REDUCING SPHERICAL ABERRATION

Artal et al. reported that in the young human eye, the average positive spherical aberration introduced by the cornea is partially offset by the negative spherical aberration induced by the crystalline lens. As the lens ages and structurally changes, this compensating internal negative spherical aberration is gradually lost, an effect that degrades optical and visual quality and contrast sensitivity. In contrast, Oshika et al. reported that the positive spherical aberration of the cornea remains relatively stable. Guirao et al. and Wang et al. submitted that the positive spherical aberration of the cornea increases slightly with age.

Replacing the cataract with a conventional biconvex or convex-plano spherical pseudophakos IOL with positive spherical aberration increases positive spherical aberration of the entire eye, in which peripheral light rays focus in front of rays entering the paraxial cornea. Higher-powered, conventional IOLs tend to introduce additional positive spherical aberration, thus leading to a reduction in the ocular modulation transfer function (eg, how well the eye is able to transfer contrast from the object to the image).

STUDY DESIGN

Holladay et al. calculated the wavefront aberrations of the anterior corneal surface of a cohort of patients of a mean age of 74 years by fitting the elevation height data with a series of Zernike polynomials; researchers tuned a conic constant to yield an average spherical aberration.
Using an optical ray-tracing package and a model eye, researchers designed an equibiconvex lens made from a high refractive index polysiloxane with a modified anterior or prolate surface (eg, sixth-order asphericity) to offset the average positive corneal spherical aberration. This aberration-correcting IOL strategy, which uses a rotationally symmetric IOL, capitalizes on the fact that spherical aberration is rotationally symmetric.

**“Higher-powered, conventional IOLs tend to introduce additional positive spherical aberration.”**

**TECNIS’ CLINICAL PERFORMANCE**

In Kershner’s study,7 patients’ UCVAs at 4 weeks postoperatively were better in the aspheric IOL group than in eyes with a conventional silicone or acrylic IOL. This improvement in UCVAs was not associated with pre- or postoperative differences in refraction. In the Mester et al6 study comparing the Tecnis IOL in one eye and a conventional IOL in the other eye of the same patient, mean high-contrast BSCVA was only marginally better with the Tecnis lens. However, both Mester et al6 and Packer et al8 reported that low-contrast visual acuity and contrast sensitivity were significantly better with the Tecnis lens. In Kershner’s study,7 wavefront analysis confirmed a reduction in entire-eye spherical aberration in eyes implanted with the Tecnis compared with eyes receiving a conventional IOL. Digital analysis of retinal imaging also showed increased threshold luminance levels in the aspheric group and a four-fold increase in image contrast.

**POTENTIAL LIMITATIONS**

In patients with very small pupils, the adverse effects of the inherent spherical aberration of the cornea and lens implant are small, and near diffraction is limited. However, with larger pupils in mesopic or scotopic conditions, a well-centered and positioned Tecnis IOL (less than 0.4-mm decentration and less than 7º of tilt) generally affords improved retinal-image quality over a conventional IOL. However, Tecnis IOL decentration may induce defocus, astigmatism, and coma, which would degrade optical transfer function and image. Decentration of an IOL with negative spherical aberration produces the opposite induced aberration of an equivalently decentred conventional IOL. For example, a decentred Tecnis IOL results in a hyperopic refractive error, whereas an equally decentred standard IOL produces a myopic shift.

In the Holladay et al study,1 which led to the design of the Tecnis IOL, a reduction in entire-eye spherical aberration is estimated to occur in 90% of the population. However, because the IOL offsets the average amount of corneal spherical aberration, there will be negative spherical aberration induced in some patients who have more prolate corneas, because the Tecnis IOL is not individually customized. Experience with conventional IOLs shows that the brain is adept at interpreting retinal images with positive spherical aberration, but, in the small percentage of patients in whom a Tecnis IOL will induce entire-eye negative aberration, will these images undergo neural processing with similar facility? Answering this question will require further study.

When attempting to offset the average corneal spherical aberration with an IOL, positive spherical aberration may help with postoperative hyperopic refraction in patients who were targeted for emmetropia. Modest amounts of positive spherical aberration can mitigate the adverse effects of chromatic aberration and higher-order chromatic aberration. Spectacle correction can compensate for spherical aberration, but cannot correct for asymmetric aberrations, such as coma, that are induced by a decentred IOL with negative-spherical aberration.

**ALTERNATIVE IOL DESIGN STRATEGIES**

An alternative to an aspheric IOL with compensating negative spherical aberration is an aspheric IOL that is aberration-free (eg, induces neither negative nor positive spherical aberration). Because such a lens would lack spherical aberration, it would not induce asymmetric aberrations if decentred, and it still would be optically superior to a centered conventional IOL (even if decentred). A light-adjustable IOL, which is under development by Calhoun Vision, Inc. (Pasadena, CA), would provide a more optimal, futuristic, aberration-correcting option that would offer the possibility of offsetting both symmetrical and nonsymmetrical aberration after implantation.

**THE BOTTOM LINE**

Well-centered IOLs of aspheric design, such as the Tecnis, have been shown to improve optical performance and contrast sensitivity at spatial frequencies below 20 cycles/degree, depending on the corneal asphericity of the individual eye. However, caution should be exercised when implanting such lenses in patients with in-out-of-the-bag placement, lens placement in the sulcus, and incongruence between the bag diameter and the overall diameter of lens. Additionally, care should be taken when implanting these lenses in patients with corectopia, a large capsulorhexis, asymmetrical capsular coverage, a radial capsular tear, or other clinical situations that may produce IOL decentration. The aforementioned scenarios may lead to degradation of
image quality and a decreased optical transfer function as compared with an equally decentered conventional IOL.

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