Researchers conclude zero spherical aberration equates with optimal visual performance

Cheryl Guttman in Stockholm

CATARACT surgery has evolved into the realm of a refractive procedure where the goal is not merely to restore best-corrected vision, but to provide patients with the best possible quality of vision. Aspheric IOLs have been developed as a technology for achieving that goal. However, the availability of different aspheric IOL models that result in different levels of residual spherical aberration after implantation creates discussion over what is the optimal spherical aberration value to target when aiming to customise correction of the eye and provide the best visual performance.

A number of studies evaluating quality of vision have been conducted to investigate that question. At the XXV Congress of the ESCRS, Jack T Holladay, MD, MSSE, and Patricia A Piers, PhD, told attendees that based on previously reported and new research, the answer for most patients should be zero. “The reason we call it an aberration is because it is not good, and our goal should be to eliminate all of the aberrations in an optical system. There are now 19 studies confirming that reducing or eliminating spherical aberration with implantation of a Tecnis aspheric IOL provides better vision with respect to a 30 per cent to 40 per cent improvement in contrast sensitivity versus maintaining average spherical aberration with use of a spherical IOL. Additionally, an increasing number of studies are being reported demonstrating that zero spherical aberration provides the best optical image on the retina and peak performance in the visual system,” said Dr Holladay, clinical professor of ophthalmology, Baylor College of Medicine, Houston, Texas.

He reviewed published studies evaluating age-related distribution of spherical aberration whose results demonstrated that the subgroup with peak visual performance, i.e., young adults aged 19 to 20 years old, also had the lowest mean spherical aberration value compared with other age groups. Furthermore, although spherical aberration values within the 13 to 20 year olds exhibit normal scatter, the data show as well that the individuals with naturally occurring “super vision” are those with zero spherical aberration.

Dr Holladay also cited an experiment conducted by Pablo Artal PhD, using an adaptive optics-based system able to eliminate existing spherical aberration with deformable mirrors. The results showed that adjusting spherical aberration to zero resulted in the best performance of the eye and also the best depth of field. “This study dispels the myth that some remaining positive spherical aberration is beneficial for depth of field because it showed depth of field was worse when spherical aberration was positive or negative compared with when it was zero,” Dr Holladay said.

As a caveat, Dr Holladay noted that if it is not possible to achieve zero spherical aberration in a presbyopic or pseudophakic patient, it is better to err on the side of leaving a slight amount of negative spherical aberration rather than positive spherical aberration. “In patients with no accommodation, zero spherical aberration still provides the best quality image. However, a small amount of negative spherical aberration affords an improvement in near vision,” he explained.

Whether a patient has a slight amount of negative spherical aberration or an equal magnitude of positive spherical aberration, there is the same potential to see halos around images, especially at night or in other dark conditions when the pupil is small. “The difference between those two conditions relates to their effects on near vision. When looking up close and the pupil constricts (synkinetic reflex), the eye with a small amount of positive spherical aberration is hyperopic in the centre while the eye with negative spherical aberration is myopic. Central hyperopia hurts near vision, myopia helps,” Dr Holladay explained.

“This is the principle of presbyLASIK and centre-near multifocal IOLs, and it is the reason why hyperopic patients who underwent LASIK or PRK with our original excimer lasers benefited with better near vision. Those hyperopic treatments induced negative spherical aberration, whereas myopic treatments induced positive spherical aberration. If we go back and compare patients who were emmetropic after hyperopic or myopic laser vision correction, those left with negative spherical aberration after hyperopic LASIK have better near vision than their myopic counterparts who had positive spherical aberration induced,” Dr Piers, Applied Research, AMO Groningen, The Netherlands, was a co-author of the original papers evaluating the potential benefits of the first aspheric IOL, the modified proliferate Tecnis IOL, for improving quality of vision by reducing or eliminating spherical aberration after cataract surgery. Since then, she has collaborated in a number of additional experiments conducted using a variety of theoretical and physiological eye models to investigate the outcomes associated with achieving different levels of spherical aberration in the eye.

At the ESCRS Congress free paper session on quality of vision/optical properties, Dr Piers presented the findings from a study conducted using the adaptive optics-based vision simulator developed by Dr Artal for clinical testing to evaluate the interaction between spherical aberration and contrast sensitivity performance. The simulator is comprised of a Hartmann-Shack wavefront sensor that measures the aberrations of the subject’s eye and relays the information via a computer to a special segmented mirror. Based on the aberration input, the mirror is adjusted to alter the light entering the eye to create a specifically modified optical profile. “This testing system is extremely powerful because each subject serves as his or her own control. Therefore, we can do pure tests of different aberration correction concepts in the same person and avoid introducing any other variances that can influence results such as occur in clinical trials when comparing outcomes between different groups of subjects,” Ms Piers explains.

The adaptive optics vision simulator was used in five subjects to determine the optimal amount of spherical aberration. The subjects ranged in age from 28 to 40 years old and had natural spherical aberration ranging from -0.02 to +0.08 microns for a 4.8mm pupil.

The pupils were dilated pharmacologically, but all subjects performed the testing with viewing through an artificial pupil. Different values of spherical aberration were dialled into the system, and the subjects were asked to find their best subjective correction in terms of sphere and cylinder. The testing was performed with small amounts of negative and positive spherical aberration, -0.09 and +0.09 microns, larger amounts of positive spherical aberration, +0.182 microns, and with spherical aberration neutral.

Contrast sensitivity testing was performed at 15 cycles/degree, both with other natural higher order aberrations (HOAs) present and with all HOAs corrected; visual performance was also measured with small amounts of defocus (+ 0.25 and +0.50 D). The results showed that when other HOAs remained at natural levels as well as when they were corrected, peak mean contrast sensitivity performance was achieved when spherical aberration was zero. Scrutiny of the outcomes for individual performance showed that when the HOAs of the eye were left uncorrected, there was variation among the participants with respect to the spherical aberration value associated with peak contrast sensitivity performance. These results have been corroborated by Liu Wang, MD, PhD, and Doug Koch, MD, in a study presented this year at the annual meeting of the Association for Research in Vision and Ophthalmology.

“This variation can be attributed to the complex interactions between the different orders of aberration in the eye, and it was also of interest that the contrast performance was not always the best when the aberration values were similar to the natural aberration patterns,” Ms Piers said.

However, in the testing with all HOAs corrected, peak contrast sensitivity performance was achieved when spherical aberration was zero.

patricia.piers@amo-inc.com
holladay@btcholladay.com