Customizing the Correction of Spherical Aberration

Undercorrection with aspheric IOLs may help patients achieve optimal outcomes.

BY GEORGE BEIKO, BM, BCH, FRCSC

Until recently, the goal of cataract surgery has been to restore a patient's Snellen visual acuity to its greatest potential. Surgeons have emphasized minimizing sphere and cylinder and helping patients obtain emmetropic results. Now, the goal of cataract surgery is to restore patients' youthful contrast sensitivity and accommodative potential. This article investigates how aspheric IOLs may help us achieve this ideal.

QUANTIFYING SPHERICAL ABERRATION

From the wavefront analysis of the optical system, we know that aberrations other than sphere and cylinder significantly affect visual function. We can characterize these aberrations with Zernike transformations.

Research has shown an inverse association between the Zernike coefficient for spherical aberration and contrast sensitivity. In other words, spherical aberration increases as contrast sensitivity decreases.[1-4] The best contrast sensitivity has been measured in people between 20 and 30 years of age.

In the phakic eye, the anterior corneal surface, posterior corneal surface, crystalline lens, and retina all contribute to the total number of higher-order aberrations. In the aphakic eye, however, 98.2% of the aberrations arise from the anterior corneal surface.[5] For the purposes of this discussion, corneal higher-order aberrations will represent those of the entire eye in cataract patients.

Zernike coefficients of the eye's higher-order aberrations can be derived from corneal topographic data.[1,5-8] Because studies have shown that small-incision cataract surgery does not significantly affect postoperative corneal topography,[4-9] we can use measurements of higher-order aberrations obtained preoperatively to manipulate the outcome of cataract surgery. If our goal is to achieve optimal spherical aberration and maximal contrast sensitivity, we can implant an aspheric IOL that will neutralize the patient's preoperative spherical aberration.

ASPHERIC IOLS AND VISUAL QUALITY

The cornea has a positive spherical aberration of approximately 0.27µm[10-12] for a 6.0-mm diameter, a measurement that does not vary significantly with aging. The implantation of an aspheric IOL such as the Tecnis Z9000 (Advanced Medical Optics, Inc., Santa Ana, CA), which possesses a spherical aberration of -0.27µm, can reportedly improve image quality and contrast sensitivity under mesopic and photopic conditions versus the implantation of a standard IOL. The spherical aberration of standard spherical IOLs tends to increase with the lens' power.[13-15]

Simulated night driving tests showed that patients who received the Tecnis IOL identified a pedestrian 45 feet or 0.5 seconds sooner at 55mph than those implanted with a spherical IOL.[16] These results suggest that the correction of spherical aberration not only improves vision but also increases patients' safety. It is important to remember, however, that these previously mentioned studies compared patients who had no residual spherical aberration with the Tecnis lens with those who had 0.30 to 0.40µm of postoperative spherical aberration with spherical IOLs.

Currently, the FDA has approved three IOLs for the correction of spherical aberration: the Tecnis; the Sofport AO (Bausch & Lomb, Rochester, NY); and the Acrysof IQ (Alcon Laboratories, Inc., Fort Worth, TX). The three lenses use different strategies to correct spherical aberration. Because the Sofport AO lens has no spherical aberration, it does not affect this characteristic of the eye. The Acrysof IQ has a negative spherical aberration of 0.20µm and thus targets a mean postoperative spherical aberration of 0.10µm. The Tecnis lens (spherical aberration = -0.27µm) targets the full correction of corneal spherical aberration.

IDENTIFYING THE OPTIMAL TARGET

Several studies have shown a potential correlation between spherical aberration and natural super vision (defined as 20/15 or better). Levy et al[17] measured the total spherical aberration in 70 eyes of 30 subjects (mean age = 24.3 ±7.7 years) with natural super vision. All measurements were made with the Nidek OPD scan wavefront aberrometer (Nidek Co., Ltd., Gamagori, Japan) across a naturally dilated, 6-mm pupil. The investigators found that the mean total spherical aberration in this population was +0.110 ±0.077µm.[17]

Another study showed a correlation between some positive spherical aberration and better-than-average visual acuity and contrast sensitivity among student naval pilots.[18]

Based on these data, and considering an average corneal spherical aberration of +0.27µm, I hypothesized that patients with a residual mean spherical aberration of approximately +0.10µm after the implantation of a Tecnis lens would have better contrast sensitivity than those who had no residual spherical aberration. In an unpublished study, I compared 13 patients who had an average preoperative spherical aberration of +0.37µm with 20 patients who had an average preoperative spherical aberration close to that found in the studies by Holladay et al[11] and by Beiko et al.[19]

Because the Tecnis' fixed spherical aberration is -0.27µm, its implantation would leave the patients in the first group (Tecnis selected) with +0.10µm of spherical aberration versus zero in the second group (Tecnis nonselected).

Postoperatively, I detected statistically significant differences between the groups for spatial frequencies of 12 cycles per degree under photopic conditions (Figure 1), and for six, 12, and 18 cycles per degree under mesopic conditions (Figure 2). In addition, the intergroup differences for spatial frequencies of six and 18 cycles per degree under photopic conditions (P=.0570 and P=.0585, respectively) were almost significant. Unlike in other studies that compared the Tecnis with hydrophobic acrylic IOLs,[13-15] the differences in contrast sensitivity between the two groups in this present study cannot be attributed their material and optical characteristics. My unpublished study confirmed that patients who had 0.10µm of residual spherical aberration had better postoperative contrast sensitivity than those that had zero postoperative spherical aberration.

In an unpublished follow-up study, unselected patients whose corneal spherical aberration was similar to that of the general population (0.27µm) were implanted with either the Acrysof IQ or the Sofport AO lens. The Acrysof IQ lens' performance was almost identical to that of the Tecnis in patients targeted for 0.10µm of postoperative spherical aberration in the previous study. Under the same conditions, the Sofport AO performed similarly to the Tecnis nonselected group in the previous study. In terms of contrast sensitivity testing, targeting a mean spherical aberration of zero (as in the Tecnis nonselected group) or 0.27µm (as in the Sofport AO group) was inferior to targeting 0.10µm.

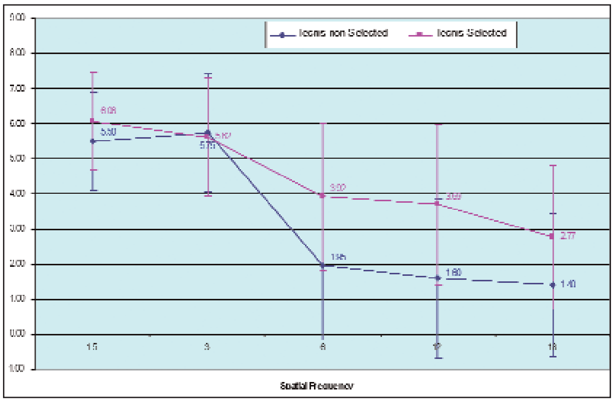


Figure 1. Patients targeted for 0.10µm of residual spherical aberration (Tecnis selected) had better postoperative contrast sensitivity in photopic conditions versus patients targeted for zero spherical aberration (Tecnis nonselected).

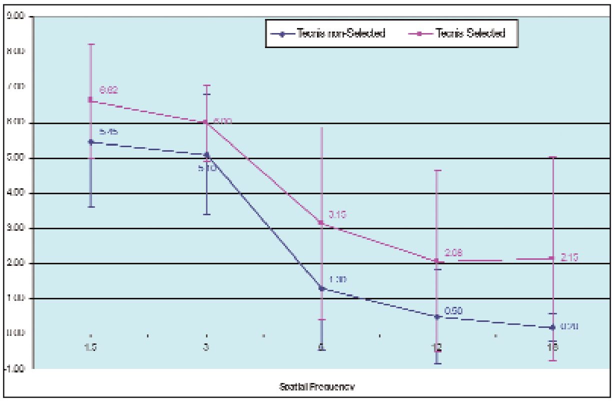


Figure 2. Patients targeted for 0.10µm of residual spherical aberration (Tecnis selected) had better postoperative contrast sensitivity in mesopic conditions versus patients targeted for zero spherical aberration (Tecnis nonselected).

Based on the results of contrast sensitivity testing, I currently advocate personalizing cataract patients' postoperative outcomes by targeting for +0.10µm of residual spherical aberration. Ideally, we would be able to choose from a range of powers on different IOL platforms. Because only a few aspheric IOLs are currently available, I measure patients' preoperative corneal spherical aberration and select an IOL as outlined in Table 1.

If it is not possible to measure spherical aberration di rectly in patients who have undergone refractive surgery, we may follow some general guidelines. Myopic laser ablation tends to increase the eye's spherical aberration, so an IOL with highly negative spherical aberration such as the Tecnis is probably appropriate. Conversely, hyperopic ablation tends to decrease the eye's spherical aberration, sometimes making it negative, so we might consider implanting a standard IOL with positive spherical aberration.

TABLE 1. LENS SELECTIONS FOR MINIMIZING POSTOPERATIVE SPHERICAL ABERRATION	
IOL Design	Preoperative Spherical Aberration (μm)
Clariflex,* Sofport AO,† Akreos AO†‡	Zero to 0.15
Acrysof IQ§	0.16 to 0.33
Tecnis Z9000*	> 0.33
Spherical IOLs	< Zero

*Advanced Medical Optics, Inc., Santa Ana, CA.
†Bausch & Lomb, Rochester, NY.
‡Not available in the US.
§Alcon Laboratories, Inc., Fort Worth, TX.

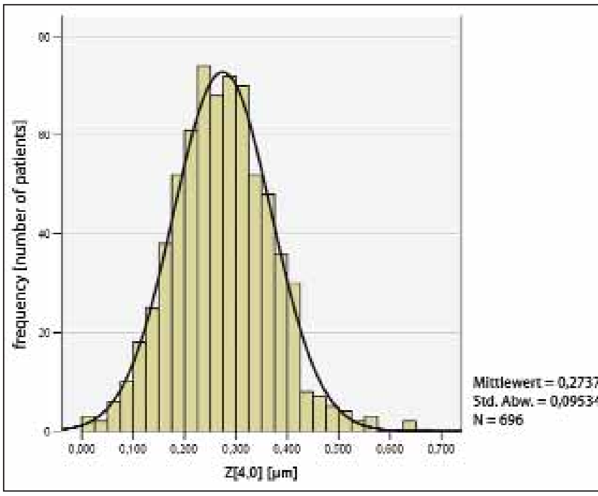


Figure 3. A normal Gaussian distribution of spherical aberration in 696 eyes shows a large standard deviation (±0.095) from the mean of 0.274μm (Z[4,0]).

CAN WE BUY THE HYPE?

The manufacturers of aspheric IOLs have proposed that their implantation as part of a targeted strategy will give all cataract patients super vision. For this premise to be true, we would have to assume that patients' spherical aberrations cluster tightly around the mean and that each strategy targets the optimal value.

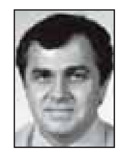
In order to investigate the manufacturers' proposals adequately, it is it is essential to know the distribution of corneal spherical aberration in the general population. A small standard deviation relative to the mean would support the idea that a few aspheric IOLs can provide optimal outcomes, whereas a larger value would suggest that surgeons need a wider range of IOLs to correct different degrees of spherical aberration.

In a recent study, my colleagues and I measured 0.274 ±0.095μm of spherical aberration among 696 eyes and concluded that the large standard deviation of the Gaussian distribution does not support the manufacturers' assertions[19] (Figure 3).

CONCLUSION

The strategies for providing customized correction after cataract surgery are constantly evolving. For example, Yoon et al[20] reported that refractive surgery patients with +0.10μm of preoperative spherical aberration achieve the best results when their myopia is undercorrected by 0.25D. Although similar results have not been reported among cataract patients, the investigators' findings suggest that these individuals may benefit from a comparable strategy.

As we learn more about how higher-order aberrations affect visual quality, we may need to revise our preferred targets for minimizing postoperative spherical aberration. ■



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