ABSTRACT

PURPOSE: To show the clinical use of the NIDEK OPD-Scan wavefront aberrometer and OPD-Station software in anterior segment surgery and pathology.

METHODS: Case examples are presented along with discussion about the relevant clinical data obtained from the OPD-Scan and OPD-Station software.

RESULTS: Six case examples including cataract surgery, secondary IOL implantation, phakic intraocular lens surgery, pterygium surgery, contact lens fitting, and multifocal ablations are discussed.

CONCLUSIONS: A complete understanding of the optics of the eye facilitates a better clinical comprehension of a variety of conditions in anterior segment surgery and pathology. [J Refract Surg. 2006;22:S1014-S1020.]

Wavefront aberrometers are increasingly used in mainstream ophthalmology. Wavefront aberrometers provide the critical first step in the measurement and correction of the spherical and cylindrical components of the refractive error in addition to the higher order aberrations of the visual system that affect visual performance. The ability to acquire a more detailed measurement of the optics of the eye may allow for achieving optical visual outcomes beyond those currently seen using conventional subtractive or additive refractive surgical procedures.\(^1,\)\(^2\)

Wavefront aberrometers are tools to diagnose visual complaints of optical origin. Hence, the use of wavefront sensors should not be restricted to the field of wavefront-guided laser correction but should be used in any clinical situation that requires precise assessment of the optical quality of the eye. The crystalline lens and the cornea contribute to the optical quality of the eye by balancing their respective aberrations in normal eyes.\(^3,\)\(^4\) The recent introduction of aspheric intraocular lenses (IOLs) to reduce the total spherical aberration and improve the optical quality of the pseudophakic eye is one potential application of aberrometry. Ideally, one may want to quantify the aberrations of the cataractous eye preoperatively to select the best IOL shape that would compensate for the corneal spherical aberration. This would require precise measurements of the preoperative corneal spherical aberration. Wavefront aberrometry could also be used postoperatively to determine the induced aberrations and their effect on visual quality. However, only a few aberrometers exist that can separately quantify the aberrations of the anterior corneal surface and internal optics of the eye.

In this article, we describe the use of one such aberrometer, the NIDEK OPD-Scan with OPD-Station software (NIDEK Co Ltd, Gamagori, Japan), in anterior segment surgery and pathology, separate from its use in customized ablations, and show its application as an “everyday practice tool.”

From the Rothschild Foundation, YAP-HP Bichat Claude Bernard Hospital, Paris VII University, Paris, France.

The authors have no financial interest in the materials presented herein.

Correspondence: Damien Gatinel, MD, 25 rue Manin, 75019 Paris, France.
E-mail: gatinel@aol.com
PATIENTS AND METHODS

Six patients undergoing anterior segment surgery are used to illustrate the use of the NIDEK OPD-Scan with OPD-Station software as an aid in clinical assessment, diagnosis, and treatment planning. The OPD-Scan is a multifunction instrument that combines Placido-based corneal topography with wavefront aberrometry of the entire eye. This wavefront measuring apparatus is based on retinoscopic principles that use a slit of infrared light to scan along all 360° meridians over a 6-mm pupil. The timing and scan rate of the reflected light are analyzed with an array of photodetectors to determine the wavefront aberrations along each meridian.

In addition to the determination of an accurate refraction,5 the OPD-Scan provides a complete set of maps, including four different corneal topography maps, local refractive power of the entire eye due to aberrations at various locations within the pupil, a variety of wavefront aberration maps, and photopic and mesopic pupillometry.6 By computing the corneal wavefront aberration and comparing it with the total wavefront map, it is possible to estimate optical quality due to the internal aberrations of the eye. The internal aberrations represent all aberrations behind the anterior corneal surface. The data provided by the OPD-Scan can be further processed using the OPD-Station software to compute useful metrics of optical quality such as the modulation transfer function (MTF) or to simulate maximum contrast visual acuity charts corresponding to the entire eye, cornea, or internal aberrations. The MTF corresponds to the variation of image contrast with spatial frequency for an object with 100% contrast. The MTF is a quantitative measure of image quality that is far superior to classic resolution criteria, because it describes the ability of the eye to transfer object contrast to the image. The MTF corresponds to the ratio of image contrast to object contrast as a function of the spatial frequency of a sinusoidal grating. The MTF describes the contrast at each spatial frequency, usually normalized to range from zero to one, zero being gray (no contrast) and one being perfect black/white contrast. If an object grating of a given spatial frequency is imaged by the eye, the intensity contrast of adjacent bars in the image at the same spatial frequency will be given by the transfer function. Perfect imagery of black/white motifs corresponds to a transfer function of one. Conversely, when the transfer function is zero, the bars in the image will undergo complete washout and appear as continuous shades of gray. The OPD-Station software allows the determination of the MTF of the entire eye as well as for each of its main optical components (cornea and lens). In addition, the effect of total higher order aberrations, specific aberrations (eg, spherical aberration), and combinations of aberrations on the MTF and visual acuity charts can be determined.

CASE EXAMPLES

PRIMARY CATARACT SURGERY

Case 1. A 55-year-old man presented with unilateral reduced vision. The patient wore spectacles with the
following prescription: $-6.00 \pm 1.25 \times 10^\circ$ (20/20) in the right eye and $-9.00 \pm 1.00 \times 90^\circ$ (20/20) in the left eye. Upon further discussion, the patient described reduced vision at night in the right eye, along with the perception of halos at night.

OPD-Scan/OPD-Station analysis of the aberrations of the entire eye showed increased levels of higher order aberrations in the right eye (root-mean-square [RMS] 0.730 µm) compared with the left eye (RMS 0.302 µm) (Figs 1A and 1B). Spherical aberration in the right eye (RMS 0.496 µm) was considerably higher than in the left eye (RMS 0.191 µm) (see Figs 1A and 1B). Corneal spherical aberration was similar in both eyes, measuring 0.119 µm for the right eye and 0.172 µm for the left eye. The difference in spherical aberration must have been due to changes in lens shape and refractive index resulting from the greater nuclear sclerosis in the right eye. A well-developed cataract was seen in the right eye and mild nuclear opalescence in the left eye with slit-lamp microscopy.

**SECONDARY IOL IMPLANTATION**

Case 2. A 25-year-old man was referred for secondary IOL implantation in the right eye. During his first decade of life, the patient had undergone intracapsular crystalline lens extraction. Spectacle correction was +6.50, yielding 20/20 best spectacle-corrected visual acuity (BSCVA). Preoperative slit-lamp examination revealed a persistent peripheral zonular and capsular rim. The preoperative OPD-Scan map showed an even distribution of hyperopic refractive power across the open pupil (Fig 2A). Comparison of the axial map and higher order map indicate that the aberrations are likely corneal (see Fig 2A).

An AcrySof MA50BM 21.00 diopter (D) spherical IOL (Alcon Laboratories Inc, Ft Worth, Tex) was implanted in the ciliary sulcus through a 3.2-mm incision placed superotemporally, centered on the 150° meridian. The postoperative course was uneventful. Two months postoperatively, uncorrected visual acuity (UCVA) was 20/25, and BSCVA was 20/20 with a man-
Manifest refraction of plano $-0.50 \times 150^\circ$. Postoperatively, the OPD-Scan map showed an uneven distribution of refractive power caused by a slight increase in some of the higher order aberrations such as coma-like and spherical aberrations (Fig 2B). The higher order aberrations increased from 0.658 µm preoperatively to 0.737 µm postoperatively. Coma increased from 0.194 µm preoperatively to 0.566 µm postoperatively. Spherical aberrations increased from 0.230 µm preoperatively to 0.397 µm after insertion of the spherical IOL. OPD-Station analysis revealed that corneal higher order aberrations decreased from 1.100 µm preoperatively to 0.909 µm postoperatively. The lower corneal aberrations postoperatively are likely due to the beneficial effects of the 3.2-mm incision on the corneal shape, improving its regularity while reducing both the second order corneal-induced astigmatism and some of the corneal higher order aberrations (see Figs 2A and 2B). Hence, the increase in higher order aberrations seen postoperatively is likely due to the internal optics of the eye. The increase in spherical aberrations due to internal origins is likely due to implantation of a spherical IOL. The increase in coma seen postoperatively is likely due to less than optimal centration of the implanted IOL.

**PHAKIC IOL SURGERY**

*Case 3.* A 35-year-old man who had undergone $(-15.00$ D) Artisan lens implantation 3 months previously was satisfied with his vision during the day; however, he complained about halos and monocular vertical diplopia at night. OPD-Scan analysis showed that higher order aberrations were $>3$ µm, which is considered very high (Fig 3A). A coma pattern dominates the higher order map, and third order coma has the highest magnitude in the Zernike graphs (Figs 3A and 3B). Slit-lamp examination revealed a slight inferior decentration of the Artisan lens, exposing a crescent of pupil superiorly. The OPD-Scan and internal OPD-Scan maps in Figure 3A show a superior "myopic rim" of persistent myopic power within the pupil corresponding to the crescent of pupil not covered by the phakic IOL. The coma aberrations are highest from
Anterior Segment Assessment With the NIDEK OPD-Scan/Gatinel & Hoang-Xuan

the internal optics of the eye (see Fig 3B). Hence, the aberrations were arising from the internal optics of the eye due to the decentered IOL. Centration of the IOL relieved the patient’s symptoms.

**PTERYGIUM SURGERY**

*Case 4.* A 38-year-old man was referred for pterygium evaluation in the right eye. Preoperative UCVA was 20/40 and BSCVA was 20/25, with a manifest refraction of +2.00 -4.00 × 180°. The patient complained of glare and permanent horizontal monocular diplopia that increased with spectacle correction. The preoperative OPD-Scan map shows multiple myopic and hyperopic areas within the pupil likely causing the diplopia and degradation of visual quality (Fig 4A). High magnitudes of coma and trefoil were present preoperatively. The preoperative simulations of the optotype images with and without best spectacle correction for a photopic pupil show significant degradation of visual quality. The patient underwent pterygium excision and limbal autograft under local anesthesia, which resulted in immediate improvement of the UCVA and BSCVA with concurrent resolution of the glare and monocular diplopia (Fig 4B).

Postoperatively, the magnitude of trefoil and coma were significantly reduced. This reduction was likely due to a combination of mechanisms, including the reduction of tear film pooling beneath the pterygium head and the release of corneal traction by the pterygium.

**CONTACT LENS FITTING AFTER COMPLICATED REFRACTIVE SURGERY**

When further surgical intervention is not possible after excimer laser refractive surgery, rigid contact lenses may be a useful alternative. The OPD-Scan can be used as an aid to contact lens fitting and selection. For example, during the trial lens-fitting procedure, the eye can be measured with the contact lens in place to determine which contact lens provides optimum visual acuity and visual quality. The magnitude of higher order aberrations, the area under the MTF, and the point spread function (PSF) are objective metrics that can be used during contact lens fitting.

*Case 5.* A 28-year-old woman was referred for the management of a decentered ablation after LASIK in her left eye. Uncorrected visual acuity was 20/30 and BSCVA was 20/25 with a manifest refraction of...
Anterior Segment Assessment With the NIDEK OPD-Scan/Gatinel & Hoang-Xuan

The patient complained about glare, vertical diplopia, and reduced contrast. The decentered ablation was not easily seen on axial corneal topography, but it was clear on the OPD-Scan map. The estimated residual posterior bed thickness was <250 µm and therefore further excimer laser treatment was not performed. Rather, a rigid gas permeable (RGP) contact lens fit was chosen as the appropriate treatment for this patient. Different types of RGP contact lenses were fitted to restore satisfactory UCVA and visual quality. Our selection criteria for the contact lens were based on the standard contact lens fitting parameters and assessing which contact lens yielded a greater reduction in the higher order aberrations, the largest area under the MTF curve, the sharper PSF, and sharper visual acuity simulation. Comparison of Figures 5A and 5B show that a Menicon (Nagoya, Japan) RGP contact lens with reverse geometry and smaller central radius provided a sharper PSF and clearer visual acuity simulation due to reduced levels of high order aberrations. Based on these parameters, we elected to provide the patient with a Menicon RGP contact lens. Upon subjective comparison, the patient preferred the Menicon RGP lens with a smaller central radius curve. An MTF graph showed a larger area under the curve after contact lens insertion, indicating better visual performance. Although contrary to conventional thinking, greater levels of higher order aberrations do not necessarily portend reduced visual quality, because different combinations of higher order aberrations may interact in a manner that is beneficial to visual quality. Therefore, we recommend using a variety of metrics of optical visual quality in combination rather than relying on a single metric to determine the effect of higher order aberrations on vision.

CHARACTERIZATION OF MULTIFOCALITY

The compensation of presbyopia can be achieved by increasing the multifocality of the eye. Multifocality can be achieved by fitting multifocal contact lenses, performing multifocal corneal ablations, or implanting an accommodating IOL. The effect of induced multifocality on the optical quality of the eye is an important factor in patient satisfaction.

**Case 6.** A 52-year-old woman underwent hyperopic LASIK for a preoperative refractive error of +3.50 +1.00 × 180°. Postoperatively, UCVA was 20/25, and the patient could read J2 at near uncorrected vision. The patient was satisfied with the outcome of the surgery, because it provided her with excellent functional results for both near and far vision. The corneal topography map showed marked steepening and an inferior decentration. However, the OPD-Scan map showed emmetropia centrally and increasing myopia up to −1.50 D inferiorly (Fig 6). The multifocality shown on the OPD-Scan map explains the excellent near and far uncorrected vision. Treatment for this patient demonstrates the importance of measuring the full optical properties of the eye rather than one aspect, such as corneal topography. In this particular patient, corneal topography evaluation alone would lead to the conclusion that this had been an unsuccessful procedure.
DISCUSSION
The precise qualitative and quantitative assessment of the main components of the eye’s optical system (cornea and crystalline lens) facilitates a better understanding of the patient’s symptoms in various clinical conditions other than customized laser refractive surgery. Modern cataract surgery and complex contact lens fitting represent a wide range of applications for the use of devices such as the OPD-Scan, which can measure corneal and internal optical quality. We believe that the use of the OPD-Scan will become an indispensable tool in daily ophthalmology practice.

REFERENCES