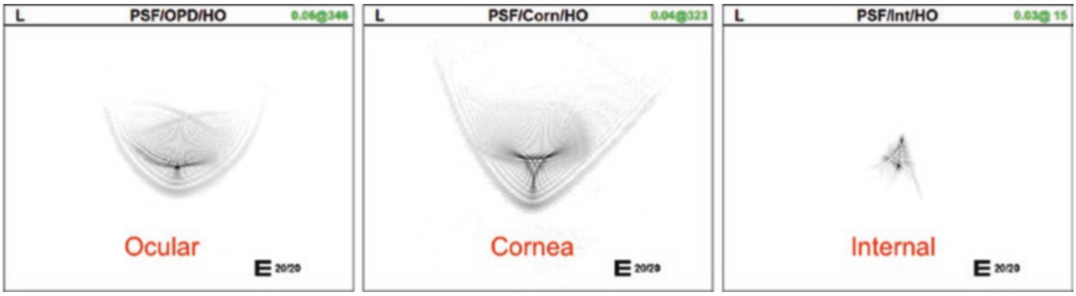

Fig. 23.3 Point spread function (PSF) from the higher-order aberrations of the entire eye (right, PSF/OPD/HO), cornea (middle, PSF/Corn/HO), and internal aberrations (left, PSF/OPD/HO) of a patient with pellucid marginal degeneration and cataract. The ocular and corneal PSF patterns are very similar and can used for patient education to explain the source of visual phenomena

The extensive data and multiple maps facilitate preoperative evaluation, surgical planning, and postoperative assessment from normal eyes to complex cases. The Overview summary presents information on refraction, corneal topography, the OPD (the whole eye), Internal OPD (everything behind the front corneal surface), pupil size, corneal astigmatism, and image quality (Fig. 23.1). This summary can be used as a screening tool for most patients. The Overview layout allows evaluation of whether corneal or internal pathology (cataract) is present and the effect on the whole eye. For example, in Fig. 23.1, the axial topography map indicates less than 0.25 D of corneal astigmatism and the Classification/Indices indicates a normal cornea. However, the OPD map and the Internal OPD maps are irregular with patterns that are similar to each other (Fig. 23.2). Additionally, the Internal OPD has −0.92 D of cylinder whereas the total and corneal astigmatism is relatively small (Fig. 23.2). Taken together, these observations indicate the source of irregularity and higher order aberrations are from the internal aspects of the eye, most likely a cataract. Clinical examination verified a visually significant cataract. The changes in the Internal OPD can be used to follow the development of the cataract and used for patient education. The Internal OPD is an excellent way to evaluate the position or possible rotation of a toric IOL.

In addition to qualitative assessment, the OPD-Scan III generates multiple values that are required for IOL calculations, surgical planning, and astigmatism management. These values include refraction, simulated keratometry (simKs), corneal spherical aberration, and Corneal Diameter (Table 23.1). The flat and steep meridians of the cornea are marked for surgical planning, including toric IOL alignment, placement of the incisions, and placement of limbal relaxing incisions. To address the accuracy of keratometry in cases with irregular corneal astigmatism, the average pupillary power (APP) is a potential alternative to simK values. The APP is the average of all the keratometry values within the photopic or mesopic pupil or at a selectable diameter, whereas the simK value is an average of 2 orthogonal keratometry values. In post-refractive surgery cases, the effective central corneal power (ECCP), developed by Jack Holladay MD, corrects traditional keratometry values by using the central mean 4.5 mm corneal refractive power and data from the unchanged corneal periphery to estimate the amount of refractive correction. The ECCP avoids the keratometric refractive index error in cases of post-myopic refractive surgery cases. In post-myopic ablation cases, the average simK values are too high leading to selection of an IOL power that results in a hyperopic outcome. In post-hyperopic ablation cases, the simK values are too low resulting in a myopic outcome after IOL implantation. Hence if conventional IOL calculation formulas are used, the ECCP can be a more appropriate keratometry value for IOL selection in post-refractive surgery cases. ECCP should not be used in post-refractive surgery formulas such as

Table 23.1 OPD-Scan III metrics used for intraocular lens selection and centration

Metric	Use in intraocular lens calculations
Simulated keratometry	Normal, virgin eye
Average pupillary power (APP)	Keratometry for irregular corneal astigmatism
Effective central corneal power (ECCP)	Keratometry for post-refractive surgery eyes
Corneal spherical aberration	Aspheric lens selection
Horizontal corneal diameter	Used in some fifth generation formulas and for phakic intraocular lens selection
Refraction	Selection of lens power
Axis of astigmatism	Toric IOL implantation, incision placement
Intraocular lens centration landmarks	Photopic angle kappa (Chord μ) Mesopic angle kappa Angle alpha (LDist on the OPD-Scan III) Photopic line of sight (pupil center) Mesopic line of sight
Photopic and mesopic pupil diameters	Multifocal lens selection
Corneal higher order aberrations	Multifocal lens selection

Haigis L, Shammas PL, or Barrett True K as the keratometric index error is internally compensated for in these formulas and using ECCP would result in double compensation.

The advent of premium IOLs has resulted in stringent tolerances for centration and alignment. To address these criteria, the OPD-Scan III includes multiple IOL centration landmarks (shown on multiples map and images) including the photopic and mesopic angle kappa (Chord μ), angle alpha, and the photopic and mesopic line of sight (pupil center) (Table 23.1). Centration landmarks can assist with IOL selection. For example, patients with photopic angle kappa (Chord μ) values greater than 0.5 mm may be poor candidates for some multifocal IOL implants. Some have advocated angle alpha (LDist value on the OPD-Scan III, Table 23.1) as a better predictor of postoperative IOL centration.

Other indices and displays for IOL selection criteria include corneal spherical aberration, Corneal Diameter, pupillometry, and pupillography. For example, patients with small physiologic pupils or misshaped pupils may not be candidates for premium presbyopic IOLs. Corneal spherical aberration is routinely used to select the appropriate aspheric IOLs for implantation. In post-hyperopic ablation cases, the increased negative spherical aberration generally indicates a spherical monofocal is more appropriate as implantation of an IOL with negative spherical aberration increases the overall magnitude of spherical aberration resulting in visual degradation akin to keratoconic corneas.

The most common summary map sets for assessing candidates for cataract surgery include the Daya Cataract Summary (developed by Sheraz Daya MD) and the Cataract Summary. Both of these predefined map sets allow quick evaluation of a candidate for cataract surgery addressing, whether the cornea is normal, the relevant corneal power values, optical quality of the cornea, corneal spherical aberration, corneal higher order aberrations, corneal cylinder, and landmarks for IOL centration. Hence, these summaries allow quick assessment of many of the relevant screening parameters for cataract surgery. Figure 23.3 presents the use of the Cataract Summary in a patient referred for cataract assessment. In this case, the corneal astigmatism was oblique, the corneal power was on the high end of normal yet within normal limits. However, the corneal screening software classified this patient as a keratoconus suspect, alerting the surgeon to delay surgery and observe the patient for signs of progression. The Cataract Summary also includes the predicted visual acuity (PVA) of the cornea for uneventful surgery with a well-centered monofocal IOL (Fig. 23.4). As this case was a keratoconus suspect, the corneal changes were too subtle to effect optical quality at presentation as indicated by the PVA (20/20) and corneal higher order visual acuity simulation chart (Fig. 23.4).

Postoperative assessment of an excellent outcome after multifocal IOL implantation is presented in Fig. 23.5. In this case of a well-centered

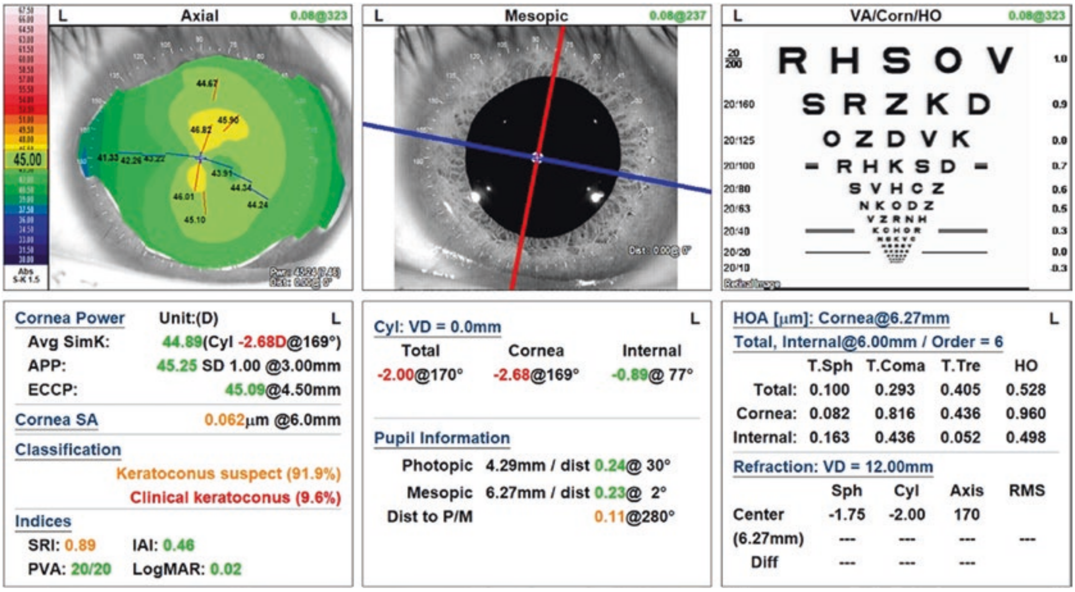

Fig. 23.4 Cataract summary of a keratoconus suspect, showing the axial topography map (top row, left) the pupil image (top row, middle) marked with the flat (blue) and steep (red) meridians on corneal topography and the simulation of corneal visual quality (top row, right). The corneal screening neural network (bottom row, left) classified this patient as a keratoconus suspect

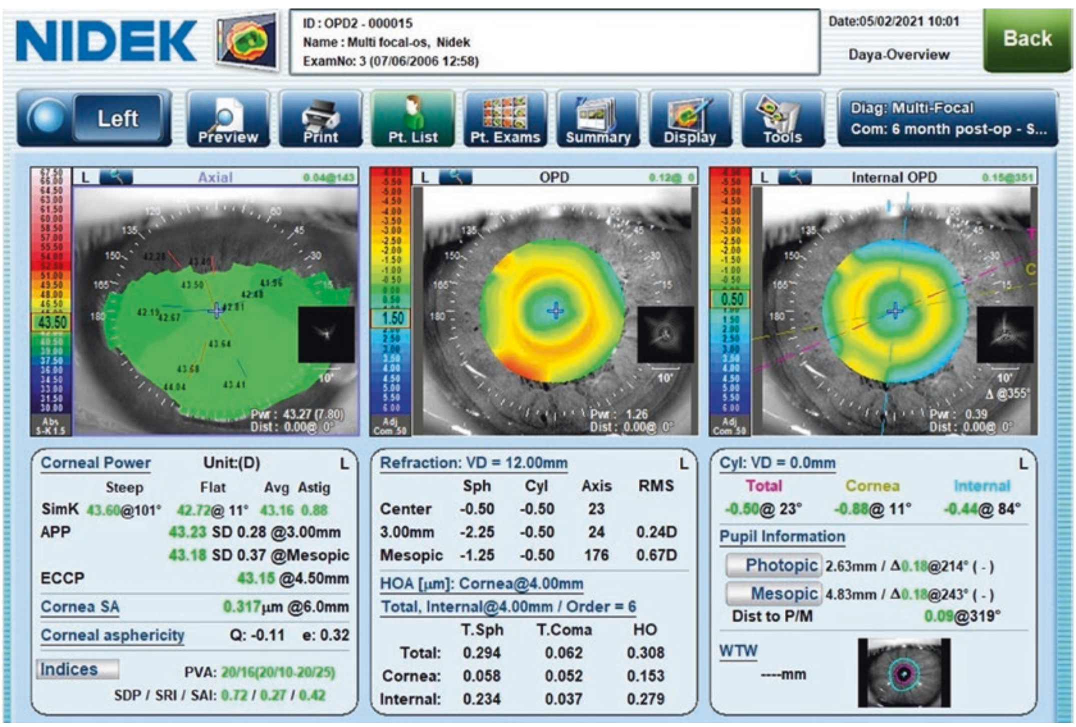

Fig. 23.5 Example of OPD-Scan III measurement of a multifocal intraocular lens implant. Showing axial corneal topography (top row, left), OPD map (top row, middle), and Internal OPD map (top row, right). On both OPD maps, the cooler colors indicate hyperopic powers, the warmer colors indicate myopic powers, and green indicates emmetropia. The central refraction in this case (bottom row, center box) was −0.50-.05X23° indicating an excellent outcome

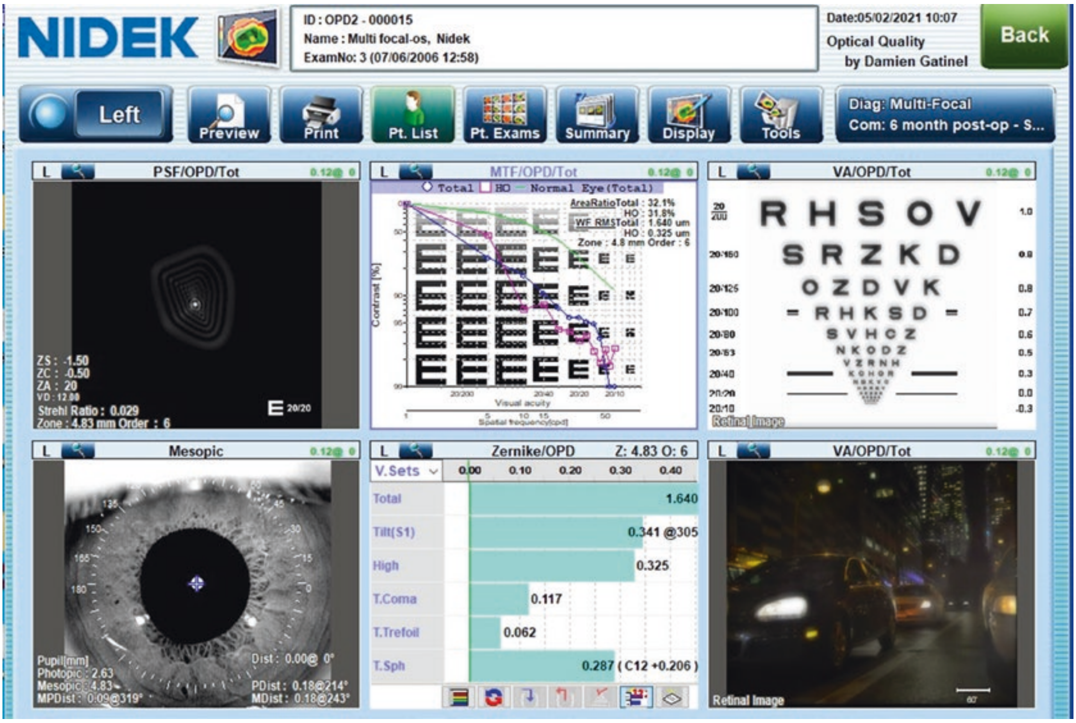

Fig. 23.6 Optical Quality summary of an eye with a multifocal intraocular lens implant with a residual refraction of −0.50-.05X23°. The modulation transfer function indicates a mild decrease in visual performance of the uncorrected (dark blue curve) and corrected eye (pink curve) compared to a that of an average curve of emmetropic patients with excellent visual quality (green curve). The point spread function (top row, left), visual acuity chart simulation (top row, right), and retinal image of night driving (bottom row, right) indicate a mild decrease in optical quality. Overall, this patient is expected to have good functional vision for the range of daily living activities

IOL, the alternating, ring-like pattern corresponds to the effect of the multifocal IOL power on the OPD and Internal OPD maps (Fig. 23.5). Using the Optical Quality summary (developed by Damien Gatinel MD PhD) to assess this case indicates an expected diminution in visual performance (modulation transfer function) and optical quality (visual acuity simulation chart and the retinal image simulation of night driving) due the multifocal optics, but the patient should have good overall functional vision (Fig. 23.6).

The Internal OPD, toric summary, or retroillumination maps are routinely used to evaluate toric IOL alignment, light adjustable lens power, tilt, and torque. Figure 23.4 presents an example of a retroillumination image for a misaligned IOL. The total refractive cylinder was 1 D after toric IOL implantation, and the internal cylinder was 1.95 D indicating that most of the cylinder power was originating from the IOL. The retroillumination image allowed assessment of the magnitude of misalignment (Fig. 23.7). Prior to surgery, toric IOL placement can be digital marked with the Toric summary by aligning the green line with a prominent iris crypt or scleral vessel and saving a digital copy of the image (or a printout) for the operating room.

The OPD-Scan III represents the first step in evaluating cataract surgery patients and for selection of premium IOL surgery candidates. In the context of the current pandemic (COVID-19), the OPD-Scan III is effectively a multiple-instrument device, increasing patient and staff safety by limiting movement from unit to unit within the clinic. Postoperatively, the OPD-Scan III is used to assess visual performance, toric IOL alignment, and IOL centration. This device can also be used to determine the source of visual phenomena if is refractive or optical.

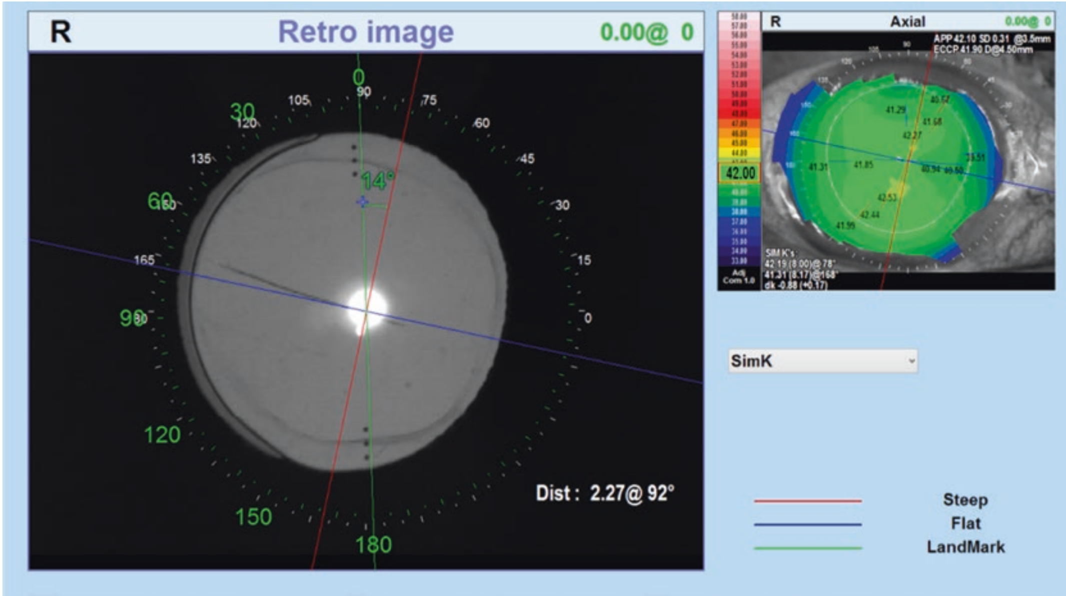

Fig. 23.7 Retroillumination image from the OPD-Scan III showing a misaligned toric intraocular lens. The red line denotes the steep corneal meridian, where the IOL should have been alignment and the blue line denotes the flat meridian. The green line can be rotated to display the difference from the steep axis (14° in this case). The inset to the top right displays the axial corneal topography

AL-Scan Optical Biometer

The AL-Scan is an optical biometer with Scheimflug imaging. Optical biometry is performed using partial coherence interferometry with an 830-nm super-luminescent diode. Scheimflug imaging is performed centrally to measure corneal thickness and anterior chamber depth. The combined functions present data on axial length, keratometry, anterior chamber depth, central corneal thickness, Corneal Diameter, pupillometry, and pupillography. The device includes a three-dimensional eye tracker and autoshot function (that can be turned on/off) to perform all the measurements within 10 s per eye, increasing office efficiency and patient flow (Fig. 23.8). The accuracy, repeatability, and reproducibility of the AL-Scan have been previously documented [7–9]. Two recent comparisons of the AL-Scan to swept source optical coherence tomography have reported clinically insignificant differences between devices [10, 11].

Fig. 23.8 AL-Scan

Axial length values are generated using multiple readings and selecting the one with the highest signal-to-noise ratio. Generally, the higher the signal-to-noise ratio, the more reliable the measure-

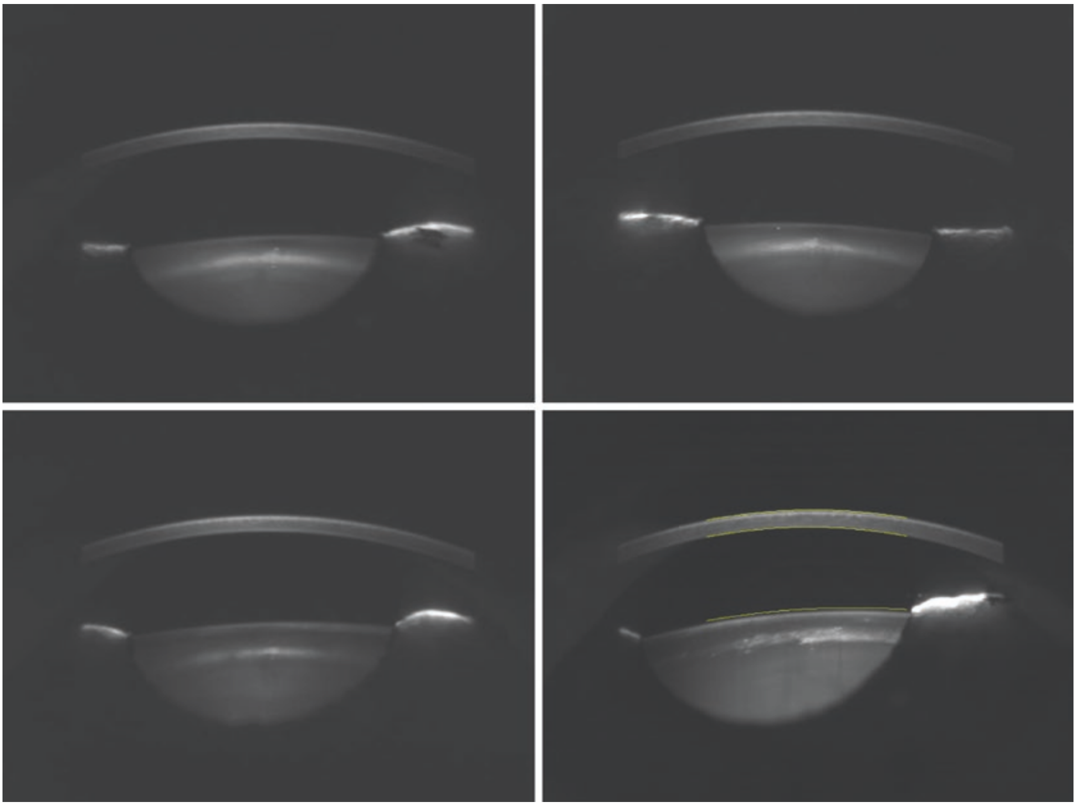

Fig. 23.9 Sample Scheimpflug images of the anterior chamber using the AL-Scan optical biometer

ment. In cases with dense cataracts, axial length can be measured by acquiring multiple readings and averaging the readings using algorithms to enhance the signal-to-noise ratio. For extremely dense cataracts, a built-in ultrasound A-scan is available with the device and can be used without having to transfer the patient to another device.

The keratometry measurements are performed with over 300 data points at each of two diameters at 2.4 mm and 3.3 mm. Historically, keratometers and optical biometers have measured corneal power at 2.4 mm diameter and IOL constants have been optimized for this diameter; hence, NIDEK elected to measure values at this diameter. Autorefractors/keratometers generally measure corneal power at 3.3 mm and IOL constants for contact ultrasound biometry are based on 3.3 mm diameter; hence, this diameter was selected for consistency to historic norms. In our experience, ptosis may yield differing delta K values between the two diameters. In cases with poor eye exposure due to lid laxity, we generally use the 2.4 mm values. For toric IOL implantation, only the 2.4 mm values are strongly recommended. The IOL calculation in the device allows selection of optical and immersion ultrasound IOL constants.

Pupil size and Corneal Diameter are automatically measured using the captured image. Manual measurement can be performed in cases with iris or conjunctival pathology. Anterior Scheimpflug imaging captures an image of the anterior chamber to automatically measure central corneal thickness and anterior chamber depth (ACD) (Fig. 23.9). Along with visual inspection of the image, ACD imaging quality checks are included to allow the user to ensure a good image was acquired.

A Toric Assist Function is available in the device to plan toric IOL alignment and for the

Table 23.2 Intraocular lens calculation formulas in the AL-Scan and Viewer software for normal and post-refractive surgery

IOL calculation formula	Comment/remarks	Post-refractive surgery
Barrett suite	Barrett universal II	
	Barrett Toric formula	
	Barrett true-K formula Post-myopic and post-hyperopic LASIK History and no history method Can be used for post-RK cases	✓
Holladay I		
Haigis	Full benefit only through triple optimization	
	With ECCP from OPD-scan III	✓
SRK	SRK/T	
	SRK II (not recommended for use, replaced by SRK/T)	
	SRK (not recommended for use, replaced by SRK/T)	
Binkhorst	Binkhorst (not recommended for use)	
Hoffer Q		
Camellin-Calossi	History and no history method Can be used for post-RK cases	✓
Shammas PL	Only for post-myopic LASIK	✓

LASIK laser in situ keratomileusis, *ECCP* effective central corneal power, *RK* radial keratotomy

Barrett Toric formula, an image is presented of the ideal rotational lens position incorporating surgically induced astigmatism due to the incision axis. As with all biometers, the device will automatically calculate the ideal IOL power without requiring additional data.

Table 23.2 presents the IOL calculation formulas available for normal unoperated corneas and post-refractive surgery eyes on the AL-Scan and the Viewer add-on software.

In our experience, a major advantage of the AL-Scan is the ease of use and the rapid acquisition of data. Using the assumption of 100 patients exams a day and that most of the other biometry devices take at least 30 s (or longer) per eye to acquire data, the AL-Scan frees up 1 h 40 min during the day. In summary, the AL-Scan increases patient flow and includes a comprehensive complement of IOL calculations for addressing normal, unoperated eyes and eyes that have undergone excimer laser surgery or radial keratotomy.

Putting It All Together

Using the OPD-Scan III, AL-Scan and related software packages provide a number of advantages. Clinically, the devices can serve as a double check on each other for measurements such as keratometry, pupil size, pupil shape, and IOL alignment. In the era of premium lens surgery, this is especially important as patients demand excellent postoperative outcomes. For premium IOL selection, preoperative patient education is fundamental and the OPD-Scan III is ideal with the various visual acuity performance simulations of the cornea and internal aspects of the eye (Fig. 23.10). The use of corneal power values such as the APP and ECCP allow treatment of complex cases such as irregular corneal astigmatism and post-LASIK eyes, respectively. Additionally, the multifunction utility of both devices, ease of use, and quick data acquisition make them ideal for in-office efficiency and patient safety. The combination of both devices is ideal for the entire patient (and surgeon) journey from preoperatively, surgical planning to postoperatively.

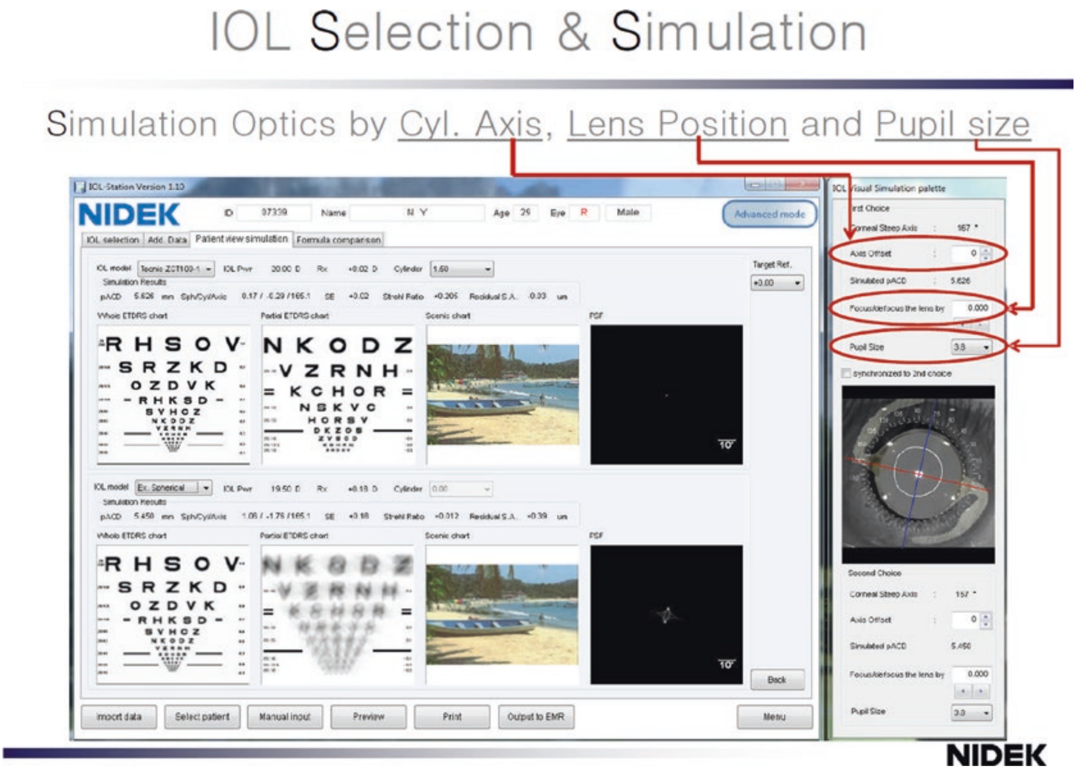

Fig. 23.10 IOL Station software that selects the ideal lens based on cornea spherical aberration and corneal cylinder and simulates the visual performance based on the lens selection (the selections can be modified). The visual acuity simulations, scenery, and point spread function can be used for patient education

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