Clinically Relevant Interpretations of Optical Bench Measurement of Intraocular Lenses

We read with interest the article by Gatinel and Loicq in the April 2016 issue.1 This study draws conclusions concerning the behavior of intraocular lenses (IOLs) based on optical bench measurements. One must always be careful when correlating the optical behavior of IOLs with their corresponding clinical behavior. For example, although the optical bench measurements of multifocal IOLs show a modulation transfer function (MTF) of essentially 0 in the intermediate range, clinically measured visual acuity values can be 20/32 or greater. In addition, when monofocal lenses are measured following the multifocal ISO standard, some models show bifocal behavior. Therefore, we must be mindful that optical bench measurements may not be fully representative of clinically relevant vision, and great care must be taken not to draw faulty conclusions based on these data.

Alarcon et al.2 described improvements in methods of optically testing IOLs to predict visual acuity. This and several other recent studies2-4 highlight the importance of three components that should be included in eye models if one hopes to provide an accurate explanation of clinical behavior:

- Eye models should be representative of the clinically measured spherical and chromatic aberration.3,4
- Measurements should also be performed using white light. Normal viewing conditions occur in white light, which (unlike green light) is affected by the eye’s chromatic aberration.
- Under normal viewing conditions, objects comprise multiple spatial frequencies. Modelling of the resolution of objects (ie, visual acuity) should include multiple spatial frequencies. An example of such a metric is MTFarea (MTFa).2

**Figure 1** shows defocus curves based on clinical results and the corresponding theoretical defocus curves derived from optical measurements taking these three factors into account. It demonstrates more realistic estimates of intermediate performance of a multifocal IOL and the continuous nature of the TECNIS Symfony IOL’s (Abbott Medical Optics, Abbott Park, IL) binocular defocus curves. Gatinel and Loicq simulated the effect of corneal spherical aberration, but not chromatic aberration. Measurements were performed in green, not white light. This distinction, although important for all IOLs, is critical for diffractive lenses because their behavior is fundamentally different under white light conditions. Their study used an instrument that is not capable of measuring in white light. The instrument measures according to the ISO standard 11979-2, which itself states that “No inference should be made to performance in real eyes.” Finally, MTF was measured for only one spatial frequency (50 c/mm). Although MTF at a single spatial frequency is correlated with distance contrast vision,3 it is known to be a poor predictor of clinical defocus curves.2 We therefore assert that the title of the Gatinel and Loicq article is extremely misleading. In addition, the authors suggest that the presence of more than one MTF peak defines multifocality, and they further claim that the TECNIS Symfony IOL can be considered a multifocal IOL with a defined add power. With MTF measurements, the characteristics and number of peaks are highly dependent on the spatial frequency measured, pupil size, aberrations, and chromatic conditions. Therefore, MTF peaks should not be used to define multifocal behavior for all IOL designs.

**REFERENCES**


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Reply

We have read with interest the letter of Piers et al. regarding our work.1 Our main goal was not to perform extensive in vitro evaluations using various metrics, wavelengths, or eye models, but instead to compare the behavior of two diffractive intraocular lenses (IOLs) labeled as bifocal and trifocal, respectively, and one IOL labeled as “extended depth of focus” (EDOF) under the same conditions. Similar work has been performed with other multifocal IOLs, both refractive and diffractive.2,3

We mentioned and discussed explicitly that the chromatic behavior of these IOLs was not within the scope of this study, and we limited our analysis to green light (543 nm), to which the sensitivity of the eye peaks in photopic conditions. Despite the monochromatic conditions, analyses of the visual performance of diffractive multifocal IOLs in green light enable realistic predictions for specific target distances of near, intermediate, and far.

Despite some limitations inherent to any “in vitro” analysis, and unlike Piers et al.’s contention, we believe that the comparative optical properties that we reported are relevant and may be useful to predict and better understand the clinical behavior that has been observed and described in the tested IOLs. In particular, our findings support the observation of deficient near uncorrected vision without mini-monovision in the EDOF IOL.

It is known that the power addition of a diffractive lens is theoretically fixed by the spacing between two consecutive diffractive rings. The EDOF IOL diffractive design comprises nine diffractive steps, which is approximately half the number of steps required for a bifocal diffractive IOL to provide simultaneous far and near uncorrected vision. This may account for the bifocal IOL behavior that was observed with the EDOF IOL with far and intermediate (add power of +1.75 diopters) modulation transfer function (MTF) peaks at the tested spatial frequency. Clinically, this would suggest that the EDOF IOL may provide satisfactory uncorrected vision at the far and intermediate vision range, but may not induce enough near uncorrected vision to fully mitigate the effect of presbyopia. This may explain the need for combined use of mini-monovision with bilateral EDOF lens implantation to extend spectacle independence for near vision in pseudophakic patients.4

Interestingly, for a small aperture (2-mm), the trifocal and EDOF IOLs showed an extended depth of focus behavior in green light, as illustrated by the merging of their respective far and intermediate vision MTF peaks, possibly due to the pinhole diffraction effect. Both the trifocal lens and the EDOF lens give rise to a continuum of MTF from far to intermediate focus; clinically, this may translate into an extended range of vision in the far to intermediate distance range on pupil constriction, with an additional focus for reading distance in the case of the trifocal lens. Contrarily, the bifocal lens with +4.00 diopter power addition does not display such a MTF continuum; the MTF peaks for distance and near vision are too far apart. In essence, this is reflected by the reduced performance of bifocal IOLs in the intermediate vision range, and has fostered the development of trifocal and EDOF IOLs, to address the need of uncorrected intermediate vision in patients with pseudophakia.

We agree that one should always be careful when trying to extrapolate the clinical properties of an IOL from some of its optical properties because it may not be certain whether improvements in its optical performance will be reflected in its visual performance. In turn, we invite Piers et al. to extend this cautiousness to clinical extrapolations from chromatic aberration corrections in the context of cataract surgery. Chromatic aberration is not particularly deleterious under normal viewing conditions because its effect is overwhelmed by the combined effect of monochromatic aberrations. The higher order aberrations help to dilute the impact of axial chromatic aberration,5 and imperfect optics may protect the eye from the effect of chromatic blur.6

However, these considerations should not preclude similar analyses under blue and red wavelengths to investigate the possible wavelength sensitivity of the seemingly bifocal behavior of the EDOF IOL in green light, and explore the properties of bifocal and trifocal diffractive IOLs in various wavelengths. We will address these specific points in future work.

REFERENCES

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