

The Monofocal Solution for Presbyopic Cataract Surgery

An overview of the early successes of aspheric IOLs for monovision.

BY J. E. "JAY" McDONALD II, MD

Monovision is a familiar technique in cataract surgery that enables patients to view both near and far visual targets in the absence of natural visual accommodation. Implanting monofocal IOLs of different focal distances improves the patient's ability to see objects at close range while maintaining excellent distance visual acuity.^{1,2} Once a popular choice of surgeons, monovision has competed in recent years with multifocal and accommodative IOL technologies.

LENS DESIGN AND SPHERICAL ABERRATION

Spherical-aberration changes in an aging eye can benefit from a monofocal, aspheric, aberration-free IOL used in a monovision technique. In a young person, the spherical aberrations of the cornea and lens are of opposite sign. This balance, or "good-coupling," between the lens or internal optics of the eye and the cornea reduces the overall amount of aberrations in the entire eye. In an older person, however, the wavefront of the lens (besides being more aberrated) has a shape that does not match the corneal wavefront. As a result of this "decoupling" between corneal and lenticular aberrations, the entire eye is more aberrated.

Removing the crystalline lens changes the results of all previous couplings between the cornea and the internal optics. Inserting a standard spherical IOL adds to the already positive spherical aberration of the cornea. Implanting an IOL with negative spherical aberration, on the other hand, can offset the positive spherical aberration of the cornea for a net-zero effect of spherical aberration. Research has demonstrated, however, that a small amount of positive spherical aberration is beneficial, because it compensates for higher-order aberrations such as coma and trefoil.^{3,4} Furthermore, spherical aberration

TABLE 1. CURVATURE, POWER, AND INHERENT ABERRATION OF SEVERAL DIFFERENT TYPES OF MONOFOCAL IOLs

Lens Type	Curvature	Power	Spherical Aberration Inherent in Lens
Standard spherical IOL	Spherical	Increases from center to edge	Positive
Aspheric (Tecnis)	Flattens from center to edge rapidly	Decreases from center to edge	Negative
Aspheric (Sofport AO)	Flattens from center to edge slowly	Constant from center to edge	None

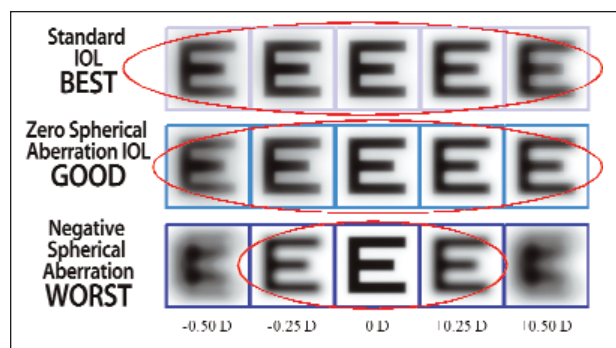


Figure 1. This chart shows the depth of field with three types of monofocal IOLs.

increases an eye's depth of field. When the object distance is infinity, image clarity is sharpest in an eye with no spherical aberration (the IOL with negative spherical aberration produces this). However, as vergence increas-

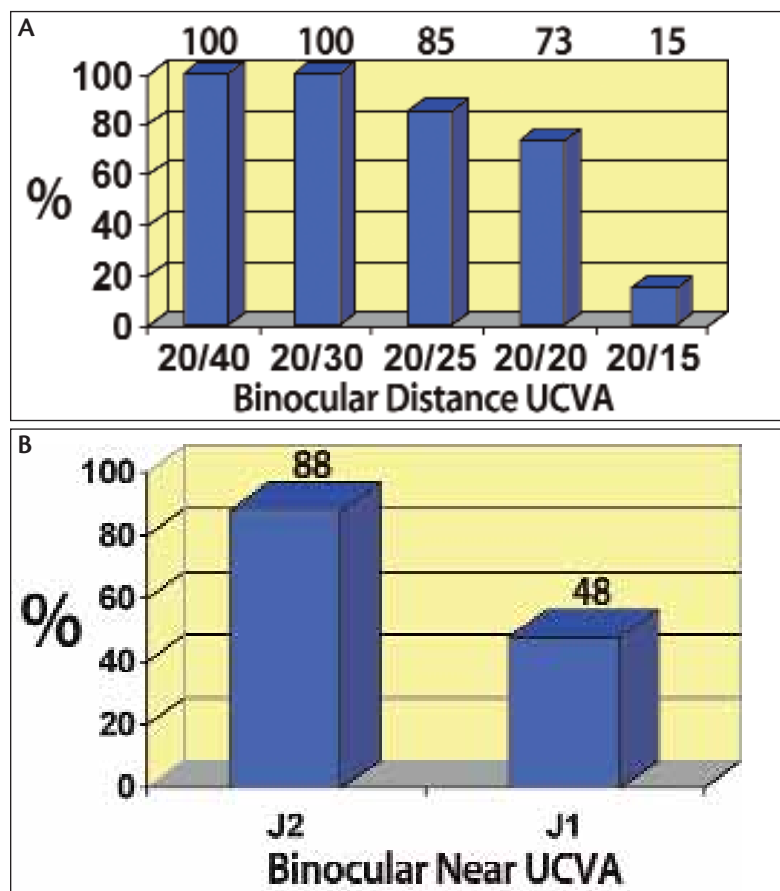


Figure 2. Distance (A) and near (B) visual outcomes in a retrospective evaluation of 80 eyes of 40 patients implanted with the Sofport AO aspheric IOL for monovision are shown.

es, image quality degrades with an IOL that has negative spherical aberration and is better with an aberration-free IOL (Sofport AO lens; Bausch & Lomb, Rochester, NY) (Table 1 and Figure 1).

An aberration-free lens is forgiving when it is implanted slightly off-center.⁵ Eyes that have undergone refractive surgery may have positive or negative spherical aberration, and the optical center of the cornea may be difficult to determine and match with the IOL's optical center. With these unknowns, adding positive or negative spherical aberration to the system could degrade image quality. If other higher-order aberrations are absent or minimal, a centered, negatively aspheric lens can provide image quality equal to or better than the aberration-free IOL in a pseudophakic monovision situation.

STUDY

I achieved great success in my clinic with the Sofport AO aberration-free aspheric IOL for monovision. In a

retrospective study with 80 eyes of 40 patients, I implanted a near vision IOL in one eye, with a targeted refraction of -0.75 to -2.00 D, and a distance vision IOL in subjects' other eye, targeted between plano and -0.50 D. Three months postoperatively, all patients had 20/30 binocular vision or better, and 73% had at least 20/20 vision. Near vision was similarly successful, with 88% of patients achieving J2 or better and 48% possessing J1 or better near binocular vision. In a survey on spectacle dependence, only 19% of patients remained dependent on glasses for near vision; in contrast, 11% needed glasses for distance vision, and only 3% needed them for intermediate vision (Figure 2).

MONOVISION AND THE HUMAN VISUAL SYSTEM

What attributes of the human visual system facilitate the use of monofocal aspheric implants in overcoming the issues of presbyopia? The monofocal solution is one that cooperates with the brain's natural processes of fusion while maintaining the highest quality of the image.

In developing new ophthalmic technologies, it seems that researchers have not paid enough attention to the naturally structured pathways of the brain. Multifocal IOLs are designed to recapture the phenomenon of accommodation, yet these lenses produce lower contrast sensitivity, are associated with a higher rate of glare and halos, and are highly sensitive to lens decentration.⁶⁻¹⁰ According to Claoue and Parmar,¹¹ patients lose 18% of light energy with multifocal IOLs, which can be attributed to the conflicting and overlapping patterns produced by these lenses. Multifocal IOLs create competing visual images at the outset of the visual pathway that are transferred to the optic nerve and then to the brain, which can cause a significant loss in contrast sensitivity. The degradation in the visual quality that occurs after the implantation of multifocal lenses cannot be reversed with spectacles. A successful monovision procedure, however, allows for visual improvement with glasses.

Recent work in neuroscience has paved the way for us to understand the differences between multifocal and monofocal lenses. Multifocal IOLs seem to rely on monoptic suppression. This phenomenon occurs when both

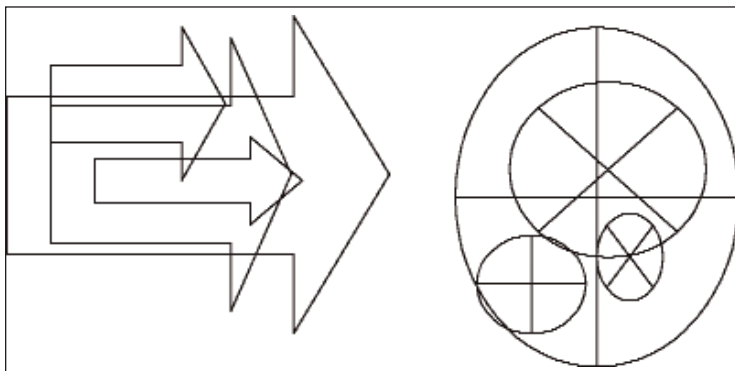


Figure 3. These two images can trigger monoptic suppression.

eyes are looking at the same target, but, within the target, there are visual cues that promote an alternating focus.¹² For example, in Figure 3, one's eyes are drawn to a number of features; they perceive certain shapes at one moment and focus on others the next. While this occurs, the neural pathway is suppressing pieces of the image as one's focus changes.

Monoptic suppression can be compared to the visual effects caused by multifocal IOLs. With these lenses, near, intermediate, and distance visual information is presented to both eyes simultaneously. Each eye must suppress certain visual information in order to perceive a clear picture. If this suppression stems from the same neural correlates as seen with monoptic suppression, it becomes obvious why multifocal patients are exhibiting significantly lower contrast sensitivity. Humans' visual pathways are not hardwired to distinguish overlapping images and simultaneously produce high-contrast output.¹³

In contrast, utilizing monofocal IOLs for monovision induces binocular fusion when desired clinical outcomes are obtained. Binocular fusion occurs when the eyes perceive two distinct images that are harmonious enough to result in a single visual product. If the images are spatially congruent, fusion can occur even if the contrast between the two images varies by a few factors. Images that differ significantly in spatial frequency and orientation prevent binocular fusion.¹⁴⁻¹⁶

Pseudophakic monovision is a natural choice for cataract replacement or lens exchange surgery, as the contrast difference resulting from monovision permits binocular fusion. The eyes present two images that vary substantially in contrast and clarity, but they are spatially congruent enough to allow fusion to occur. Information from the eyes is transmitted to the visual cortex, where data from the eye producing higher contrast will be accepted as the dominant percept. The visual cortex provides neural feedback to reduce the influence of the lower-contrast eye and thus generate excellent contrast sensitivity and visual acuity at all distances.

CONCLUSION

The theories presented herein help explain the early successes of aspheric IOLs for monovision as well as the visual frustrations and loss of contrast sensitivity that can result from multifocal IOL implants. As research further explains the mechanisms of the brain, I anticipate a more effective solution to the presbyopic problem. ■

Section Editor Eric D. Donnerfeld, MD, is a partner in Ophthalmic Consultants of Long Island and is Co-Chairman of Corneal and External Disease at the Manhattan Eye, Ear & Throat

Hospital in New York. He is a consultant and performs research for Alcon Laboratories, Inc., Advanced Medical Optics, Inc., and Bausch & Lomb, but he acknowledged no financial interest in the products mentioned herein. Dr. Donnerfeld may be reached at (516) 766-2519; eddoph@aol.com.

J. E. "Jay" McDonald II, MD, is Editor of the ASCRS Eye Mail. He acknowledged no financial interest in the products or companies mentioned herein. Dr. McDonald may be reached at (479) 521-2555; mcdonaldje@mcdonaldeye.com.



- Boerner CF, Thrasher BH. Results of monovision correction in bilateral pseudophakes. *J Am Intraocular Implant Soc.* 1984;10:49-50.
- Greenbaum S. Monovision pseudophakia. *J Cataract Refract Surg.* 2002;28:1439-1443.
- Artal P, Berrio E, Guirao A, Piers P. Contribution of the cornea and internal surfaces to the change of ocular aberrations with age. *J Opt Soc Am A Opt Image Sci Vis.* 2002;19:137-143.
- Applegate RA, Marsack JD, Ramos R, Sarver EJ. Interaction between aberrations to improve or reduce visual performance. *J Cataract Refract Surg.* 2003;29:1487-1495.
- Altmann GE, Nichamin LD, Lane SS, Pepose JS. Optical performance of 3 intraocular lens designs in the presence of decentration. *J Cataract Refract Surg.* 2005;31:574-585.
- Chiam PJ, Chan JH, Aggarwal RK, et al. ReSTOR intraocular lens implantation in cataract surgery: quality of vision. *J Cataract Refract Surg.* 2006;32:1459-1463.
- Souza CE, Muccioli C, Soriano ES, et al. Visual performance of AcrySof ReSTOR apodized diffractive IOL: a prospective comparative trial. *Am J Ophthalmol.* 2006;141:827-832.
- Rocha KM, Chalita MR, Souza CE, et al. Postoperative wavefront analysis and contrast sensitivity of a multifocal apodized diffractive IOL (ReSTOR) and three monofocal IOLs. *J Refract Surg.* 2005;21:S808-812.
- Javitt JC, Steinert RF. Cataract extraction with multifocal intraocular lens implantation: a multinational clinical trial evaluation clinical, functional, and quality-of-life outcomes. *Ophthalmology.* 2000;107:2040-2048.
- Hayashi K, Hayashi H, Nakao F, Hayashi F. Correlation between pupillary size and intraocular lens decentration and visual acuity of a zonal-progressive multifocal lens and a monofocal lens. *Ophthalmology.* 2001;108:2011-2017.
- Claoue C, Parmar D. Multifocal intraocular lenses. *Dev Ophthalmol.* 2002;34:217-237.
- Sengpiel F, Vorobyov V. Intracortical origins of interocular suppression in the visual cortex. *J Neurosci.* 2005;25:6394-6400.
- Tse PU, Martinez-Conde S, Schlegel AA, Macknik SL. Visibility, visual awareness, and visual masking of simple unattended targets are confined to areas in the occipital cortex beyond human V1/V2. *Proceedings of the National Academy of Sciences of the United States of America.* 2005;102:17178-17183.
- Schor C, Heckmann T, Tyler CW. Binocular fusion limits are independent of contrast, luminance gradient and component phases. *Vision Res.* 1989;29:821-835.
- Schor C, Heckmann T. Interocular differences in contrast and spatial frequency: effects on stereopsis and fusion. *Vision Res.* 1989;29:837-847.
- Liu L, Tyler CW, Schor CM. Failure of rivalry at low contrast: evidence of a suprathreshold binocular summation process. *Vision Res.* 1992;32:1471-1479.