EDITORIAL

What is the relevance of asphericity in today's ophthalmic practice?

When performing cataract surgery, we replace the cataractous lens with an IOL. The combined effect of the spherical aberration of the cornea and IOL plays a big role in the quality of vision of the entire optical system.

ASPHERICITY is a measure of the shape of a refractive medium and how it affects bending of light. When light goes through an optical medium or lens surface, the shape of the optical medium affects where the central and peripheral rays of light eventually focus behind this medium. The cornea, the natural lens, and an intraocular lens (IOL) are refractive media that have their own asphericity.

Descriptively, we can address the shape of a refractive surface as spherical, prolate aspheric, or oblate aspheric. A sphere is perfectly round. A prolate asphere is steeper in the center and flatter in the periphery. An oblate asphere is flatter in the center and steeper in the periphery. Quantitatively, we can express asphericity as the Q value wherein Q = b2/a2 -1. Q = 0 is spherical; negative Q value is prolate aspheric, and positive Q value is oblate aspheric.

Indirectly, asphericity can be correlated with spherical aberration. Spherical aberration is one of many higher-order aberrations but has been found to be the most significant in terms of degrading the quality of vision outside of spherical error and astigmatism. It is a fourth-order aberration that is measured in microns as a root mean square (RMS). A surface with a more positive Q value is an oblate asphere which has a higher spherical aberration. Conversely, the more negative the Q value, the more prolate the shape and the lower the spherical aberration.

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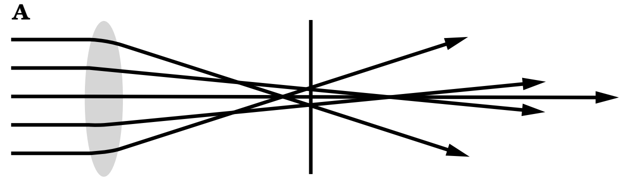

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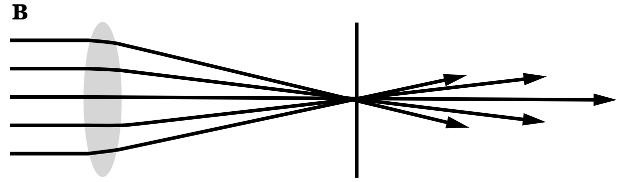

When parallel rays pass through a spherical medium, the central rays focus more posteriorly while peripheral rays progressively focus more anteriorly in an even fashion (Figure A). The Q value is zero and the spherical aberration mildly positive. A prolate surface, steeper centrally and flatter peripherally, focuses peripheral rays more posteriorly and thus more coincident to central rays (Figure B). The Q value is negative and the spherical aberration negative as well. Maintaining or inducing prolateness, decreasing spherical aberration and lowering Q values increase quality of vision and sharpness of focus because all light rays come into a single focus. An oblate surface, flatter centrally and steeper peripherally, focuses peripheral rays significantly more anterior than a spherical surface, farther away from the posterior foci of central rays. The Q value and spherical aberration are both very positive. Inducing oblateness increases Q values and spherical aberration, degrading image quality, decreasing contrast sensitivity and causing poor low contrast vision.

Two parts of the eye that exert asphericity are the cornea and lens. The cornea is naturally prolate with a spherical aberration value of approximately +0.1 µm. The cornea is steep centrally and becomes flatter going towards the limbus. This is believed to stay constant throughout a person's lifetime unless they undergo corneal surgery.

Myopic correction comprises majority of laser refractive surgery procedures. In myopic Lasik, the central cornea is ablated making it flatter. In our effort to correct myopic sphere and cylinder, we inadvertently convert a prolate cornea into an oblate one, increasing the Q value and spherical aberration. Vision is grossly improved but in dim light, when the pupils dilate and peripheral rays of light come into play, the quality of vision is degraded and glare and haloes are induced. Wavefront-guided Lasik was designed to reduce most higher-order aberrations but it was later discovered that myopic treatments still increased spherical aberration. Aspheric or wavefront-optimized algorithms were later introduced to counteract the spherical aberration produced by myopic Lasik. Aspheric Lasik is Lasik using a conventional algorithm with an aspheric overlay. It did not address the other higher-order aberrations similar to wavefront-guided treatments but a predetermined amount of laser pulses was added in the transition zone to smoothen the slope in the corneal mid-periphery, causing a mild steepness in the paracentral zone. The Q value is controlled and induction of spherical aberration is reduced with the net effect of preserving good quality of vision in dim light with pupils dilated. However, the best quality of vision in Lasik can be obtained when using a combined wavefront-guided and aspheric algorithm wherein sphere, cylinder, and higher-order aberrations are corrected and induction of spherical aberration is reduced.

In the internal eye, the natural lens is slightly prolate with a slightly negative spherical aberration in the young. This neutralizes the mildly positive spherical aberration of the cornea. As one grows older, the spherical aberration of the natural lens increases. Combined with the positive spherical aberration of the cornea, a progressive deterioration of quality of vision occurs.

When performing cataract surgery, we replace the cataractous lens with an intraocular lens (IOL). The combined effects of the spherical aberrations of the cornea and IOL play a big role in the quality of vision of the entire optical system. A traditional non-aspheric monofocal IOL has a constant curvature throughout the entire breadth of the lens similar to a spherical surface. Central rays are focused more posteriorly compared to peripheral rays. This results in positive spherical aberration of the optical system. Despite improving the patient's overall quantity of vision with cataract removal and decreasing refractive error, it does not maximize the quality of vision.

The concept of using aspheric monofocal IOLs is intended to avoid adding to or to counteract the positive asphericity of the cornea. By targeting the least positive or converting the optical system to a negative spherical aberration, we provide a better quality of vision for the pseudophakic eye. An aspheric IOL has a variable curvature over its surface wherein central and peripheral rays are designed to focus at or near each other closest to the retina, offering a single sharper focus. Some aspheric IOLs, such as the Bausch and Lomb Adapt AO, are aberration neutral (zero aberration) while others have negative asphericity such as the Tecnis (−0.27 µm aberration) and the Alcon Acrysof IQ (−0.20 µm aberration). Zero-aberration lenses do not increase or reduce the spherical aberration of the cornea. Maintaining the mild positive spherical aberration from the cornea is believed to be beneficial in mildly increasing the depth of focus. In addition, maintaining a neutral aberration makes it insensitive to lens decentration. The Alcon IQ and Tecnis IOLs are negative spherical aberration lens which counteract the corneal spherical aberration and induce a negative aberration onto the entire optical system. This produces the sharpest focus for distance vision. However, any decentration of a negative aspheric lens will cause an irregular astigmatism-like aberration called a coma, which can degrade the quality of vision. For cataract patients who have an active lifestyle, large pupils, and greater demands in low-contrast or nighttime vision, aspheric IOLs are recommended.

We have learned a lot about aspheric and wavefront optics over the past 10 years. Whether for refractive or cataract surgery, let us put these learnings to good use for the benefit of our patients.