# At What Pupillary Size Does an Aspheric Matter?

Evaluating higher-order aberrations as a function of the pupil's diameter after the implantation of an aspheric or a spherical IOL.

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Studies evaluating spherical-like aberrations in phakic eyes have shown rising values with increasing pupillary diameter.[1,2] This fact is also important in pseudophakic eyes, especially for the implantation of aspheric IOLs. These lenses were designed to compensate for corneal, primary spherical aberration (Z[4,0]), and they should restore the pseudophakic eye to the Z(4,0) values of young phakic eyes. Because earlier clinical research did not take different pupillary sizes into account, we designed a study protocol to evaluate higher-order aberrations as a function of the pupil's diameter.[3]

## SUBJECTS AND METHODS

### Patients

We included the eyes of 21 patients who needed IOL implantation because of cataract. They randomly received an aspheric Tecnis IOL (Z9000; Advanced Medical Optics, Inc., Santa Ana, CA) in one eye and a spherical Sensar IOL (AR40e; Advanced Medical Optics, Inc.) in their contralateral eye. No subject had eye disease other than cataract. The study population reflected a normal cataract population with a mean age of 71 years (range, 59 to 82 years). Professor Kohnen performed all of the surgeries, and no intra- or postoperative complications occurred.

### Wavefront Measurement and Analysis

One month after cataract surgery, we used a Hartmann-Shack sensor (Zywave; Bausch & Lomb, Rochester, NY) to perform wavefront measurements of the whole eye under maximal pharmacological mydriasis. Using VOLPro software (Sarver and Associates, Inc., Carbondale, IL), we calculated higher-order aberrations, including Z(4,0), for virtual pupillary diameters of 3 to 6mm, and we performed intraindividual comparisons.

To exclude influences on the whole eye's measurement from differences in corneal Z(4,0), we performed corneal topographic measurements (Orbscan IIz; Bausch & Lomb) and calculated the Z(4,0) of the central 6-mm zone.

### Measurement of Pupillary Size

To evaluate the physiological pupillary size of the study population under different lighting conditions, we measured the pupil's size with a digital infrared pupillometer (Procyon P2000SA Pupillometer; Procyon Instruments Ltd., Grosmont, England). All measurements were performed without pharmacological treatment for luminance levels of 6.61 lux (highly mesopic), 0.88 lux (mesopic), and 0.07 lux (low mesopic).

## RESULTS

### Higher-Order Aberrations of the Whole Eye as a Function of Pupillary Diameter

We found rising values for all of the evaluated wavefront errors with the virtual pupil's increasing diameter regardless of the IOL implanted.

The most interesting wavefront error after the implantation of aspheric IOLs is Z(4,0). For the Tecnis IOL, we found statistically significantly lower values for all calcu-

lated pupillary diameters (3 to 6mm). The absolute amount of the differences for small pupils (3 and 4mm) was minor, but it rose as the pupil's size grew (5 and 6mm). It is remarkable that some of the eyes with aspheric IOLs even reached negative values.

For total higher-order aberrations (third- to fifth-order RMS), we found statistically significant differences with lower values in the aspheric group only with a pupillary diameter of 6mm. Coma-like aberrations such as third- and fifth-order RMS did not show any statistically significant differences between the study groups at any calculated pupillary diameter.

**Z(4,0) of the Cornea**

We did not find a statistically significant difference for Z(4,0) of the central 6-mm cornea between the study groups. We therefore concluded that all calculated differences in Z(4,0) of the whole eye were the consequence of the implantation of different types of IOLs.

**Physiological Pupillary Sizes Under Mesopic Conditions**

The median pupillary sizes under highly mesopic luminance were 3.25mm (Tecnis group) and 3.20mm (Sensar group). The pupil's size increased under mesopic illumination to as great as 4.04 and 4.05mm, respectively. Under low mesopic luminance (0.07 lux), the median pupillary diameters were 4.90 and 5.03mm in the Tecnis and Sensar groups, respectively. Inspecting the absolute values of pupillary size, we found that only one patient reached a 5-mm pupillary diameter under mesopic conditions. For low mesopic conditions, 23 of the 42 eyes (55%) attained a 5-mm pupil. We did not find any statistically significant differences between the groups.

## DISCUSSION

Spherical aberrations, mainly Z(4,0), affect optical quality by reducing image contrast. A recognition of this problem led to the design of new IOLs such as the Tecnis to reduce Z(4,0) and thus increase contrast sensitivity after cataract surgery. Aspheric lenses should reduce the level of Z(4,0) to that of young eyes. Of interest is whether every cataract patient can profit from the implantation of this type of IOL.

To answer this question, we focused on pupillary diameter. It is commonly understood that the elderly have smaller pupils than the young. In our study, for example, just 55% of subjects attained a pupillary size of 5mm, and they did so only under nearly scotopic lighting conditions of 0.07 lux. For mesopic conditions, only one of 21 patients reached this pupillary size.

Why do we think 5mm is an important margin? Our calculations of Z(4,0) of the whole eye also yielded statistically lower values for 3- and 4-mm pupils. Nevertheless, these statistical differences were based on small differences of the absolute values. Clear differences were only present for 5- and 6-mm pupils. Moreover, Z(4,0) did not affect optical quality alone. A statistically significant difference for total higher-order aberrations (third- to fifth-order RMS) could only be calculated at the 6-mm pupillary diameter. Higher-order aberration values, however, are only one element of optical quality. It is not known what difference in Z(4,0) or total higher-order aberrations must be reached to obtain a clinical relevance with better contrast sensitivity.

It is our conclusion that patients with larger pupils can derive a greater benefit from aspheric IOLs than people with smaller pupils. These theoretical considerations must be proven by clinical testing of contrast sensitivity. In a subsequent investigation, we tested our study population with the observer-independent Frankfurt-Freiburg Contrast and Acuity Test System under different mesopic luminance conditions. We did not find any statistically significant difference between the Tecnis and Sensar IOLs.[4] These results support our theory that patients with larger pupils than ours had could profit more from aspheric IOLs. This idea can only be proven, however, by new studies that compare contrast sensitivity after the implantation of aspheric IOLs in eyes with pupils that are larger or smaller than 5mm. ■

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