Optical performance of monofocal versus multifocal intraocular lenses

In their recent paper, Ortiz et al.[1] studied the optical performance of monofocal and multifocal intraocular lenses (IOLs) in the human eye. Their main conclusion was that of the IOLs studied, the hybrid refractive–diffractive IOL was the least affected by pupil diameter in terms of intraocular aberrations. This IOL type also showed a smaller increase in optical aberrations during pupil dilation. I question the validity of the authors' comparison of monofocal and multifocal IOLs because they failed to verify 2 conditions.

1. The authors used a reconstructed wavefront to compare the optical quality of the pseudophakic eyes analyzed in the study. Therefore, these metrics relied on the underlying assumption that the wavefront was accurately reconstructed by the Hartmann-Shack system or at least that the fidelity of the wavefront reconstruction was equal for all tested IOLs. Classic data analysis from a Hartmann-Shack wavefront sensor does not consider the quality of individual spots formed by the lenslet array. Only the displacement of spots is needed for computing the local slope of the wavefront over each lenslet aperture. The underlying assumption is that the wavefront is locally flat over the face of the lenslet, which is not true for diffractive IOLs.

Diffractive IOLs separate the incident light into 2 converging waves: distance wavefront and near wavefront. The local phase of the wavefront collected by the Hartmann-Shack lenslet array shows rapid phase shifts, and the wavefront is significantly distorted over the area of the lenslet on a very fine spatial scale. These microfluctuations scatter light, resulting in blurred or double spots. Light centration may be difficult or arbitrary to localize, even for an aberrometer with a high spatial resolution such as the Complete Ophthalmic Analysis System (Wavefront Science, Inc.). These limitations, which have been reported,[2–4] cause the actual diffracted wavefront to be undersampled and inaccurately sampled. Therefore, the final reconstructed wavefront does not capture every characteristic of the actual wavefront. Finally, the Fourier-calculated metrics may largely overestimate the optical quality of diffractive IOLs.

As the nondiffractive part of the spherical AcrySof ReSTOR IOL (Alcon Laboratories) has the same geometric (ie, surface curvature) and material characteristics as the monofocal AcrySof MA60, no difference in the distance spherical aberration wavefront should be measured. Hence, the ReSTOR's reduced positive spherical aberration, as measured in this study, may have been caused by an artifact that resulted from inadequate centroid detection. It seems hazardous for the authors to derive any clinically relevant conclusion regarding the value of spherical aberration for bifocal diffractive IOLs at various pupil diameters. The retinal image formed by the IOL would be impaired by some defocused light diverging from the near foci and forming concentric halos around the center of the retinal point spread function (PSF). Additionally, 20% of the light is diffracted in higher diffraction orders and the effect of this is not measured by the Hartmann-Shack wavefront-sensing instruments.

2. The objective optical quality provided by a diffractive IOL depends not only on the phase of the wavefront, but also on the light intensity (ie, energy) at the focal plane. The incident light received by a multifocal IOL is divided between the different focal lengths. Therefore, only a fraction of the incident light is directed toward the distance foci. Even in the hypothetical situation of a refractive or diffractive multifocal IOL achieving a nonaberrated image at the distance focal plane, the light transmission efficiency would be inferior to that of a nonaberrated monofocal IOL. This is important because human vision does not work well in low light. In the case of a hybrid refractive–diffractive IOL, the amount of light diffracted toward the distance foci would increase with the pupil diameter; however, it would remain less than that refracted by a monofocal IOL for a large pupil diameter. Unfortunately, this point, although crucial in the frame of objective in vivo optical quality evaluation, was omitted by Ortiz et al.[1] and other authors also.[5,6]

Multifocal pseudophakic IOLs represent a growing and competitive market, and it is urgent to develop accurate and objective standards for measuring and reporting the optical quality of eyes implanted with diffractive optics.

Although I believe that some of the conclusions drawn by Ortiz et al. are not valid, the general scope of the paper is extremely valuable. Currently, we believe there are no commercially available methods to accurately reconstruct the ocular wavefront after diffractive IOL implantation because of the rapid phase variations caused by bifocal diffractive optics. It must also be emphasized that if the modulation transfer function (MTF) is a powerful technique for expressing the effects of optical systems in Fourier series from the phase wavefront reconstruction, it may not work well (or need numerous terms) when the details are similar to sharp, discontinuous phase variations, such as those caused by diffractive optics. Double-pass aberrometry is based on the actual (not calculated) PSF measurement. It may enable clinicians to capture the direct effect of the light impinging on the patient's retina and may be more adapted to provide metrics such as the MTF or Strehl ratio for distance correction.

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REPLY: Gatinel has opened an interesting discussion about the validity and accuracy of measuring wavefront aberration in patients with diffractive IOLs, given that the aberrometer may wrongly reconstruct the wavefront of an eye implanted with an IOL.

To test the capability of wavefront sensors in the optical analysis of eyes implanted with different IOL types, we may first look at the sensor's ability to obtain a measurement and then at how accurately this corresponds to the clinical refraction of the eye. In our study, the ocular aberrations were measured with the Complete Ophthalmic Analysis System (COAS), a high-resolution Hartmann-Shack aberrometer. This aberrometer has a spatial resolution of 210 μm, analyzing a total of 872 samples for a pupil up to 7.0 mm. For each eye, measurements were repeated at least 3 times to obtain a well-focused, properly aligned image of the eye. If the device had had problems during detection of the centroids, as Gatinel suggests, the measurement would have been impossible to obtain as valid, as occurs in highly myopic eyes[1] or eyes affected by high levels of corneal aberrations, as in keratoconus.[2] This was not the case in any of our clinical studies[3,4] in which a proper measurement was always obtained. Our data on clinical refraction of the patients always corresponded well and accurately to the refraction obtained by the COAS aberrometric study (patient 2, right eye [ReSTOR group]: subjective refraction $0.25\ -0.25 \times 120$ versus wavefront refraction $0.19\ -0.26 \times 135$). This was not the case in a recent report[5] in which the disparity between the clinical refraction and the aberrometry refraction with refractive multifocal IOLs was large, indicating the lack of accuracy of global wavefront technology in such IOLs. On the other hand, we think the absolute values might be questioned but not the relative ones used for comparison between different IOLs, for which the error should be the same in all cases (standard error).

Regarding the double-pass techniques, we agree that they may be adequate to evaluate the actual PSF and MTF in patients with IOLs.[6] However, this device evaluates the global eye's optical quality, which is affected by the corneal aberrations of the individual eye. When the MTF of a patient implanted with a multifocal IOL is measured, we obtain the measurement as global but also ignore the focus of the measurement: near, distance, or intermediate.

In summary, our report and Gatinel's letter highlight an important issue—the need for isolated optical measurements of IOLs when implanted inside the eye, a condition different from those of IOL measurements at the optical bench. Such information is critical today when data on IOLs of innovative design inside the eye may lead to important decisions about which IOLs are better or perform more successfully when implanted in the human eye.—*Dolores Ortiz, PhD, Jorge L. Alió, MD, PhD*

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Metaanalysis of cataract after phakic intraocular lens surgery

A recent article by Chen et al.[1] describes cataract development after phakic intraocular lens (pIOL) implantation but does not distinguish between cataract development due to age and cataract development