Limited accuracy of Hartmann-Shack wavefront sensing in eyes with diffractive multifocal IOLs

In their recent article, Toto et al.[1] evaluated and compared the wavefront error, among other parameters, in patients with 2 diffractive multifocal intraocular lenses (DMIOLs). However, many elements suggest that the Hartmann-Shack (H-S)-based wavefront sensing method used by these authors cannot accurately represent the ocular aberrations induced by DMIOLs using Zernike decomposition.

An H-S sensor divides the incoming beam into subbeams, dividing the wavefront into separate facets, each focused by a microlens onto a subarray of pixels of a charge-coupled device camera. It is then possible to determine the local wavefront inclination (or tilt), which depends on where the focal spot of each facet strikes its subarray of pixels. Subsequent analysis of all facets together leads to determination of the overall wavefront shape. This shape carries phase information that can be used to calculate metrics such as the point spread function and the modulation transfer function. Hence, accurate phase estimation is mandatory to permit the relevant calculation of these metrics. The main drawback of H-S wavefront sensing methods is the lack of information about higher-order aberrations and scattering because of the limitation imposed by the lens sampling.

Bifocal IOLs such as the AcrySof ReSTOR (Alcon Laboratories, Inc.) and Tecnis ZM900 (Advanced Medical Optics, Inc.) multifocal IOLs investigated by Toto et al.[1] use diffractive zones to create 2 focal points, one at distance and one at near. To achieve this effect, these IOLs use concentric stepped zones that induce discrete repetitive phase jumps to make the light interfere constructively at more than one foci. The H-S sampling of such locally distorted wavefronts may result in the apparition of some additional centroids straying inside or outside their pixel subarrays. Since the IOL diffractive zones are arranged in a circular concentric manner whereas the H-S uses a square microlens array, the spatial distribution of these additional centroids would be difficult to predict. Eventually, the rapid phase variations caused by the diffractive IOL zones may be under-sampled and/or inadequately reconstructed using conventional H-S technology.

Moreover, H-S sensors are not designed to capture the scattering incurred by the discrete junctions between the diffractive zones, and looking at the wavefront error only may lead to significant overestimation of the optical quality of eyes with DMIOLs. These inaccuracies may be more pronounced after implantation of a DMIOL with a full diffractive surface, such as the Tecnis ZM900, than one with a central 3.6 mm diffractive surface, such as the AcrySof ReSTOR. It must be emphasized that even in the hypothetical case of proper phase sampling, the fit of Zernike polynomials may fail to capture the highly detailed information of a diffracted wavefront.[2]

In consideration of these remarks, I do not think it is possible to accurately estimate and thus compare ocular wavefront errors after the insertion of DMIOLs with the H-S technology as described in the study by Toto et al.[1] Despite the absence of direct phase information, double-pass techniques, which are sensitive to all the optical defects involved in retinal image degradation, such as diffraction, aberration, and scattering, may provide more accurate estimates of the eye's image quality after diffractive IOL implantation.[3] I recommend that further investigations be performed to identify better methods to accurately measure the complex wavefront aberrations in eyes with diffractive optics.

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REPLY: We agree with Gatinel that in general, there is a lack of information on the Shack-Hartman wavefront sensors on the higher-order aberrations and scattering related to the limitation imposed by the small lens sampling. However, the H-S wavefront sensor used in our study was a Wasca wavefront analyzer aberrometer (Asclepion-Meditec AG) with 1452 lenslets for 9.0 mm of analysis—the highest number of lenslets among the commercially available ocular wavefront sensors. A precise definition and calculation of aberrations in terms of Zernike polynomials up to the 4th order is therefore possible.

Gatinel is right in pointing out that the wavefront error induced by DMIOLs could be underestimated or wrongly reconstructed by the H-S device because of mismatches between concentric diffractive steps and square microlens array. However, our results confirm that the Tecnis ZM900 multifocal IOL, which was created to induce low spherical aberrations, similar to monofocal aspherical IOLs, is related to a lower

Published by Elsevier Inc.
0886-3350/08/$—see front matter
doi:10.1016/j.jcrs.2007.11.038

spherical wavefront error compared with the AcrySof ReSTOR multifocal IOL, thus demonstrating a reliable analysis of symmetrical aberrations such as spherical aberration.

Gatinel added that the H-S wavefront sensor provides no information about scattering that contributes, together with diffraction and aberrations, to a degradation of retinal image quality. Scattering that is normally small after cataract extraction and implantation of conventional IOLs increases after DMIOL implantation.

We agree that double-pass techniques, which are also sensitive to scattering, would permit a more precise objective evaluation of the optical quality of eyes with DMIOLs. At the same time, we think a subjective evaluation of visual performance such as measurement of contrast sensitivity or visual acuity at low contrast, as performed in our study, is productive and provides indirect information about the total optical degradation of the eye.—*Lisa Toto, MD, Gennaro Falconio, MD, Luca Vecchiarino, MD, Vincenzo Scorcia, MD, Marta Di Nicola, PhD, Enzo Ballone, PhD, Leonardo Mastropasqua, MD*

Intraocular lens power calculation in phacovitrectomy patients

In their study of the accuracy of intraocular lens (IOL) power calculations in eyes having phacotrabeculectomy for macular hole, Patel et al.[1] failed to address certain issues before drawing conclusions. The accuracy of formulas in predicting IOL power depends on the estimated lens position, also known as estimated postoperative anterior chamber depth (ACD).[2] The SRK/T formula[3] used by the authors is based on the thin lens optics and relies on a single A-constant to determine ACD. The actual ACD measurement is not taken into account. Formulas such as Haigis[4] and Holladay 2 (Holladay LASIK Institute, Houston, Texas, USA) incorporate ACD measurements in the calculations. As a result, with Haigis and Holladay 2 formulas, a difference in measurement of the optical ACD would give a different IOL power, even when axial length and keratometry measurements remained the same. Since Patel et al. hypothesized that myopic overcorrection after phacovitrectomy might be a result of the gas bubble causing forward displacement of the capsular bag, the authors should reconsider the use of the SRK/T formula in these patients.

Even for the SRK/T formula, surgeons should optimize the A-constant in patients having phacovitrectomy rather than aim for residual hyperopia to counteract the overcorrection. Also, if surgeons perform biometry in these patients preoperatively and postoperatively, it will assist in determining whether the myopic shift is caused by forward displacement of the capsular bag by the gas bubble or by inaccuracy in the axial length measurement caused by fixation problems because of the macular hole.

Finally, although the authors claim that the achieved refractions in their patients are comparable to those after phacoemulsification alone, the available data suggest that much better accuracy can be obtained with optimization. Using optimized constants, Eleftheriadis[5] found that with the Holladay 2 formula and the SRK/T formula, 96% of patients and 95% of patients, respectively, achieved a refraction within ±1.0 diopter of the targeted refraction. Depending on which IOL is used, with the optimized Haigis formula, 93% of the patients could achieve a refraction within ±1.0 diopter.[2]

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REPLY: I would like to respond to Partwardhan's constructive comments. First, Partwardhan recommends the use of fourth-generation IOL formulas such as Holladay II and Haigis to calculate a patient's specific ELP. I agree with the comments and may consider using these formulas in future IOL calculations for combined surgery. However, further studies comparing the various formulas would be required to prove their validity in this specific group of patients. To our knowledge, other authors[1,2] reporting the refractive outcomes after combined surgery have used the SRK/T formula as a standard.

Second, Partwardhan commented on the postoperative myopic shift in our group of patients and recommended preoperative and postoperative biometry to determine whether the gas bubble had displaced the capsular bag forward. I evaluated the postoperative posterior vitreous length (PVL) in 18 of the study patients (unpublished data). The PVL showed a mean increase of 3.19 mm (from 15.83 mm preoperatively