The Use of NIDEK OPD Scan II Wavefront Aberrometry in Toric Intraocular Lens Implantation

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ABSTRACT

PURPOSE: To present case examples outlining the use of wavefront aberrometry for toric intraocular lens (IOL) implantation pre- and postoperatively.

METHODS: Twelve eyes that underwent AcrySof Toric IOL (Alcon Inc Laboratories) implantation were assessed pre- and postoperatively using the NIDEK OPD Scan II (NIDEK Co Ltd). Wavefront aberrometry, corneal topography, and objective visual quality were measured using the OPD Scan II with OPD-Station software. The internal and corneal aberrations were evaluated separately to determine whether the source of astigmatism was corneal, internal, or a combination of both.

RESULTS: All IOLs were implanted using a 2.75-mm incision. Wavefront aberrometry was used to determine the position of the incision to minimize postoperative astigmatism. The postoperative objective visual quality and wavefront maps were used to determine the effect of residual irregular or regular astigmatism.

CONCLUSIONS: The OPD Scan II determines whether irregular or regular astigmatism is due to the corneal surface or to the internal aberrations of the eye. The magnitude, type, and location of astigmatism can guide the proper placement of toric IOLs.

The cornea is the major refracting element of the eye, accounting for approximately 43.00 diopters (D) at the apex. With an average radius of curvature of 7.80 mm, the major refractive element is the front corneal surface (or tear film) compared with the posterior surface. Corneal shape and refractive power both provide a measure of corneal astigmatism. Accurate measurement and orientation of astigmatism may improve visual quality and patient satisfaction from surgical or optical treatments. Corneal topography measures both corneal shape and astigmatism using Placido-disk reflection from the tear film.

Using corneal topography, keratometry is measured and the curvature of different corneal meridians is determined. The image size of the reflex is converted to corneal radius using the mathematical relationship:

$$r = 2a \frac{Y}{y}$$

where $r$ = anterior corneal radius, $a$ = distance from keratometer's mire to cornea, $Y$ = image size, and $y$ = mire size.

The corneal radius is converted to refractive power using the relationship:

$$RP = \frac{337.5}{r}$$

Corneal topography allows the quantitative and qualitative assessment of the cornea using a set of color-coded maps. Corneal topography can determine the magnitude, location, and extent of irregular astigmatism.

In an astigmatic cornea, there is an increase in the curvature along one meridian forming a toroidal surface. This toroidal surface usually has orthogonal maximum and minimum curvatures. The orientations that contain the maximum curvatures are the principal meridians and have different powers forming foci at different points. Astigmatism is regular when the principal meridians are perpendicular to each other.
other and in this case is correctable with conventional spherocylindrical lenses. However, irregularly shaped corneas that cannot be described by spherical or toric sections have irregular astigmatism where the principal meridians are not perpendicular to each other.

Corneal astigmatism is expressed in diopters as the difference between the two principal meridians. Most human eyes have varying magnitudes of astigmatism that occur due to the corneal surface in the majority of cases or the crystalline lens in some cases. In other cases, the lens and cornea both contribute to refractive astigmatism. Astigmatism due to the crystalline lens can occur due to the front and/or back surfaces or due to a physiologic tilt with respect to the cornea (oblique astigmatism).

The effective correction of astigmatism is fundamental to refractive cataract surgery. The implantation of toric intraocular lenses (IOLs) has allowed better management of astigmatism leading to spectacle independence for increasing numbers of cataract surgery patients. The placement and size of the incisions are fundamental in minimizing postoperative astigmatism. Our preferred approach for astigmatism correction for cataract surgery is the toric IOL implant using the AcrySof lens (Alcon Inc Laboratories, Ft Worth, Tex). The Acrysof lens, based on the SN60AT (Alcon Inc Laboratories) design, is a one-piece hydrophobic acrylic lens with a yellow chromophore. The posterior surface of the IOL has cylinder power and axis marks to allow placement at the correct axis in the capsular bag.

Preoperatively, it is fundamental to accurately measure the magnitude and pattern of astigmatism. From the wavefront perspective, regular astigmatism is classified as a lower order aberration. In an astigmatic eye, light rays leave the eye in different directions, and the wavefront (which is perpendicular to the rays) will vary according to the axis.

The recent introduction of wavefront aberrometers adds an additional dimension to optical analysis by plotting the effect of the aberrations inherent to the eye and their effect on vision. One such aberrometer, the OPD Scan II (NIDEK Co Ltd, Gamagori, Japan) combines corneal topography and total eye wavefront to measure the refractive and optical effects of the aberrations of the eye. The combined measurements can be separated to determine the effect of corneal and internal aberrations. Toric IOLs are able to correct only regular corneal astigmatism. Therefore, the first step is to determine whether the astigmatism is regular and on the anterior surface of the cornea or due to the internal optics of the eye. Aberrometry is being used clinically for cataract and intraocular surgery. In this study, we describe the clinical application of aberrometry in cataract surgery.

Figure 1. Axial corneal topography and toric IOL calculation for an eye with a manifest refraction of $-3.50 -3.00 \times 27^\circ$. 
MATERIALS AND METHODS

Patients undergoing Acrysof toric IOL implantation are used to illustrate the use of the NIDEK OPD Scan II with OPD-Station software for pre- and postoperative evaluation and treatment planning. The OPD Scan II is a multifunction instrument that combines Placido-based corneal topography with wavefront aberrometry of the entire eye and measures mesopic and photopic pupil diameter, autokeratometry, and autorefraction. The wavefront measuring apparatus is based on the principle of retinoscopy that uses an infrared slit of light to scan all 360° meridians over a 6-mm pupil. The time difference of the reflected light to stimulate an array of photodetectors is converted to a refractive wavefront map.7

The steeper corneal meridian of the anterior corneal surface was used for alignment of the IOL in all cases. The keratometry values used for IOL calculations were determined from the IOLMaster (Carl Zeiss Meditec, Jena, Germany) and the axial corneal topography from the OPD Scan II. The toric calculator (Alcon Laboratories Inc) was used to select the appropriate IOL power and optimal axis direction within the capsular bag (Fig 1).

RESULTS

POSTOPERATIVE EVALUATION

Figure 2 shows the postoperative aberrometry of a patient who underwent toric IOL implantation. A 2.75-mm temporal corneal incision was made to implant the SN60 T4 +2.25-D IOL. Isolating just the cylindrical component of the total, corneal, and internal wavefront allows one to determine whether the IOL is compensating for the corneal astigmatism (see Fig 2). For example, the corneal astigmatism and IOL astigmatism in this case combined to reduce the astigmatism to 0.50 D postoperatively, indicated by the subtle (green to light green) color change on the total wavefront map (see Fig 2). The objective visual performance can be simulated using the modulation transfer function (MTF) graph that describes the fidelity of contrast transfer at different spatial frequencies (Fig 3). Postoperatively, the ratios of the patient’s postoperative uncorrected visual performance (red curve) and best corrected curve (pink curve) are similar (ie, A/B and H/B ratio are similar), indicating a well-corrected eye in which additional gains in visual performance will only be achieved by correcting the higher order aberrations of the eye (Fig 3).
Figure 3. Modulation transfer function (MTF) of an eye that underwent toric IOL implantation. The dark blue curve represents the diffraction limited curve (D.Limited), which is visual performance of the best optical system such as a camera. The green curve (BMTF) represents the visual performance of a population of patients with emmetropia with excellent contrast sensitivity. The red curve (Ave) represents the visual performance of the patient’s uncorrected eye. The pink curve (HOave) represents the visual performance of the patient’s eye if the sphere and cylinder are corrected but the higher order aberrations remain. The A/B ratio represents the area under the curve of the red curve (Ave) and the green curve (BMTF). The higher this ratio, the better the visual performance. All wavefront measurements were performed with a 4.80-mm pupil to the eighth order.

Figure 4. A) Preoperative and corneal topography and corneal (upper right), internal (middle), and total (lower right) aberrometry. Only the cylindrical aberrations have been plotted. The difference in colors and corresponding patterns (yellow and green) of the corneal and total wavefront maps indicate that the cornea is the source of the astigmatism of the eye. The lower right plots the MTF. B) Postoperative measurement showing the total cylinder (lower left) has been eliminated, indicated by the green.
PRE- AND POSTOPERATIVE EVALUATION

A candidate with 2.40 D of topographic astigmatism is presented in Figure 4. The corneal wavefront map (isolating the Zernike second-order astigmatism component only) shows significant distortion in a pattern consistent with astigmatism (Fig 4). The internal wavefront map (isolating the Zernike second-order astigmatism component only) shows little distortion, indicating that the majority of the astigmatism must arise from the corneal component (see Fig 4). A SN60T5 +21.00-D IOL was implanted with two 2.75-mm incisions positioned at 108° and 18° corresponding to the meridians on the axial topography map. Postoperatively, the corneal astigmatism and the toric IOL compensate for each other, reducing refractive cylinder to −0.25 D. Postoperatively, the A/B ratio on the MTF graph increased by almost 15%, indicating an increase in postoperative visual performance (see Fig 4).
Visual Quality Analyses Pre- and Postoperatively

A patient with a visually significant cataract with a manifest refraction of −2.25 −1.75 × 15° was evaluated using the OPD Scan II. The preoperative point spread function (PSF) indicated reduced visual quality due to the internal optics of the eye (Fig 5). Two months postoperatively, the total PSF was significantly tighter, occupied less space, and was less distorted than preoperatively; the manifest refraction was 0 −0.50 × 100° (see Fig 5). Simulations of the visual acuity chart and scenery both indicate satisfactory visual quality postoperatively (see Fig 5).

Discussion

The separation of the anterior corneal surface from internal aberrations enables the surgeon to determine the source of refractive astigmatism. Postoperatively, the placement of the IOL, residual astigmatism, and induced aberrations could be determined using the various maps provided in the OPD-Station software. The PSF can be used to separately evaluate the effect of the optics of the cornea and crystalline lens or IOL on the retinal image. Preoperative evaluation of the PSF or the visual acuity allows quick interpretation of the visual quality before surgical intervention. Patients with clinically significant nuclear cataracts will have a large magnitude of internal spherical aberration resulting in reports of halos. In this case series, we present one such example in Figure 5, where the internal PSF is significantly distorted and radiates out symmetrically, indicating internal spherical aberration as a major cause of visual degradation. Spherical aberration would cause halos around letters in visual acuity simulations. Once the cataract was removed and IOL implanted, the PSF is reduced in size and shape, indicating a reduction in spherical aberration (see Fig 5).

The ability to separate out the effect of any aberration (astigmatism in our case) allows the surgeon to determine the effect of IOL placement postoperatively. This can be done by evaluating the internal wavefront map. For example, a tilted or torqued IOL will produce significant coma postoperatively. Coma will result in two refractive planes bisecting the pupil, causing complaints of shadowing, ghosting, or diplopia if the difference in the induced refraction is significantly large. Incorrect alignment of the toric IOL will result in postoperative astigmatism on the internal wavefront map. Change in the internal aberrations and visual quality using the PSF or MTF graphs could be followed over time to determine the effect of cataract progression and to intervene based on objective parameters and patient symptoms.

In our clinical practice for toric IOL implantation, we prefer to examine the wavefront pattern of regular astigmatism because the AcrySof Toric IOL will correct regular astigmatism of the anterior surface of the cornea. However, visual performance using the MTF allows us to determine the effects of higher order aberrations (HOave curve and H/B) postoperatively.

References