Influence of Multifocal Intraocular Lenses on Standard Automated Perimetry Test Results

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Importance: A multifocal intraocular lens (MFIOL) allows for spectacle independence after cataract surgery and is thus a seemingly attractive option. However, several optical limitations have been reported or can be hypothesized.

Objective: To evaluate the influence of an MFIOL on standard automated perimetry (SAP) size III and size V test results.

Design: Cross-sectional case-control.

Setting: The University Medical Center Groningen and the Nij Smellinghe Hospital Drachten, the Netherlands.

Participants: Sixteen eyes of 16 patients with a diffractive MFIOL (median age, 64 years), 18 phakic eyes of 18 healthy individuals serving as controls (median age, 62 years), and 12 eyes of 12 patients with a monofocal IOL (median age, 64 years) were included.

Interventions: All participants underwent (1) SAP using a 30-2 grid and the Swedish Interactive Threshold Algorithm standard strategy with stimulus size III and (2) a full threshold test with stimulus size V.

Main Outcome Measures: Primary outcome measures were the mean deviation (MD) for size III and the mean sensitivity (MS) for size V. Comparisons between groups were adjusted for age and pupil size.

Results: For SAP size III, the average difference in MD between patients in the MFIOL group and phakic controls was –2.40 dB (P < .001) and between patients in the monofocal IOL group and phakic controls was –0.32 dB (P = .32). For SAP size V, the corresponding differences in MS were –1.61 dB (P = .002) and –0.80 dB (P = .09), respectively. The differences were essentially independent of eccentricity for both SAP size III and SAP size V.

Conclusions and Relevance: Patients with a diffractive MFIOL have a clinically relevant reduction of the visual sensitivity as assessed with SAP size III and size V. The reduction seems to be related to the multifocal design of the IOL rather than to pseudophakia. The reduction interferes with the assessment of common eye diseases such as glaucoma and comes on top of the decline of visual sensitivity due to normal aging or age-related eye diseases, thus potentially accelerating visual impairment.


Clincal Sciences

Cataract surgery is one of the most established interventions in the realm of ophthalmology and is considered to be a safe procedure with good visual outcome. In pursuit of optimal postoperative lens performance, generations of innovative lens designs have led to the introduction of diffractive multifocal intraocular lenses (MFIOLs). These lenses allow the luxury of distance and near spectacle independence and are based on the optical principle of creating 2 focal planes, one for distance vision and the other for near vision. Several studies reported that these new-generation diffractive MFIOLs provide satisfactory vision for distance and near conditions and enhance the quality of life.

Nonetheless, MFIOLs appear to induce unwanted visual phenomena, including glare, flare, streaks, and halos. Reduced contrast sensitivity has also been reported in various studies as an important drawback of MFIOLs. Contrast sensitivity usually declines with age and may be further affected pathologically by different eye diseases. For example, is an insidious chronic progressive eye disease that affects the optic nerve with subsequent unnoticed retinal sensitivity loss. This loss in sensitivity is clinically measured by means of standard automated perimetry (SAP), which measures differential light sensitivity thresholds at various locations across the visual field and is a fundamental tool in the diagnosis and follow-up of glaucoma. Taking the various causes of reduced contrast sensitivity, as well as the possibility of MFIOL and glaucoma coexistence, into consideration, it is therefore justifiable to the...
The present study had a cross-sectional case-control design and included patients with MFIOLs, patients with monofocal IOLs, and individuals with phakic eyes serving as controls. By comparing 3 groups, it should be possible to differentiate between effects due to pseudophakia and effects due to the multifocal design. In addition to SAP and the default size III stimulus, the participants performed a test with stimulus size V (1.72 mm diameter; 4 mm²). This test was conducted so that participants could become accustomed to the perimeter but would not be tired before the onset of testing. Subsequently, participants performed a 30-2 Swedish Interactive Threshold Algorithm (SITA) standard test with stimulus size III. Finally, participants performed another shortened visual field test with 15 test locations twice, now with stimulus size V (1.72 mm diameter; 64 mm²). Regarding the 15 test locations, 7 were within 10° eccentricity (gray area) and 8 outside 10° eccentricity (left eye representation).

Figure 1. Subset of test locations used in the shortened tests (numbers in bold). Including the fovea (not shown), there were 7 test locations within 10° eccentricity (gray area) and 8 outside 10° eccentricity (left eye representation).

### METHODS

#### STUDY POPULATION

The present study had a cross-sectional case-control design and included patients with MFIOLs (MFIOL group), patients with monofocal IOLs (monofocal IOL group), and healthy individuals with phakic eyes (phakic controls). This study conformed with the tenets of the Declaration of Helsinki and was approved by the medical ethics committee of the University Medical Center Groningen and of the Nij Smellinghe Hospital Drachten, both in the Netherlands. All participants gave written informed consent prior to participation.

Patients with MFIOLs and monofocal IOLs were recruited from the cataract databases of the departments of ophthalmology of the University Medical Center Groningen and of the Nij Smellinghe Hospital Drachten. Healthy volunteers were recruited through advertisement. All participants underwent a complete eye examination, including best-corrected visual acuity testing, near vision testing (Jaeger reading chart), slitlamp biomicroscopy, an intraocular pressure measurement with noncontact tonometry (TCT80; Topcon Medical Systems Inc), and a fundus examination with an ultra-widefield retinal imaging device (200TX ultra-widefield retinal image; Optos). The pupil diameter was measured by means of the Auto Pupil function of the Humphrey Field Analyzer (see the “Perimetry” subsection).

Inclusion criteria for this study were age 18 to 75 years and, for the MFIOL and monofocal IOL groups, a postoperative period of at least 3 months. Exclusion criteria were an overall astigmatism exceeding 2.5 D, a spherical equivalent refractive error above +5 or below −5 D, a best-corrected visual acuity above 0.5 logMAR (in individuals ≥50 years) or 0.1 logMAR (>50 years), an intraocular pressure above 21 mm Hg, a family history of glaucoma, a vertical cup-disc ratio exceeding 0.5 or any other fundus abnormality, significant lens opacities or after cataract on slitlamp examination, and a history of eye trauma or surgery other than cataract surgery or any other eye disease. All participants were inexperienced with regard to perimetry. If a participant was eligible with both eyes, 1 randomly chosen eye was included.

#### IOL CHARACTERISTICS

The MFIOLs in this study comprised exclusively diffractive MFIOLs. Two types of diffractive MFIOLs were used in our study population (Tecnis ZM900; Abbott Medical Optics Inc [2 eyes]; and the Zeiss 809M, AT LISA; Carl Zeiss Meditec Inc [14 eyes]). The Tecnis MFIOL is a silicone 3-piece aspheric diffractive lens. The power of the add is +4.00 D with a 50/50 distance/near light distribution. The Zeiss MFIOL is an acrylic single-piece aspheric diffractive lens. The power of the add is +3.75 D with a 65/35 light distribution. All the patients with monofocal IOLs had a monofocal Tecnis (ZA9003; Abbott Medical Optics Inc).

#### PERIMETRY

Perimetry was performed with the Humphrey Field Analyzer (Carl Zeiss Meditec Inc). First, all participants performed a shortened visual field test, consisting of 15 test locations distributed over a 30-2 grid (Figure 1) using the 4-2-2 staircase strategy with size III stimulus (0.43” diameter; 4 mm²). This test was conducted so that participants could become accustomed to the perimeter but would not be tired before the onset of testing. Subsequently, participants performed a 30-2 Swedish Interactive Threshold Algorithm (SITA) standard test with stimulus size III. Finally, participants performed another shortened visual field test with 15 test locations twice, now with stimulus size V (1.72” diameter; 64 mm²). Regarding the 15 test locations, 7 were within 10° eccentricity (Figure 1). We used a shortened test because no SITA program is available for size V and we aimed to avoid fatigue effects resulting from the lengthy full-threshold testing. The SITA standard size III test and the second shortened test with stimulus size V were included in the analysis.

The recommendations of the Humphrey Field Analyzer’s manufacturer for using corrective lenses were followed. No corrective lenses were used in patients with MFIOLs unless the near-vision test showed a value below Jaeger 2, which could be improved with corrective lenses at the recommended testing distance of 33 cm. A test result was considered unreliable if false-positive classifications exceeded 10%, the technician reported poor fixation, or lens rim artifacts were observed. If this was the case, the test was repeated after additional explanation. At least 5 minutes of rest was scheduled between the different tests to lower the influence of fatigue.

#### STATISTICAL ANALYSIS

The main outcome measures of the visual field tests were the mean deviation (MD) for size III and the mean sensitivity (MS)
for size V. The MD is a measure commonly used in clinical practice; the MS can be considered a proxy of the MD. The MD is an age-adjusted measure (a study participant is compared with age-matched peers) provided by the software of the Humphrey Field Analyzer. For size V, we used a customized grid (see the “Perimetry” section); therefore, no MD value was provided by the device. For that reason we calculated the MS by averaging the recorded raw sensitivities of the included test locations. We also used the MS to explore the effect of eccentricity for both size III and size V by calculating the MS for a subset of test locations within and outside 10° eccentricity (Figure 1). The blind spot and the fovea were excluded from the MS calculation.

Differences in characteristics between the MFIOL group, monofocal IOL group, and phakic controls were analyzed with 1-way analysis of variance for continuous variables and the χ² test for proportions. Because of our recruitment approach (advertisement), the median age of our originally recruited 45 phakic controls (49 years) was considerably lower than that of the MFIOL group (64 years). To exclude any residual age-related confounding, we performed the analyses on an age-matched subset of phakic controls. This subset was formed by excluding controls, starting with the youngest, until the mean age of the controls equaled that of the MFIOL group. The MD and MS intergroup differences were assessed using multiple linear regression analysis including either the MD or the MS as the dependent variable and age, pupil size, and group as independent variables. For group differences, we used 2 dummy variables for the MFIOL group and monofocal IOL group, with the phakic controls as the reference.

All analyses were performed using commercial software (SPSS, version 18.0.3; SPSS Inc). Statistical significance was set at P ≤ .05.

**RESULTS**

The Table presents the participants’ characteristics. Sixteen patients with MFIOLs, 18 phakic controls, and 12 patients with monofocal IOLs were enrolled in this study. No eyes showed relevant pathologic characteristics. There were significant univariate intergroup differences in pupil diameter, best-corrected visual acuity, MD, MS, and pattern standard deviation. There were no significant intergroup differences in age, sex, and intraocular pressure. As for near vision, all participants attained Jaeger 2 at 33 cm, with or without correction. In the MFIOL group, 4 of 16 patients needed additional correction (+0.75, +1.00, +2.00, and +2.50 D).

**Figure 2** depicts the differences in unadjusted MD between the MFIOL group, the monofocal IOL group, and the phakic controls when conducting visual field testing with SAP size III. Adjusted for age and pupil size, the MD was, on average, 2.40 dB lower in the MFIOL group than in the phakic controls (P < .001) and 0.32 dB lower in the monofocal IOL group than in the phakic controls (P = .52).

### Abbreviations

- BCVA: best-corrected visual acuity
- IOL: intraocular lens
- IOP: intraocular pressure
- MD: mean deviation
- MFIOL: multifocal IOL
- MS: mean sensitivity
- PSD: pattern standard deviation

### Table. Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>MFIOL Group</th>
<th>Phakic Control Group</th>
<th>Monofocal IOL Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of eyes</td>
<td>16</td>
<td>18</td>
<td>12</td>
<td>.82</td>
</tr>
<tr>
<td>Age, y</td>
<td>64 (47 to 74)</td>
<td>62 (53 to 74)</td>
<td>64 (48 to 71)</td>
<td>.64</td>
</tr>
<tr>
<td>Sex, No.</td>
<td>Male 6</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female 10</td>
<td>9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pupil diameter, mm</td>
<td>3.9 (2.9 to 5.2)</td>
<td>5.2 (3.8 to 7.3)</td>
<td>5.2 (3.8 to 6.2)</td>
<td>.001</td>
</tr>
<tr>
<td>IOP, mm Hg</td>
<td>14 (8 to 19)</td>
<td>14 (8 to 21)</td>
<td>11 (8 to 16)</td>
<td>.09</td>
</tr>
<tr>
<td>BCVA, logMAR</td>
<td>0.0 (0.1 to –0.1)</td>
<td>0.0 (0.0 to –0.2)</td>
<td>–0.1 (0.0 to –0.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Size III MD, dB</td>
<td>–3.0 (–5.4 to –0.7)</td>
<td>–0.5 (–2.1 to 2.0)</td>
<td>–1.0 (–1.8 to 0.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Size III PSD, dB</td>
<td>2.2 (1.5 to 4.2)</td>
<td>1.8 (1.3 to 3.5)</td>
<td>2.0 (1.5 to 2.6)</td>
<td>.01</td>
</tr>
<tr>
<td>Size V MS, dB</td>
<td>33.2 (30.9 to 35.8)</td>
<td>34.9 (33.0 to 37.2)</td>
<td>34.2 (32.9 to 35.5)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: BCVA, best-corrected visual acuity; IOL, intraocular lens; IOP, intraocular pressure; MD, mean deviation; MFIOL, multifocal IOL; MS, mean sensitivity; PSD, pattern standard deviation.
Multifocal intraocular lenses reduce the visual sensitivity in SAP, by approximately 2 dB. This reduction is roughly similar for size III and size V and regardless of eccentricity. The reduction seems to be related to the multifocal design of the IOLs rather than to pseudophakia.

To our knowledge, no previous study has evaluated the effect of diffractive MFIOLs on SAP compared with healthy controls. However, various studies have evaluated the influence of MFIOLs on other perimetric tests in comparison with monofocal IOLs. Bojkian et al\textsuperscript{12} reported that diffractive MFIOLs have no influence on the MD of the Matrix frequency doubling perimeter compared with monofocal IOLs. Their results do not contradict our findings because frequency doubling perimetry uses a stimulus with a very low spatial frequency and is, compared to SAP, less sensitive to optical blur.\textsuperscript{18,19} Interestingly, Kang and Lee\textsuperscript{11} found a significant difference between MFIOLs and monofocal IOLs using Goldmann kinetic perimetry. Stanojcic et al\textsuperscript{14} assessed the difference in binocular visual fields in patients who underwent bilateral cataract surgery with either diffractive MFIOLs or monofocal IOLs by means of the Esternman binocular visual field test. They reported no significant difference between their 2 groups. However, it is not possible to compare our results with those of Stanojcic et al because the Esternman test is based on suprathreshold testing, whereas we tested visual sensitivity at threshold. Bi et al\textsuperscript{15} compared a group of patients who received the AcrySof ReSTOR MFIOL (SA60D3; Alcon Laboratories Inc) with a control group receiving the AcrySof Natural (SN60AT) monofocal IOL following cataract surgery. They performed comparisons in visual acuity, depth of focus, corneal astigmatism, contrast sensitivity, glare sensitivity, visual fields, and spherical aberration. Perimetry was performed using the Octopus 101. The investigators found no significant difference in the MD between groups. This result, which apparently conflicted with our study, might be explained by differences in threshold algorithm, which was not specified in their study.

As for the influence that monofocal IOLs may exhibit on SAP, Mutlu et al\textsuperscript{20} found a significant negative effect of monofocal IOLs on the MD, namely, 1.34 dB lower compared with age-matched phakic subjects. At first sight, this suggests that about half the negative effect on the MD we found in patients with MFIOLs could be an IOL effect not specific of the multifocal design. However, we found essentially no differences between the monofocal IOL group and the phakic controls. A possible explanation for this apparent contradiction is that the monofocal IOLs as assessed by Mutlu et al were spherical, whereas the IOLs used in our study were aspheric. There are significant differences in modulation transfer between aspheric and spherical IOLs; the modulation transfer of an aspheric IOL is approximately equal to that of the human lens, whereas it is higher than that of a spherical IOL.\textsuperscript{21} A 1.34-dB difference in MD between eyes with a spherical monofocal IOL and phakic eyes is in line with the differences in modulation transfer as reported in the literature.\textsuperscript{21} This tentatively suggests that the mul-

Figure 3 illustrates the intergroup differences in unadjusted MS for size V. Adjusted for age and pupil size, the MS was, on average, 1.61 dB lower in the MFIOL group than in the phakic controls (P = .002) and 0.80 dB lower in the monofocal IOL group than in the phakic controls (P = .09).

For the subset of test locations within 10° eccentricity, the age- and pupil size–adjusted difference in MS between the MFIOL group and the phakic controls was –2.28 dB for size III (P = .001) and –1.87 dB for size V (P = .003). For the monofocal IOL group vs the phakic controls, these differences were 0.15 dB (P = .77) and –0.39 dB (P = .49), respectively. For the subset of test locations outside 10° eccentricity, the age and pupil size–adjusted differences in MS between the MFIOL group and phakic controls were –2.49 dB (P < .001) for size III and –1.27 dB (P = .01) for size V. For the monofocal IOL group vs the phakic controls, these differences were –0.32 dB (P = .59) and –1.29 dB (P = .01), respectively. The age- and pupil size–adjusted foveal sensitivity of the SAP test results was a mean of 2.05 dB lower in the MFIOL group than in the phakic controls (P = .006) and 0.30 dB greater in the monofocal IOL group than in the phakic controls (P = .65). The age- and pupil size–adjusted pattern standard deviation of the SAP test results did not differ significantly between the MFIOL group and the phakic controls (P = .07) or between the monofocal IOL group and the phakic controls (P = .70). These findings indicate that the effect of an MFIOL on visual sensitivity is essentially similar across the entire visual field; this agrees with a subjective assessment of the visual fields. Approximately 50% of the MFIOL visual fields showed normal total and pattern deviation probability plots; the other 50% showed a general reduction of sensitivity picture: diffuse abnormalities in the total deviation probability plot combined with an intact pattern deviation probability plot. Eleven of 16 patients with MFIOLs had an MD value below normal, at the P < .05 level according to the Humphrey Field Analyzer database.
tifocal design degrades the MD by about 2 dB, as we found in our study. Two studies22,23 evaluated the effect of cataract extraction on the visual fields of patients with glaucoma after multifocal IOL implantation. Both studies reported modest to negligible improvement in MD postoperatively. Obviously, the effects of the removal of the cataract and the implantation of a multifocal IOL on the MD are entangled here.

Intergroup differences in pupil size were encountered in our study, and this makes pupil size a potential confounder.24 To avoid confounding, our multiple linear regression analyses were adjusted for pupil size. In these analyses, pupil size was not significant. Thus, although our study included eyes with a significant intergroup difference in pupil size, this difference does not explain our findings.

Our study included 2 different types of diffractive MFIOLs: the Tecnis (ZM900; Abbott Medical Optics Inc; 2 eyes) and the Zeiss (809M, AT LISA; Carl Zeiss Meditec, Inc, 14 eyes). Despite the fact that there is a difference in distance/near light distribution between these 2 MFIOL types (50/50 for Tecnis and 65/35 for Zeiss), the MD values of the 2 participants with a Tecnis lens (−1.44 and −3.05 dB) fall within the interquartile range of the MFIOL group as a whole. This tentatively suggests that the reduced visual sensitivity is a generic property of diffractive MFIOLs rather than specific for one type. Obviously, the sample size was too small for a decent subgroup analysis.

In conclusion, the results of this study suggest that eyes with MFIOLs will show reductions in visual sensitivity of approximately 2 dB. Therefore, we recommend a new perimetric baseline in patients with MFIOLs with (suspect) glaucoma and preferably in all patients with MFIOLs to guarantee a correct interpretation of any future abnormality. Moreover, patients should be preoperatively informed about MFIOL-related loss of visual sensitivity that may show a further decline with normal aging or age-related eye diseases. As a consequence, the originally highly appreciated spectacle independence might be regretted later.

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Author Contributions: Drs Aychoua and Junoy Montolio contributed equally to this study. The authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflict of Interest Disclosures: None reported.

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