Are All Spherical IOLs the Same?

The lenses' powers, designs, and materials are some of the factors influencing the induction of spherical aberration.

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Any spherical IOL contributes to the positive spherical aberration of the pseudophakic eye, as evident from physical optics and confirmed by several studies.[1-4] The amount of spherical aberration induced by the IOL can be determined by subtracting the aberration of the corneal surface from that of the entire eye. Simultaneous measurements of the corneal and other ocular aberrations provide a more precise alignment of the corneal topography and ocular aberrometry, and they improve the evaluation of the internal aberrations.[2] One can therefore analyze any aberration introduced into an eye by an IOL. The contribution of the posterior corneal surface is low, owing to the small difference in the refractive indices of the cornea and aqueous humor.

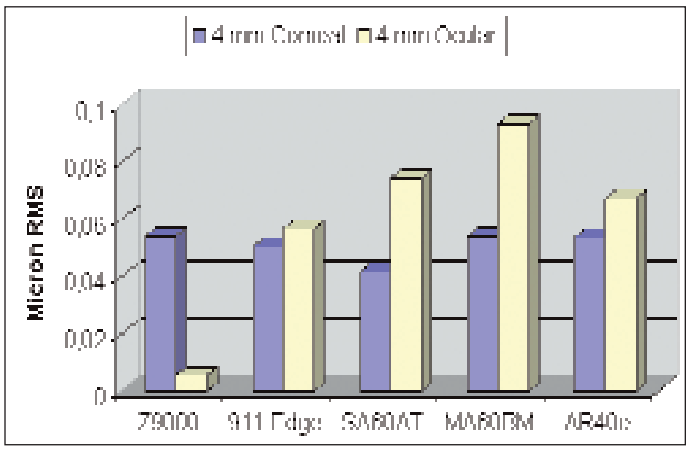

Figure 1. The authors calculated corneal spherical aberration by topography and ocular spherical aberration as measured by a Hartmann-Shack sensor for a series of pseudophakic eyes with IOLs of comparable power.

The amount of spherical aberration induced by the various spherical IOLs available differs. Figure 1 shows a series of our measurements in pseudophakic eyes with five lenses/eyes per group. The graph reports only the pure spherical aberration Z(4,0) and excludes the other fourth-order aberrations, secondary astigmatism and quadrafoil. The discrepancy in the amounts of aberrations induced is due to a number of parameters, some related to the IOLs and others to the implanted eye. The IOL-related factors include the dioptric power, design, and material.

POWER

Comparative studies of induced aberrations have always used IOLs of approximately the same power in order to avoid any bias introduced by different dioptric powers on spherical aberration. Dr. Bellucci reported the relationship between induced spherical aberration and the lens' power in implanted eyes in 2003.[5] The study included eyes with different powers of the Acrysof MA60BM IOL (Alcon Laboratories, Inc., Forth Worth, TX) (Figure 2). Recently, further research on the same IOL yielded similar results and confirmed that the amount of induced spherical aberration rose as the lens' dioptric power increased.[6]

Neither study included an IOL of more than +30.00D, but ophthalmologists commonly implant lens powers as high as +40.00D in hyperopic patients. One may anticipate very high spherical aberration in those individuals after IOL surgery with all the relevant effects on the sharpness of images, refraction, and depth of focus. Low-powered IOLs induce less spherical aberration, but some is present with flat surfaces.[7] Negative, low-powered lens-

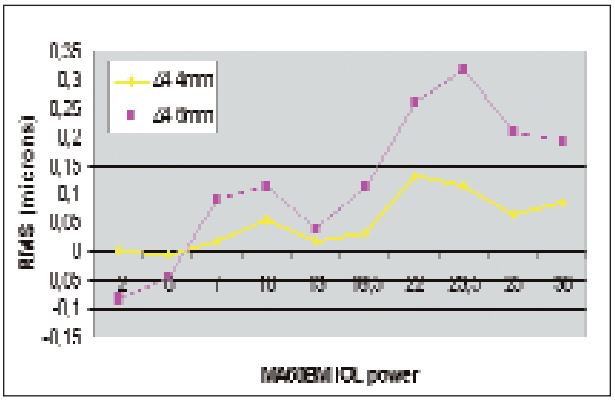

Figure 2. This graph shows the relationship between total spherical aberration and dioptric power for the Acrysof MA60BM lens.

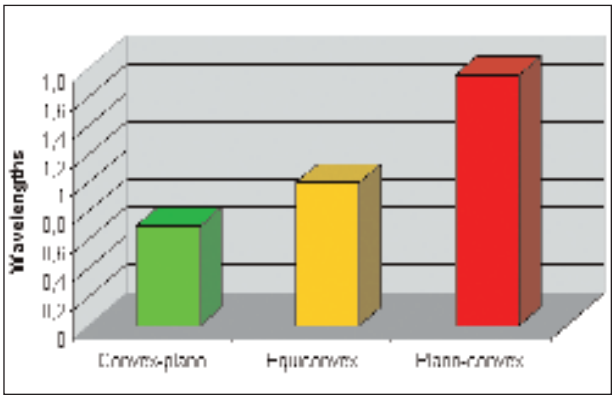

Figure 3. Atchison[8] determined this relationship between the amount of induced spherical aberration and an IOL's shape.

es induce negative spherical aberration but only a small amount due to their low dioptric power.

DESIGN

Ophthalmologists have long been aware that a lens' design influences the induction of spherical aberration.[8] Generally speaking, IOLs have curved surfaces because the refractive index of their materials (approximately 1.46 to 1.49) is similar to the refractive index of the aqueous humor (approximately 1.336). The distribution of curvatures between the lens' anterior and posterior surfaces affects the amount of spherical aberration induced by the IOL. For normal corneas with positive spherical aberration, convex-plano lenses induce the lowest amount of spherical aberration, followed by equiconvex lenses and plano-convex lenses[8] (Figure 3). One may therefore expect any IOL to induce lower amounts of positive spherical aberration as the anterior surface becomes more curved.[7]

> "One may ... expect IOLs with a high refractive index to induce more spherical aberration."

In implanted eyes, we found less spherical aberration with the Acrysof SA60 IOL (Alcon Laboratories, Inc.) than with the MA60BM IOL,[2] and recent research has confirmed our results. For example, Taketani et al[9] compared two Acrysof lens designs. They found slight differences in spherical aberration in favor of the more curved anterior design but only at 6-mm aperture diameters. In a similar study, Rocha et al[10] showed similar levels of higher-order aberrations with the Acrysof Restor, MA30, and SA30 lenses (all from Alcon Laboratories, Inc.), but the multifocal Acrysof Restor lens demonstrated the lowest amount of spherical aberration.

MATERIAL

The optics of today's IOLs are made of several materials—PMMA, hydrophobic and hydrophilic acrylic, and silicone. Each material has its own refractive index and consequently its own curvatures for a given power. Both elements affect the amount of spherical aberration induced by the IOL's implantation. Studying refracting media with flat surfaces reveals a relationship between the refractive index and spherical aberration[7] as well as between curvature and aberrations.[7,8] The higher the refractive index, the lower the curvature. One may therefore expect IOLs with a high refractive index to induce more spherical aberration.

Interestingly, all of the studies comparing spherical IOLs found the greatest amount of induced spherical aberration for the material with the highest refractive index.[2,11,12] Martin and Sanders[11] considered four IOL types and materials: the STAAR Collamer lens (refractive index = 1.44; STAAR Surgical Company, Monrovia, CA); the STAAR Silicone lens (refractive index = 1.41; STAAR Surgical Company); the hydrophobic acrylic Sensar lens (refractive index = 1.47; Advanced Medical Optics, Inc., Santa Ana, CA); and the Acrysof SA60 hydrophobic acrylic IOL (refractive index = 1.55). The STAAR Collamer lens induced slightly less spherical aberration than the Acrysof IOL, but only the total amounts of induced aberration were clearly different on statistical analysis. Rohart et al[12] found that the Acrysof MA60AC hydrophobic acrylic lens (refractive index = 1.55; Alcon Laboratories, Inc.) induced a greater amount of spherical aberration

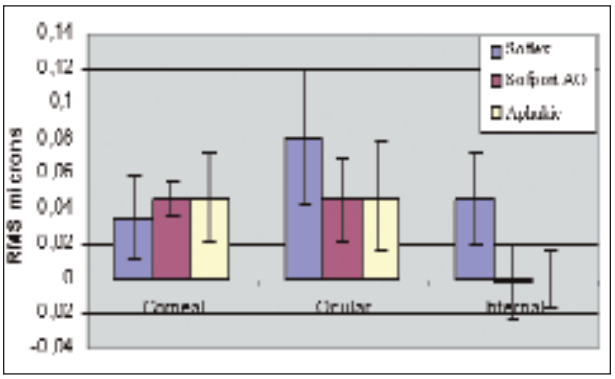

Figure 4. The aberration-neutral IOLs with no spherical aberration do not contribute to the positive spherical aberration of the cornea as a mean. This aberration varies slightly in every implanted eye, however, and a standard deviation of this zero contribution appears. The optical zones were 4mm.

than the hydrophobic acrylic XLSTABI lens (not available in the US; refractive index = 1.46; IOLTech Laboratories, La Rochelle, France). In neither study did the investigators consider the shape of the IOLs' surfaces or their indices of refraction as possible causes of the increased spherical aberration observed with the Acrysof IOL.

OTHER INFLUENCES

According to physical optics, the amount of spherical aberration that an IOL introduces into pseudophakic eyes also depends on the curvature of the refractive surfaces and the total dioptric power of the optical system.[8] In other words, the same lens and power can change the spherical aberration of two individual eyes differently according to their corneal curvature and the total refractive power attained (cornea + IOL). The change therefore relates in some degree to the axial length.

Actually, any set of measures of induced spherical aberration is presented as a mean and standard deviation, even in the case of the so-called aberration-neutral lenses (Figure 4). In practice, the eye itself plays a role in the final amount of spherical aberration, although its influence is minor compared with the IOL-related parameters.

SELECTION OF AN IOL

The aforementioned differences in the amount of positive spherical aberration induced by spherical lenses permit some suggestions for the proper selection of an IOL. With low-powered lenses, the resulting spherical aberration of the eye will be close to the corneal spherical aberration. With high-powered lenses, the increase in positive spherical aberration will grow as the curvature of the IOL's anterior surface diminishes. According to specific corneal curvatures—such as those of the corneas ablated by an excimer laser—selecting an IOL properly could limit or increase the eye's level of spherical aberration. With very high-powered lenses, the induction of positive spherical aberration could decrease contrast sensitivity but simultaneously increase the depth of focus to such an extent as to favor near vision.

CONCLUSION

How much spherical aberration a spherical IOL induces depends on lens-related as well as eye-related factors. Surgeons therefore cannot precisely anticipate the amount of aberration that will be induced in a given eye without performing complex optical calculations. As a general rule, lenses with more curved anterior surfaces will induce less spherical aberration than those with flat anterior surfaces, and low-powered IOLs will deliver less spherical aberration than high-powered ones. ■

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