Preoperative Tools for the Management of Astigmatism

Diagnostic and imaging tools can help surgeons address astigmatism at the time of cataract surgery.

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Astigmatism accounts for about 13% of refractive errors of the human eye.[1] Due to advances in cataract surgery, astigmatism can be addressed at the time of surgery, resulting in improved quality of unaided vision. In this article, we discuss the preoperative assessment tools currently being used to quantify astigmatism in order to plan and execute a possible solution at the time of cataract removal.

MANIFEST REFRACTION

Refraction is the basic tool used to measure astigmatism. It is a subjective measure of total astigmatism and can only identify regular astigmatism, with one steep and one flat axis. Almost all patients are refracted before they undergo cataract surgery, but this subjective measurement can be inaccurate due to the presence of the cataract.

KERATOMETRY

Keratometry measures a small central corneal surface and assumes that the corneal surface is a symmetric spherocylindrical shape with steep and flat axes separated by 90°. It does not account for spherical aberration and is susceptible to focusing and misalignment errors. Manual keratometry measures the radius of curvature of the anterior cornea between two points 3 or 4 mm apart and provides no information within or outside of those points. It does not take into account lenticular astigmatism or astigmatism of the posterior corneal surface. Measuring and quantifying irregular astigmatism can be difficult due to distortion of the mires.

Traditionally, two basic keratometers, Helmholtz (Bausch + Lomb, Rochester, New York) and the Javal-Schiotz (Rodenstock, Dusseldorf, Germany), have been used to measure corneal curvature. In the past decade, partial coherence interferometry (PCI) has been widely adopted as a means for obtaining keratometry data in cataract surgery patients. The IOLMaster (Carl Zeiss-Meditec, Jena, Germany; Figure 1), introduced in 2000, was the first PCI-based noncontact automatic biometry system. In addition to keratometry, it can calculate axial length, anterior chamber depth, and white-to-white distance, and it can be used to predict IOL power. The IOLMaster provides more accurate keratometry measurements compared with manual keratometers because it averages three consecutive readings of data collected from six points close to the center of the cornea (2.5 mm).

Figure 1. The IOLMaster 500 uses partial coherence interferometry to calculate biometric data.

CORNEAL TOPOGRAPHY

Corneal topography measurements began with Placido's disc in 1880, and this principle was later utilized in photok-

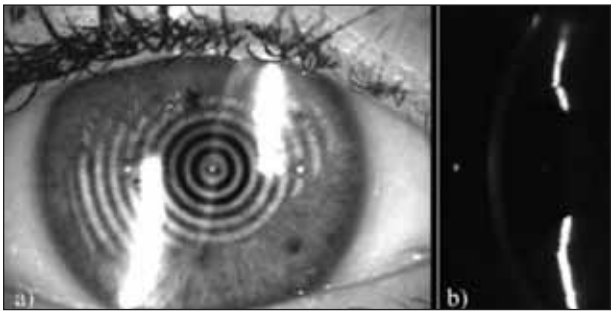

Figure 2. The Orbscan II uses slit-scanning elevation topography to assess the anterior and posterior corneal curvatures and the anterior surface of the lens and iris.

eratoscope and videokeratoscope devices. Topography evaluates qualitative and quantitative measurements from the entire corneal surface, making it an ideal tool for assessing the cornea. This method can identify multiple steep and flat meridia at a 3-, 5-, or 7-mm radius. Most new machines can also evaluate the posterior corneal curvature.

Until techniques such as slit-scanning and Scheimpflug imaging were introduced, the field of corneal imaging was restricted to the analysis of the shape and optical quality of the anterior corneal surface.[2] These newer imaging techniques can produce a 3-D image of the cornea from 2-D optical cross-sections, greatly enhancing our ability to understand corneal properties. Based on these new technologies, corneal topography has the capacity to provide true images of both anterior and posterior corneal surfaces and to calculate corneal thickness. These machines provide far more corneal parameters than Placido-disc–based topography.

Placido-based topography is a valuable tool for gauging the refractive status of the cornea, but it does not directly portray true elevation topography. The Corneal Topography System (CTS; PAR Vision Systems Corporation, New Hartford, New York) was reportedly the first unit to use elevation topography, establish-

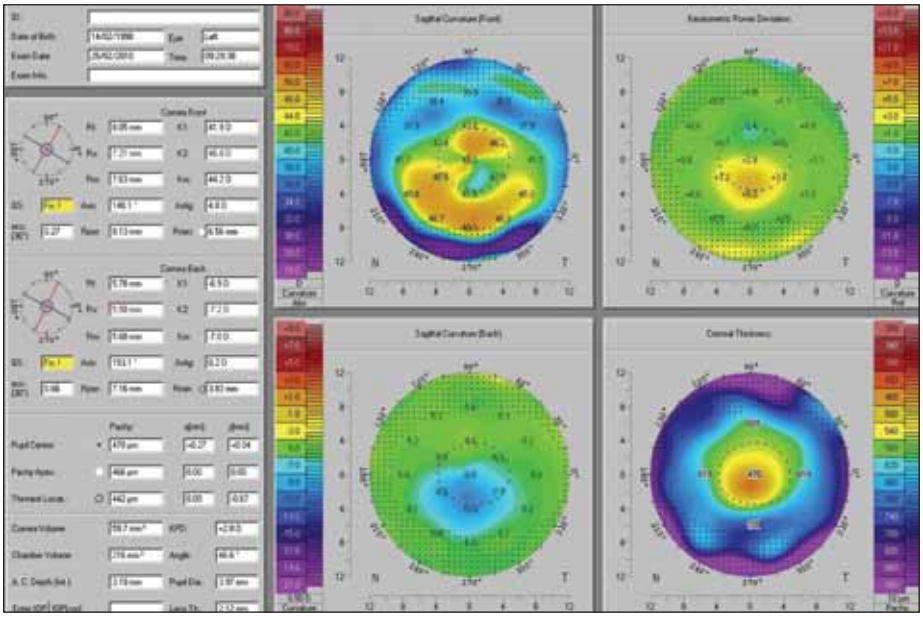

Figure 3. The Pentacam uses Scheimpflug photography to generate data including posterior corneal curvature.

LARGE STUDY MAY PROVIDE NORMATIVE DATA FOR CORNEAL ASTIGMATISM, BIOMETRY

BY JENNIFER KREATSOULAS, PHD, SENIOR ASSOCIATE EDITOR

A clinical study in Germany has reported biometry and astigmatism data for a large cohort of cataract patients.[1] The study authors suggest that their findings may serve as a normative reference for surgeons and may help manufacturers tailor toric IOLs to the cataract marketplace.

With data from 23,239 eyes, the retrospective study is the largest of its kind ever published, more than tripling the number of data sets included in Hoffer's series of 7,500 eyes in 1980.[2] Additionally, it updates the technology, with measurements taken using the current standard of partial coherence interferometry, rather than immersion ultrasound, the state of the art in1980.

Researchers found that anterior chamber depth and axis of astigmatism correlated with age. Mean axial length was 23.45 ±1.51 mm (standard deviation), mean corneal radius was 7.69 ±0.28 mm, mean white-to-white distance was 11.82 ±0.40 mm, and mean anterior chamber depth was 3.11 ±0.43 mm. The axial length, corneal radius, and white-to-white distance correlated with one another. Eight percent of eyes had corneal astigmatism greater than 2.00 D, and 2.6% had more than 3.00 D. With-the-rule astigmatism was found in 46.8% of eyes, against-the-rule in 34.4%, and oblique in 18.9%. High astigmatism was predominantly with-the-rule, the study authors said.

1. Hoffmann PC, Hütz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. *J Cataract Refract Surg.* 2010;36(9):1479-1485.
2. Hoffer KJ. Biometry of 7,500 cataractous eyes. *Am J Ophthalmol.* 1980;90:360-368; correction, 890.

Figure 4. Ray tracing generates an exact computer model of each patient's eye.

ing the true shape of the anterior corneal surface in 3-D space.[3] The CTS is more accurate than Placido-based devices,[4] but its reproducibility is poorer than that of Placido-based systems.[5] Unfortunately, both of these systems provide limited information only regarding the anterior corneal surface.

The development of slit-scanning elevation topography, as used by Orbscan (Bausch + Lomb), made it possible to assess the anterior and posterior corneal curvatures along with the anterior surface of the lens and iris.[5] The Orbscan II (Figure 2) incorporates a Placido-disc attachment to obtain curvatures directly, providing the benefits of both approaches to corneal topography.[5] The latest upgrade (Orbscan IIz) also has an aberrometer (Zywave II wavefront aberrometer; Bausch + Lomb) integrated into the workstation.

A number of currently available devices generate topography data using a rotating Scheimpflug camera system, which capture multiple photographs of the anterior segment that share a common point at the center of rotation.[6] The major advancement in Scheimpflug-based devices is the ability to accurately image the posterior corneal curvature, providing a complete pachymetric evaluation.[7] The posterior corneal surface is a sensitive indicator of corneal disease, and the ability to image it accurately is a major leap forward in assessing the cornea. The limitation of Scheimpflug imaging is that it is dependent on transparent media and cannot image posterior to the iris or the angle.[7]

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Many ophthalmologists have started using the term tomography to distinguish Scheimplug imaging from Placido-based topography.[7] Placido-based topography is an indirect method that integrates curvature measurements into formulas to determine height measurements.

The term topography should not be used to describe Placido-based instruments because they are not topographers. Topography analyzes shape. Placido-based systems do not have the ability to measure true shape. Scheimplug imaging systems are true topographic instruments that measure both the anterior and posterior corneal surfaces.

At least four commercial units incorporate Scheimpflug cross-sectional imaging: the Pentacam (Oculus Optikgeräte GmbH,Wetzlar, Germany), the WaveLight Allegro Oculyzer (Alcon Labortories, Inc., Fort Worth, Texas), the Galilei (Ziemer Group, Port, Switzerland); and the Sirius (Costruzione Strumenti Oftalmici, Florence, Italy). Figure 3 shows a typical screen shot of measurements taken with the Pentacam.

WAVEFRONT ABERROMETRY

Wavefront aberrometry is a method of measuring refractive error. In addition to calculating sphere and cylinder, it measures higher-order aberrations. Aberrometry uses a technique of wavefront sensing to measure the complete refractive status of the eye, including irregular astigmatism. The emergence of wavefront-guided refractive surgery[8] led to a change in the concept of refractive error correction. Wavefront analysis showed that there is a small degree of irregular astigmatism even in normal eyes, and factors such as blinking, accommodation, and age can influence it.

There are different types of aberrometry, including the Hartmann-Shack sensor, the cross-cylinder aberrometer for retinal imaging, the Tscherning aberrometer, and the sequential retinal ray-tracing method.[9] Additionally, there are ingoing feedback aberrometers such as those used in the spatially resolved refractometer and the optical path

TAKE-HOME MESSAGE

- Corneal topography technologies have the capacity to provide true images of both anterior and posterior corneal surfaces to calculate corneal thickness.
- Aberrometry uses a technique of wavefront sensing to measure the complete refractive status of the eye, including irregular astigmatism.
- Ray tracing measures intraocular structures and dimensions with extreme accuracy.

difference method.[9] Aberrometers are used as pre- and postoperative assessment tools for refractive surgery in most of the developed world.

RAY TRACING

The highest possible accuracy can be achieved only by taking into consideration all of the optical structures in the patient's eye. With the advent of partial coherence reflectometry, intraocular structures and dimensions can now be measured with extreme accuracy. Using these details, an exact computer model of each patient's eye can be generated (Figure 4).[10] The ray-tracing profile is calculated using biometric data such as corneal pachymetry, anterior chamber depth, lens thickness, axial length, and data from wavefront maps and corneal tomographers.[10] This method can greatly enhance the outcomes of laser refractive surgery, both in terms of accuracy and safety.

CONCLUSION

All of these techniques provide useful information about the astigmatic status of the eye. Most surgeons use some combination of them to assess their patients and to plan the most appropriate intervention. ■

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