



ABERRATIONS IN REFRACTIVE CATARACT SURGERY



Remember that good vision is as much about quality as it is about quantity.

BY NICHOLAS J. BRUNS, OD, FAAO

Although accuracy and control are crucial in refractive surgery, it's also important to note that visual performance is based on more than visual acuity; numerous qualitative factors can have significant effects. With a phoropter, we can measure lower-order aberrations, such as myopia, hyperopia, and astigmatism, without much difficulty, but this is just the tip of the iceberg. With modern technology, understanding the effect of higher-order aberrations (HOAs) helps us better achieve optimal outcomes.

HOAs IN CATARACT AND REFRACTIVE SURGERY

Visual performance is affected by both quantitative and qualitative factors that are often much more sophisticated than what can be fully corrected

AT A GLANCE

- ▶ Lower-order aberrations (eg, myopia, hyperopia, astigmatism) are commonly recognized, while higher-order aberrations (HOAs), including spherical aberration, coma, and trefoil, among others, are less understood.
- ▶ Aberrometers can measure the cornea and the entire optical system, helping to elucidate the root cause of HOAs in pre- and postoperative management.
- ▶ There is a direct correlation between tear film quality and HOAs, highlighting the importance of tear film optimization to allow for maximum performance of monofocal and advanced IOLs.

by a pair of glasses. An aberration, as we know, is a defect in an optical system leading to loss of image quality.¹

ODs are familiar with lower-order aberrations such as myopia, hyperopia, and astigmatism, but HOAs, including

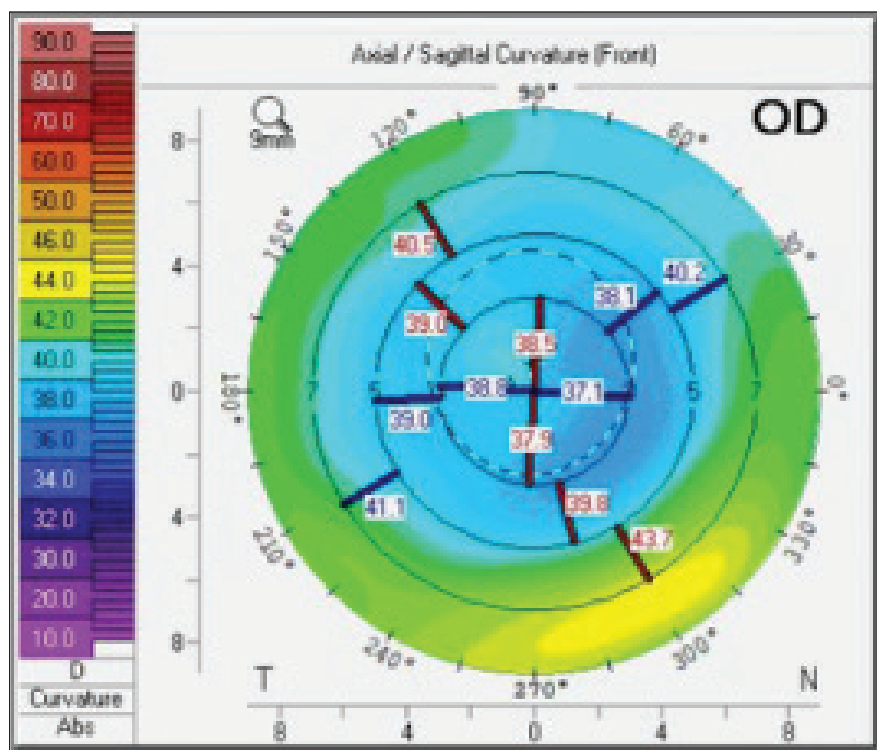


Figure 1. A previously highly myopic patient post-LASIK. Notice the extremely flat central cornea, leaving this patient highly susceptible to positive SA.

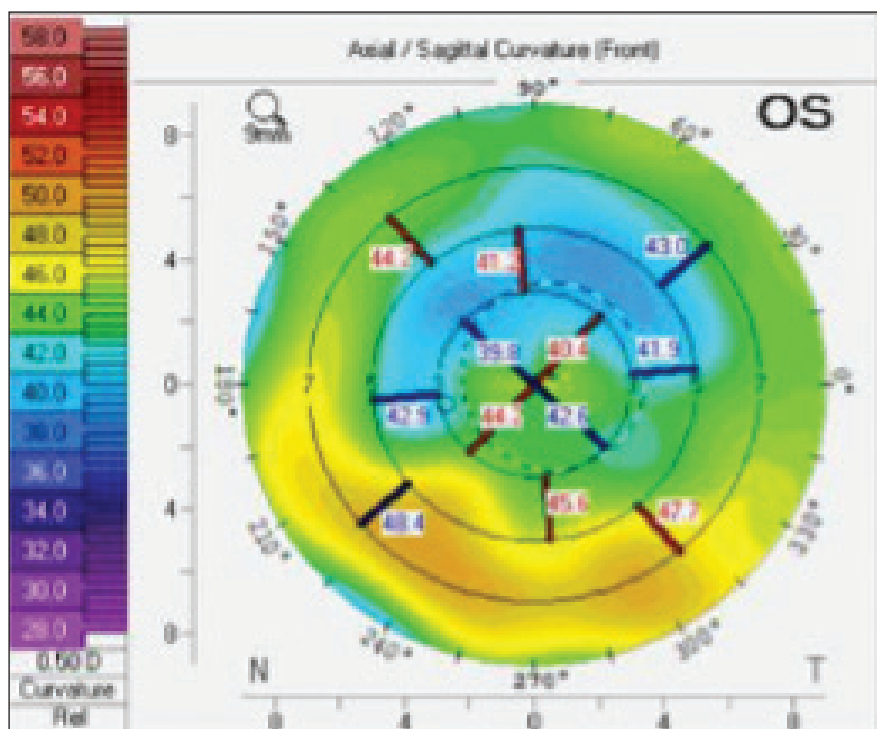


Figure 2. A topography of a patient after eight-cut radial keratotomy showing high asymmetry and steepening inferiorly. This patient will have significant coma and trefoil due to irregular astigmatism.

spherical aberration (SA), coma, and trefoil, among others, are less understood.

Calculations are made during surgical planning that assume the human eye has a certain minimal level of HOA, while in reality that amount of HOA can be highly variable patient to patient. Minimizing refractive error without further inducing HOAs is often easier said than done.

Spherical Aberration

SA is one of the most common HOAs observed in cataract surgery and is heavily influenced by prior corneal refractive surgery.² It is a fourth-order aberration that occurs when paraxial rays focus before or after central rays and produce halos. SA can be either positive or negative; it is considered positive when the paraxial rays focus in front of central rays and negative when paraxial rays focus behind central rays.

The human cornea has a slightly prolate shape, meaning it is steeper centrally and flatter in the periphery. Overall, the total SA of the cornea tends to be more positive, between + 0.27 μm and + 0.30 μm . The crystalline lens compensates for this with a slightly negatively induced SA.³

Coma

Coma, a third-order aberration, occurs when rays at one side of the pupil focus before rays on the opposite side, giving the image a “comet-like” appearance. This is common in pathologies such as keratoconus or post-LASIK ectasia.

Trefoil

Trefoil, also a third-order aberration, is a triangular astigmatism with three axes that produces blur and glare. Trefoil is seen frequently in patients post-RK.

DETECTING HOAS: QUALITY VS QUANTITY

The concept of aberrometry is not new; it was mainly applied in astronomy up until the 1990s, when it first was

introduced in ophthalmology as a result of the growing popularity of wavefront-guided laser vision correction.⁴ With the ability to detect and quantify HOAs, surgeons obtained a deeper understanding of how to manage qualitative visual outcomes. Refractive surgery can target two places: the cornea and the lens. During a LASIK procedure for a patient with myopia, for example, we would ablate the central cornea, flattening its shape. By taking a dome-shaped cornea and making it more of a plateau shape, we would create a more oblate cornea, thus inducing positive SA. The higher the ablation, the more induced positive SA.

The exact opposite is true in the case of LASIK for a patient with hyperopia, where we would steepen the central cornea (and flatten the periphery), creating a more prolate shape, thus inducing more negative SA. This can have an effect on BCVA, of course, but may also impact contrast sensitivity.⁵

TOOLS OF THE TRADE

Several aberrometers are available, all highly advanced with different methods of data collection. The iTrace (Tracey Technologies) uses ray tracing for wavefront analysis by projecting 256 individual near-infrared beams through the entrance pupil and measuring where they land on the retina. The OPD-Scan III VS (Nidek) uses skiascopic phase difference to measure refractive error and aberrations by sending slit light beams through the pupil and analyzing them as a function of how they bounce back, similar to a sophisticated form of retinoscopy from several different angles.⁵ The WaveDyn Vision Analyzer (Wavefront Dynamics) uses the Shack-Hartmann principle over time, producing a more comprehensive analysis of aberrometry instead of a single point.⁶ Each of these devices can measure the cornea and the entire optical system, including internal and lenticular aberrations. With the

ability to separate internal from corneal aberrations, we can understand the root cause of HOAs in pre- and postoperative management.

Other Methods

Although aberrometers provide more comprehensive analysis and quantification of HOAs, there are other methods for anticipating effects of HOAs on a visual system. Remember, the cornea is the principal refracting surface in the human eye, so a simple topographer can provide sufficient analysis of the cornea to at least determine whether HOAs are likely. Symmetry and regularity are basic items to view with a topographer: The more symmetrical the corneal curvature, the less likely there will be induced HOAs (Figures 1 and 2). The tear film can have a significant effect on topography, because an unstable tear film can induce irregular astigmatism and/or contribute to fluctuating HOAs over time.

MANAGING ABERRATIONS

Controlling aberrations is a proactive process that mostly takes place before surgery. In laser vision correction, we can use wavefront-guided treatments to minimize HOAs but not eliminate them. With lens-based procedures, several advanced IOLs use the principles of HOAs to provide defocus, allowing enhanced depth of focus, range of vision, or multifocality. Because these lenses rely on adding HOAs, compounding “built in” HOAs with a cornea that already is highly aberrated can have a significant negative effect on visual quality. Understanding the optical architecture of an IOL and how it will interact with the eye’s optical system is essential. There are anatomical hurdles that can’t necessarily be controlled, but the integrity of the tear film typically can be. There is a direct association between tear film and HOAs, highlighting the importance

of tear film optimization to allow maximum performance of monofocal and especially advanced IOLs.⁷

In cataract surgery, we are limited to preoperative biometry and calculations to predict a proper IOL power based on effective lens position. Intraoperative aberrometry, however, allows a higher level of accuracy for spherical and toric correction by providing real-time analysis before and after a lens has been implanted. This can be particularly useful for toric IOL axis placement. The Light Adjustable Lens (RxSight) can also help by allowing the variability of the healing process to happen prior to changing IOL power or toricity. In highly aberrated eyes, rigid gas permeable and scleral lenses can be customized based on wavefront aberrometry, reducing the burden of HOAs past what surgical methods allow.

GO BEYOND 20/20 VISION

Refractive surgery aims to minimize negative qualitative factors as much as possible. Detecting, quantifying, and managing HOAs is an important piece in the surgical process to ensure optimal visual performance. ■

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