

Hoya iSymm[™] IOL (FY-60AD, FC-60AD)
with Aspheric Balanced Curve (ABC) Optics

Abstract

The iSymm™ acrylic IOL from Hoya Surgical Optics, Inc. (HSO) has a unique aspheric optical design developed to maintain the advantages of an aspheric IOL even under conditions where the IOL is not aligned with the visual axis (decentration). The Aspheric Balanced Curve (ABC) design of the iSymm IOL, a 2nd-generation aspheric optic, creates an aspheric optic such that the asphericity of the central zones improves optical performance compared to a spherical IOL even when decentered. Studies show that optical performance of 1st-generation aspheric IOLs with negative spherical aberrations decreases with lens decentration, dipping below that of a spherical IOL at about 0.5 mm of decentration. Notably, this is the range (0.2-0.5 mm) of mean IOL decentration reported in recently (last 5 years) published clinical studies. In this same range, those clinical studies concluded that the iSymm IOL optical performance is consistently superior to spherical IOLs. The performance of the iSymm IOL is further demonstrated by both optical and clinical measures showing better resolution, decreased spherical aberration, and improved overall contrast sensitivity compared to a similar spherical IOL.

Introduction

The goal of cataract surgery has expanded beyond providing excellent high contrast Snellen visual acuity to include providing the best quality of vision for patients. Hoya has responded

by introducing the iSymm™ aspheric acrylic IOL. The iSymm IOL is a negative spherical aberration (SA) aspheric lens that balances the positive SA of the cornea. Unlike other 1st-generation negative SA aspheric IOLs, the iSymm IOL has unique aspheric zones designed to decrease the impact of misalignment between the lens and the visual axis (decentration) on quality of vision, providing good refractive predictability and quality of vision for a wide range of pseudophakic patients.

Background

A strong indicator of quality of vision is contrast sensitivity (CS), the ability to distinguish an object from its background. Contrast sensitivity declines with age,¹ leading to increased risk of falling² and of automobile collisions in the elderly.³ A number of studies have attributed this decline to changes in the wavefront aberrations of the crystalline lens, particularly higher order spherical aberrations, with age.^{1,4,5}

Spherical aberration occurs when light passing through a spherical lens is refracted more strongly at the edge of the lens optic than light passing through the center. This results in multiple focal points and a blurry image on the retina. A lens with positive SA (Figure 1) focuses peripheral rays (red lines) slightly closer to the lens than light rays passing through the center of the lens (green lines). A lens with negative SA will focus peripheral light farther from the lens than light rays passing through the center of the lens.

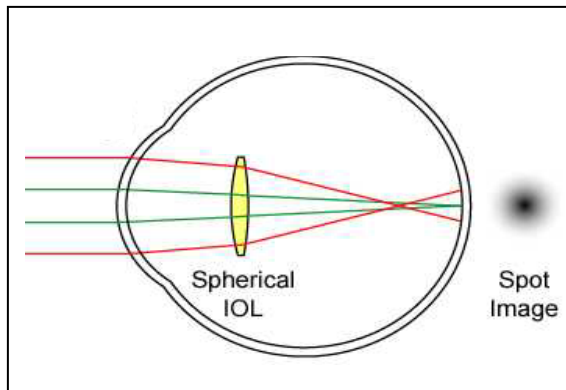


Figure 1: Diagram of light rays passing through the center (green) and periphery (red lines) of a spherical IOL demonstrating the convergence of peripheral light rays in front of the retina leading to a slightly blurry image on the retina.

In young adults, the SA of the cornea is slightly positive and the SA of the lens is slightly negative. In this case, the SA of the total ocular system, lens and cornea, is near zero. As the eye ages, the SA of the lens becomes more positive so that the total SA of the ocular system becomes positive, leading to decreased contrast sensitivity.⁵

Aspheric IOLs

Traditional intraocular lenses are spherical and add positive SA to the already positive SA of the cornea. This means that CS for pseudophakic patients is no better than that of their age-matched phakic counterparts, even though the optical clarity of the pseudophakic lens is superior to that of the aged crystalline lens.⁶ In order to improve visual function in post-cataract patients, aspheric IOLs were developed to avoid adding further positive SA to the ocular system. Aspheric IOLs have a prolate shape, where the surface flattens away from its vertex (negative SA), so that light rays are focused on the retina. This helps refine the image

on the retina, decreasing the blur from unfocused light rays and improving the contrast of the image (Figure 2).

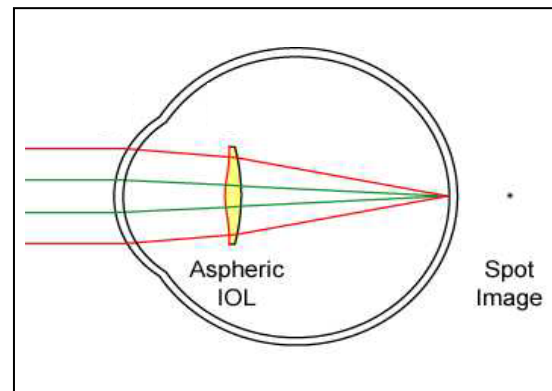


Figure 2: Diagram of light rays passing through the center (green) and aspheric periphery (red lines) of an aspheric IOL demonstrating the convergence of central and peripheral light rays on the retina to produce a well focused spot image.

There are a number of aspheric IOLs now available. Although these IOLs have aspheric optics, the amount they deviate from a true sphere varies. Some IOLs have negative aspheric optics and are designed to compensate for the average positive SA of the human cornea ($\sim 0.27 \mu\text{m}$) to produce a total ocular SA close to zero. Other IOLs correct some of the corneal SA, but leave the total ocular SA slightly positive ($\sim 0.1 \mu\text{m}$). However, all these 1st-generation negative SA IOLs are designed to function best when they are perfectly centered on the visual axis.

Finally, some aspheric IOLs are 'aberration-free'. They neither add nor subtract from the SA of the cornea. Like spherical IOLs, they are relatively insensitive to decentration or tilt.⁷ The degree of image improvement with these lenses is usually somewhere between a spherical lens and a negative SA lens.

Numerous studies have demonstrated improved CS, particularly under low-light (mesopic) conditions, with aspheric IOLs compared to spherical IOLs (for an excellent review, see Montés-Micó et al, 2009⁸). Well-designed 1st-generation aspheric IOLs decrease higher order wavefront SA and improve the quality of the image the retina receives.

The drawback to these lenses is that they function best when perfectly aligned with the visual axis. Lens decentration can induce wavefront aberrations that decrease quality of vision.^{9,10} In the real world, neither the crystalline lens, aphakic capsular bag, nor intraocular lens is always in perfect alignment with the visual axis. Studies have demonstrated an average decentration of the crystalline lens that ranges from 0.16 mm to 0.34 mm^{11,12,13,14} and an average decentration of intraocular lenses ranging from 0.2 mm to 0.41 mm.^{12,15,16,17,18,19} It has been hypothesized that decentration of the lens from the visual axis may occur developmentally to compensate for lateral coma at the level of the cornea.²⁰

iSymm Aspheric IOL with ABC Optics

The iSymm IOL (FC-60AD, FY-60AD) has an innovative design developed to maximize the benefits of lens asphericity by minimizing the effect of decentration upon the optical quality of the visual system. This is done with the Aspheric Balanced Curve (ABC) design, shown in Figure 3. The optic of the iSymm IOL is

uniquely aspherized across zones 1 and 2, unlike conventional 1st-generation aspheric IOLs. This central asphericity is not great enough to adversely affect visual quality when the lens is perfectly centered along the visual axis, but serves to maintain the aspheric effect with lens decentration of up to 0.5 mm. More peripherally, in zone 3, the lens resembles other negative SA aspheric IOLs. The overall effective SA of the iSymm IOL is $-0.18 \mu\text{m}$, for a residual SA of approximately $+0.1 \mu\text{m}$, which approximates the total ocular SA in a young phakic (age 25) eye.⁴

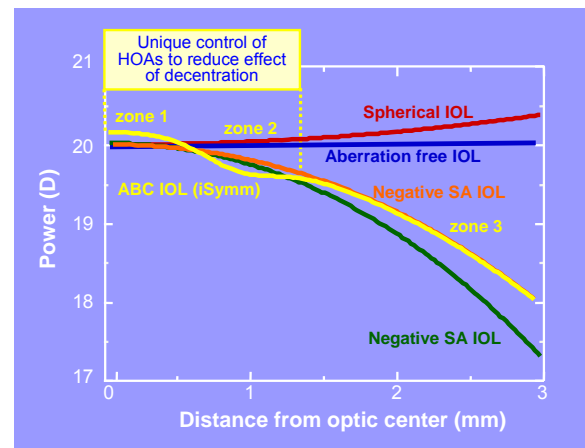


Figure 3: Curve representing the curvature (optic power) of the iSymm and a spherical IOL along the radius of the lens optic. HOAs=higher order aberrations

The iSymm IOL is designed to reduce SA, thus bringing incoming light to a sharper focus on the retina. As can be seen in Figure 4, the point spread function (PSF) for a traditional spherical IOL is much more diffuse than that of the iSymm IOL with ABC optics. This diffusion of light creates a ‘fuzzy’ image on the retina that decreases quality of vision.

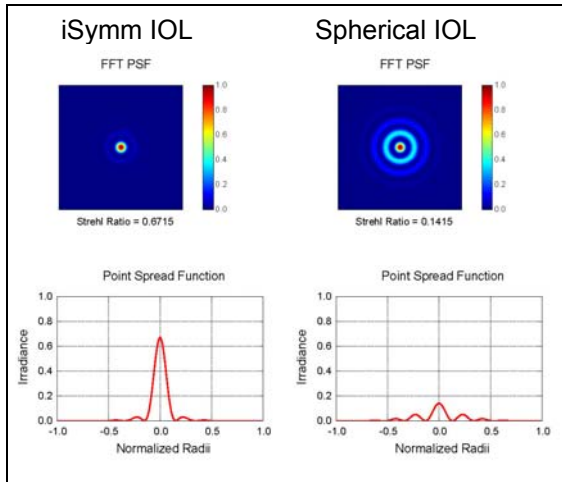


Figure 4: Comparison of point-spread-functions (PSF) for the iSymm IOL and a traditional spherical IOL. The top row contains spot diagrams representing the spread of light from a single point source after passing through the lens. The bottom row shows light dispersion from the center as a graph.

Using US Air Force resolution efficiency charts, the difference in the quality of the image that reaches the retina through an iSymm IOL and a traditional spherical IOL can be demonstrated. Figure 5 shows the resolution of the chart through the iSymm IOL (FY-60AD) and its spherical counterpart IOL (YA-60BBR). As can be seen, the aspheric iSymm lens provides better resolution of the image than the spherical IOL.

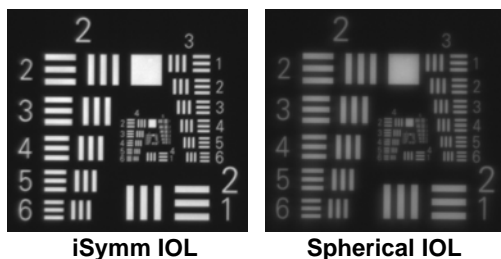


Figure 5: Improved resolution with an aspheric IOL. US Air Force Resolution Efficiency Charts through the aspheric iSymm IOL and a traditional spherical IOL (YA-60BBR).

The ABC design of the iSymm IOL maintains the ability to improve image quality over spherical IOLs even when the lens is decentered. This is an improvement over 1st-generation negative SA aspheric IOLs which lose the advantages of aspheric design with lens decentration (Figure 6).

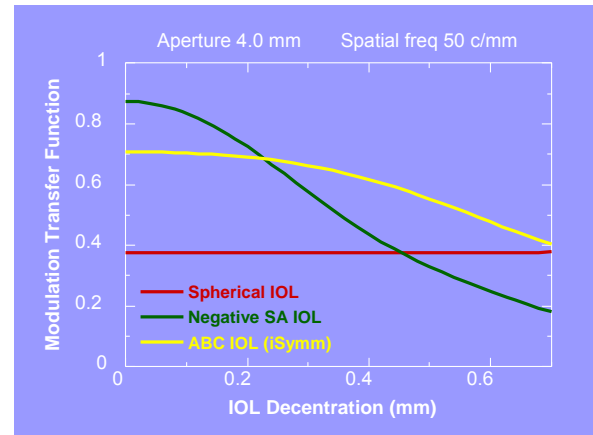


Figure 6: MTF function by decentration in a model eye with a cornea having SA of $+0.27 \mu\text{m}$. Optical quality of the negative SA aspheric IOL decreases swiftly with decentration until its performance dips below that of a spherical IOL at approximately 0.5 mm of decentration. Optical quality of the iSymm IOL decreases slightly with decentration, but remains greater than that of a spherical IOL due to its unique ABC design.

In a model eye with the corneal SA of $+0.27 \mu\text{m}$, both the iSymm and the traditional negative SA aspheric IOL perform well when centered. As the lens decenters, the performance of the iSymm IOL remains relatively consistent through decentrations of 0.2 mm to 0.5 mm while the performance of the negative SA aspheric IOL drops off quickly, finally reaching levels below that of a spherical IOL.

The difference in image quality with 0.4 mm of decentration is shown in Figure 7. Both the 1st-generation negative SA aspheric IOL and the iSymm IOL show

good image quality when centered, but the loss of image quality at 0.4 mm decentration is greater for the 1st-generation negative SA aspheric IOL than for the iSymm IOL with ABC optics.²¹

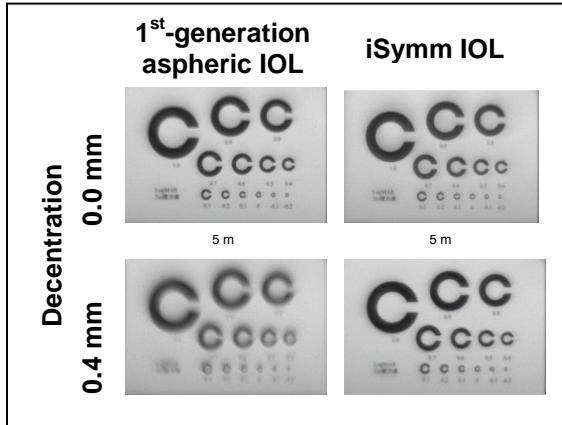


Figure 7: Simulated image quality through a 1st-generation negative SA aspheric IOL and the iSymm IOL with ABC optics at 0 mm and 0.4 mm of decentration demonstrating greater degradation of image quality with the 1st-generation negative SA aspheric IOL compared to the iSymm IOL.²¹

Clinically, eyes implanted with the iSymm IOL demonstrate decreased higher order spherical wavefront aberrations and improved CS when compared with a spherical IOL of the same overall design. In a paired-eye study of 51 subjects, one eye was implanted with the aspheric iSymm IOL (FY-60AD) and the fellow eye implanted with a spherical IOL (YA-60BBR) of identical design. At one month postoperative, the mean IOL decentration was approximately 0.21 mm in both groups. This is in line with published studies noting mean decentration values of 0.2 mm to 0.5 mm.^{12,15-19} The range of decentration at

one month was 0.03 mm to 0.54 mm for the FY-60AD and 0.02 mm to 0.43 mm for the YA-60BBR.

The difference in spherical aberration between the aspheric iSymm IOL and the spherical IOL was significantly different with a 4 or a 6 mm pupil.²² With a 6 mm pupil, there was approximately +0.10 μ m of total ocular SA, which approximates the SA of the 25-year-old eye.⁴

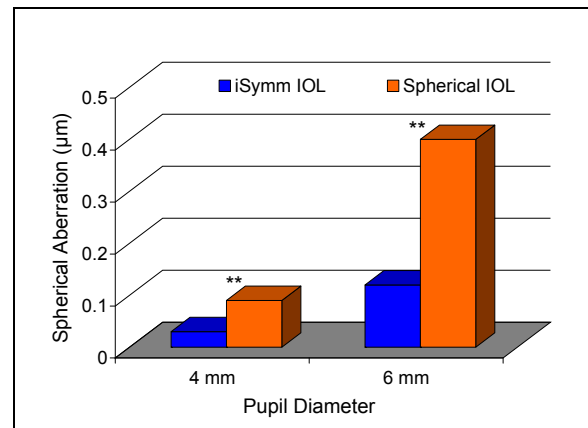


Figure 8: Comparison of spherical aberrations at one month in eyes implanted with either the aspheric iSymm (FY-60AD) or spherical (YA-60BBR) IOL through a 4 mm or 6 mm entrance pupil. ****** $p < 0.01$.²²

Contrast sensitivity was similar for the aspheric and spherical IOL eyes under photopic (bright light) conditions. There was a significant improvement in CS for aspheric compared to spherical IOL eyes at 3, 6, and 18 cycles per degree (cpd) under mesopic (dim light) conditions, and at 1.5 and 3 cpd under scotopic (minimal light) conditions (Figure 9).²²

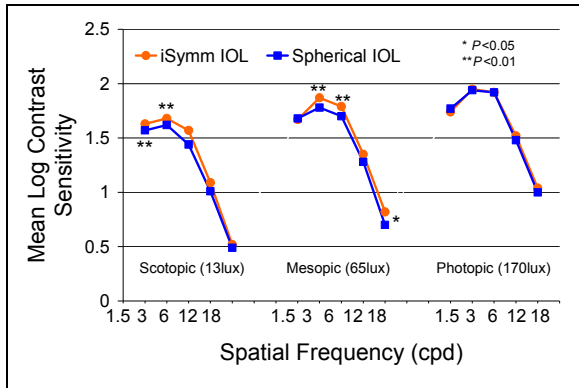


Figure 9: Mean contrast sensitivity scores for eyes implanted with either the aspheric (FY-60AD) or spherical (YA-60BBR) IOL.²²

To assess overall CS, the area under the log contrast sensitivity function curve (AULCSF) was calculated. Overall mean CS was significantly greater in the aspheric IOL eyes compared to the spherical IOL eyes (Figure 10)²².

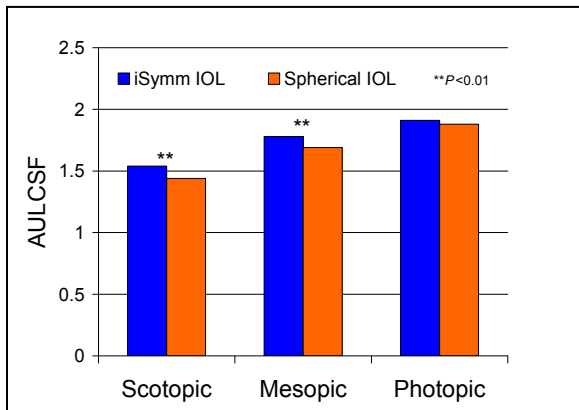


Figure 10: Mean overall contrast sensitivity scores (area under the log contrast sensitivity function) for eyes implanted with either the aspheric (FY-60AD) or spherical (YA-60BBR) IOL.²²

Clinically, the iSymm IOL achieved its design goal of decreased spherical aberration and increased CS compared to a spherical IOL of the same design.

Conclusion

The iSymm aspheric acrylic IOL with ABC optics provides comparable optical performance to 1st-generation aspheric IOLs when centered on the visual axis and superior performance with levels of decentration commonly reported in the clinical literature. Both optical and clinical performance measures confirm decreased spherical aberrations and improved CS with the iSymm IOL compared to a similar spherical IOL. This lens should provide a valuable addition to the surgeon's armamentarium.

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