# Maximizing Optical Quality

Aspheric IOLs can improve patients' contrast sensitivity and visual acuity.

BY MARK PACKER, MD; I. HOWARD FINE, MD; AND RICHARD S. HOFFMAN, MD

The youthful, accommodating, emmetropic, and minimally aberrated eye is the standard by which the results of cataract and refractive surgery are evaluated.[1] The erosion of accommodation and the decline in functional vision that occur with age[2] are linked to changes in the crystalline lens.[3,4] Cataract and refractive lens exchange surgery offer an intuitive avenue for correcting presbyopia as well as for reversing increased lenticular spherical aberration. Because the optical wavefront of the cornea remains essentially stable throughout life,[5] refractive lens exchange represents a permanent solution to the challenges of restoring accommodation and achieving a youthful quality of vision.

The positive spherical aberration of a spherical pseudophakic IOL tends to increase total optical aberrations, a problem that has led to the development of aspheric IOLs.[6] These designs may reduce or eliminate ocular spherical aberration and improve functional vision compared with a spherical pseudophakic implant. Three aspheric IOL designs are currently marketed in the US: the Tecnis Z9000 IOL (Advanced Medical Optics, Inc., Santa Ana, CA); the Acrysof IQ IOL (Alcon Laboratories, Inc., Fort Worth, TX); and the Sofport AO IOL (Bausch & Lomb, Rochester, NY).

## ASPHERIC IOLs

### Tecnis IOL

The Tecnis IOL was designed with a modified prolate anterior surface to compensate for the average corneal spherical aberration found in the adult eye. This lens introduces -0.27µm of spherical aberration into the eye. The results for clinical studies of the Tecnis IOL, which were submitted to the FDA, showed that the IOL eliminated patients' mean spherical aberration and significantly improved their functional vision compared with a standard spherical IOL.[7]

### Acrysof IQ IOL

The Acrysof IQ IOL incorporates both the ultraviolet- and blue-light–filtering chromophores found in the single-piece acrylic Acrysof Natural IOL (Alcon Laboratories, Inc). The Acrysof IQ lens, however, has a posterior, aspheric surface designed to compensate for spherical aberration by addressing the effects of overrefraction at the periphery. It adds -0.20µm of spherical aberration to the eye.

### Sofport AO IOL

The Sofport AO IOL is an aspheric IOL that has been specifically designed with zero spherical aberration so that it will not contribute to any preexisting higher-order aberrations. This lens' silicone, sharp-edged optic design incorporates haptics with zero angulation to permit atraumatic placement in the capsular bag.

## STUDIES COMPARING DIFFERENT ASPHERIC IOLs

According to the literature, the Tecnis IOL has demonstrably reduced spherical aberration and provided superior contrast sensitivity and contrast acuity in comparison to a variety of spherical IOLs (as of press time, there were no peer-reviewed publications evaluating the clinical results with either of the other two aspheric IOLs available in the US).[8-15] Data show that the mean spherical aberration in the eyes implanted with the Tecnis IOL is, as stated by executives from the FDA, "not different from zero."[16] Subjects in the FDA-monitored night driving simulation study of the Tecnis IOL performed functionally better in 20 of 24 driving conditions (and statistically better in 10 conditions) when using BSCVA with the eye implanted with the Tecnis IOL compared to BSCVA with the eye implanted with the Acrysof IQ.[6] These findings represent the basis for the FDA labeling indicating that the Tecnis IOL improves functional vision and enhances highway safety "for elderly drivers and those with whom they share the road."[6] Optical laboratory studies' results nevertheless have cast doubt on the efficacy of IOLs with negative spherical aberration (eg, the Tecnis and Acrysof IQ) due to the range of tilt and decentration of pseudophakic lenses in general[17,18] (see *The Tilt and Decentration of Aspheric IOLs: What Are the Limits of Tolerance?* on page 84).

## MULTIFOCAL IOLs

### Array Lens

From 1997 until 2005, the only FDA-approved multifocal IOL available was the Array IOL (Advanced Medical Optics, Inc.) This zonal progressive lens has five concentric zones on its anterior surface. Zones one, three, and five are distance dominant, whereas zones two and four are near dominant. The lens has an aspheric component whereby each zone repeats the entire refractive sequence corresponding to distance, intermediate, and near foci. This configuration provides patients with vision over a range of distances.

The lens uses 100% of the incoming available light and is weighted for optimum light distribution. With typically sized pupils, approximately half of the light is distributed for distance, one third for near vision, and the remainder for intermediate vision. Because the lens utilizes a continuous surface construction, there is no loss of light through diffraction and no degradation of image quality as a result of surface discontinuities.[19] The lens has a foldable silicone optic that is 6mm in diameter, PMMA haptics, and an overall diameter of 13mm. It can be inserted through a clear corneal incision that is 2.8mm wide by means of the Unfolder injector system (Advanced Medical Optics, Inc.).

### Rezoom Lens

In 2005, the FDA approved two new multifocal designs, the Rezoom IOL (Advanced Medical Optics, Inc.) and the Acrysof Restor IOL (Alcon Laboratories, Inc.). The former represents new engineering of the Array platform, including a hydrophobic acrylic material and a shift of the zonal progression. Zones one, three, and five are all distance dominant, whereas zones two and four are near dominant. The large, distance-dominant, central zone one is designed to provide vision in bright light (eg, for daytime driving). The Rezoom IOL's expanded zone three facilitates distance vision in moderate-to-low light when the pupil is more fully dilated, and zone five is designed to supply distance vision in low light (eg, for nighttime driving). Zone two, the large zone immediately peripheral to zone one, is intended to give near vision in moderate-to-low light. Zone four serves to provide near vision for lower-light situations. Aspheric transitions between the zones offer intermediate vision. The near-dominant zones provide +3.50D of add power at the IOL's plane for near vision, yielding approximately +2.57D of add power in the spectacle plane. This power addition translates to a near point of vision of 39cm or 16 inches.

Optiedge technology (Advanced Medical Optics, Inc.) inhibits the migration of lens epithelial cells without causing visual disturbances or glare (sata on file with Advanced Medical Optics, Inc.). Buehl et al[20] demonstrated low rates of posterior capsular opacification (PCO) in cataract patients implanted with an IOL that has a modified, sharp, posterior optic edge design.

The Rezoom IOL reduces the amount of light that goes to the near foci in low-light conditions (ie, larger pupils) and reallocates it to the distance foci. The intermediate power of this lens allows the formation of images on the retina, even if the distance and near powers form slightly out-of-focus images. The intermediate power should theoretically reduce the unfocused light on the retina, leading to fewer halos and less glare. Reduced photic phenomena (such as internal reflections and edge glares) and minimized PCO are the goals of the IOL's Optiedge design.

### Acrysof Restor Lens

The Acrysof Restor IOL employs a central apodized diffractive area surrounded by a purely refractive outer zone. This lens has a central 3.6-mm diffractive optic region. Twelve concentric diffractive zones on the anterior surface of the lens divide the light into two diffractive orders to create two lens powers. A region that has no diffractive structure over the remainder of the 6.0-mm–diameter lens surrounds the central 3.6-mm zone. The near correction is calculated at +4.00D at the lens' plane, resulting in approximately +3.20D at the spectacle plane. This add power provides a defocus curve of 6.00D of pseudoaccommodation at the 20/40 level.

The apodized diffractive structure of the Acrysof Restor IOL provides a gradual centrifugal decrease in step height of 12 diffractive circular structures. This design creates a transition of light between the foci and theoretically reduces disturbing optical phenomena like glare and halos. The results of a current study of the Acrysof Restor IOL show excellent near visual acuity and no compromise of subjects' distance vision, with approximately 80% not needing spectacles for near, distance, or intermediate vision.[21]

With the Acrysof Restor lens, the logic of placing the diffractive element centrally depends upon the near synkinesis of convergence, accommodation, and miosis. As the pupil constricts, the focal dominance of the lens shifts from almost purely distance to equal parts distance and near. This approach conserves efficiency for mesopic activities when the pupil is larger (eg, nighttime driving) but reduces near vision under mesopic conditions (eg, reading a menu by candlelight).

**Comparative Studies**

Many investigators have evaluated both the objective and subjective qualities of contrast sensitivity, stereoacuity, glare, and photic phenomena following the implantation of multifocal IOLs. Refractive multifocal IOLs such as the Array are better than diffractive multifocal IOLs in terms of contrast sensitivity and glare.[22] Recent reports comparing refractive and diffractive IOLs, however, revealed similar distance-vision qualities evaluated by modulation transfer functions but better near vision for the diffractive lens.

In terms of contrast sensitivity testing, the Array produces a small loss of contrast sensitivity that is equivalent to one line of visual acuity at the 11% contrast level using Regan contrast sensitivity charts.[23] This loss of contrast sensitivity at low levels of contrast is only present when the Array is implanted monocularly. It is not seen in patients with bilateral implants and binocular testing.[24] Regan testing, however, is not as sensitive as sine wave grating tests that evaluate a broader range of spatial frequencies. With the latter approach, reduced contrast sensitivity occurred in eyes implanted with the Array in the lower spatial frequencies compared with monofocal lenses when a halogen glare source was absent. When a moderate glare source was introduced, no significant difference in contrast sensitivity between the multifocal or monofocal lenses was observed.[25]

Practitioners implanting the Array have noted a period of neural adaptation in patients.[26] Similarly, researchers have shown that contrast sensitivity normalizes over a 6-month period.[27]

According to recent reports, there is a reduction in tritan color contrast sensitivity function in refractive multifocal IOLs compared with monofocal lenses under conditions of glare. These differences were significant for distance vision in the lower spatial frequencies and for near vision in the low and middle spatial frequencies.[28] A newer aspheric multifocal IOL, the Progress 3 (Domilens Laboratories, Lyon, France; not available in the US), also significantly lowers mean contrast sensitivity with the Pelli-Robson chart when compared to monofocal IOLs.[29]

Ultimately, these contrast sensitivity tests reveal that, in order to deliver multiple foci to the retina, there is always some loss of efficiency with multifocal IOLs when compared with monofocal IOLs. Contrast sensitivity loss, random-dot stereopsis, and aniseikonia improve, however, when multifocal IOLs are placed bilaterally versus unilaterally.[30] A recent publication evaluating a three-zone refractive multifocal IOL showed an improvement in stereopsis, less aniseikonia, and a greater likelihood of spectacle independence with bilateral versus unilateral implantation.[31] There is also evidence that contrast sensitivity with multifocal IOLs improves over time, approximating the levels found with spherical monofocal lenses by 6 months postoperatively.[25]

**Disadvantages**

One of the persistent drawbacks of multifocal lens technology has been the potential for patients to see glare or halos around point sources of light at night in the early weeks and months following surgery.[32,33] A meta-analysis of the peer-reviewed literature on multifocal IOLs shows a greater incidence of glare and halos with the multifocal than monofocal IOLs.[34] According to a clinical investigation of the Acrysof Restor IOL, 23.2% of subjects implanted bilaterally complained of moderate halos at night, although 7.2% complained of severe halos, versus 1.9% and 1.3%, respectively, of subjects implanted bilaterally with a control monofocal IOL.[35] Severe halos were reported by 15.3% of subjects bilaterally implanted with the Array IOL, the Rezoom IOL's precedecessor.[36] Fortunately, most people learn to disregard halos with time, and bilateral implantation appears to improve these subjective symptoms.[37]

## ASPHERIC MULTIFOCAL IOL

The Tecnis Multifocal IOL (Advanced Medical Optics, Inc.) is a wavefront-designed, diffractive, foldable IOL with a modified prolate anterior surface. It has received CE Marking for the treatment of presbyopia, and clinical trials in the US are ongoing. Optical bench studies reveal a superior modulation transfer function at both distance and near compared with standard monofocal IOLs with a 5-mm pupil and equivalence to standard monofocal IOLs with a 4-mm pupil. When compared to the Array multifocal IOL, the Tecnis Multifocal IOL performed better in the presence of a 2-mm pupil at near and a 5-mm pupil at distance and near. From these laboratory studies, it appears that combining diffractive multifocal optics with an aspheric, prolate design may enhance the functional vision of pseudophakic patients.[38]

Huetz et al[39] performed a prospective, randomized study comparing three bilaterally implanted multifocal IOLs: the Array; the Acrysof Restor; and the Tecnis Multifocal. They found faster uncorrected and best distance-corrected reading speeds among patients with the Tecnis Multifocal than the other lenses under both photopic and mesopic conditions. The reading speed with the Tecnis Multifocal was significantly faster with near correction under photopic conditions, and it was significantly better than in patients with the Acrysof Restor (but not the

Array) under mesopic conditions. The latter finding probably reflects the fact that the larger pupil under mesopic conditions benefits near vision with the zonal progressive Array but reduces near vision with the apodized diffractive Acrysof Restor. Anecdotally, our patients, after receiving refractive multifocal lenses (Array and Rezoom), have remarked that they read more easily in dim versus bright light. ■

## ONE SIZE DOES NOT FIT ALL

The availability of presbyopia-correcting IOLs, refractive lens exchange, and customized aspheric IOLs is changing ophthalmic practice. Informed consent takes on a new meaning when the surgeon and the patient decide together which IOL technology best fits his lifestyle and visual demands. Customizing the selection of IOLs is now essential to the practice of refractive lenticular surgery.

*I. Howard Fine, MD, is Clinical Professor of Ophthalmology at the Casey Eye Institute, Oregon Health & Science University, and he is in private practice at Drs. Fine, Hoffman, & Packer in Eugene, Oregon. Dr. Fine is a consultant for Advanced Medical Optics, Inc., and Bausch & Lomb, Inc. Dr. Fine may be reached at (541) 687-2110; hfine@finemd.com.*

*Richard S. Hoffman, MD, is Clinical Associate Professor of Ophthalmology at the Casey Eye Institute, Oregon Health & Science University, and he is in private practice at Drs. Fine, Hoffman, & Packer in Eugene, Oregon. He acknowledged no financial interest in the products or companies mentioned herein. Dr. Hoffman may be reached at (541) 687-2110; rshoffman@finemd.com.*

*Mark Packer, MD, is Clinical Associate Professor of Ophthalmology at the Casey Eye Institute, Oregon Health & Science University, and he is in private practice at Drs. Fine, Hoffman, & Packer in Eugene, Oregon. Dr. Packer is a consultant for Advanced Medical Optics, Inc., and Bausch & Lomb, Inc. Dr. Packer may be reached at (541) 687-2110; mpacker@finemd.com.*

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