Bilateral Implantation of Asymmetrical Diffractive Multifocal Intraocular Lenses

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Objective: To evaluate visual results after bilateral implantation of multifocal intraocular lenses (IOLs) with asymmetrical light distribution for the far and near focus.

Methods: Twenty-nine patients underwent bilateral implantation of silicone-optic, foldable, diffractive IOLs in a prospective, 2-center, noncontrolled interventional study. Each patient had a distant-dominant multifocal IOL implanted in 1 eye and a near-dominant multifocal IOL implanted in the fellow eye. Refractive and visual results, including contrast acuity and binocular visual function, were determined. Patients were questioned for postoperative spectacle usage.

Results: Visual and contrast acuity in the dominant focus of either lens was superior to that in the nondominant focus at 3.5 to 12 months postoperatively, ie, performance was best at distance for the distant-dominant and at near for the near-dominant lens. In binocular viewing, the monocular maximal results added up to an improved binocular visual performance. Binocular visual function was within normal limits. Eighty percent of patients reported no use of spectacles at any time postoperatively.

Conclusions: Bilateral implantation of asymmetrical diffractive IOLs is an effective alternative for restoring simultaneous distance and near vision with a potential for improved contrast sensitivity compared with conventional multifocal IOLs.


The primary goal in intraocular lens (IOL) implantation surgery has been to eliminate the handicaps and inconveniences of spectacle and contact lens correction in aphakic patients. However, conventional IOLs have a single focus, which does not allow patients good, spectacle-free vision at both far and near distances. Various attempts to reestablish some degree of pseudoaccommodation after cataract surgery have been made, such as aiming for myopic astigmatism, targeting 1 eye for myopia as in monovision, or multifocal IOL implantation. Substantial commercial investments have been made in the engineering, manufacturing, and clinical investigation of a wide variety of multifocal IOLs. Multifocal IOLs in general provide both far and near vision by splitting light to 2 or more focal points. Despite differences in design and optical principle in current multifocal IOLs, they all have in common a reduced image contrast resulting in a loss of contrast sensitivity. This is a critical issue among ophthalmologists and health care professionals, especially with respect to the ability of the elderly patient to see while driving.

Efforts have been made to produce distant-dominant multifocal IOLs that distribute more light to the far than to the near focus, thus enhancing contrast sensitivity at distance. However, the consequence of this gain at far is a reduction in near visual function.

To overcome some of the limitations induced by the multifocal IOLs, Jacobi and Eisenmann developed a new concept termed asymmetrical bilateral multifocal IOL implantation. This method uses 2 types of multifocal IOLs that differ from each other in the light distribution for the far and near focus. A distant-dominant multifocal IOL with a light distribution of 70% for the far and 30% for the near focus is implanted into 1 eye, thus rendering this eye dominant for distant vision. This eye sees a sharp-contoured, high-contrast image for far and a sharp-contoured, low-contrast image for near. Alternately, a near-dominant multifocal IOL with a light distribution of 30% for the far focus and 70% for the near focus is implanted into the fellow eye, rendering this eye dominant for near vision. Accordingly, this eye sees a sharp-contoured, low-contrast image for far and a sharp-contoured, high-contrast image for near vision. In binocular viewing, both eyes receive a distinct image of objects at distance and at near, but image contrast differs between both eyes at the respective distances. The concept is based on the hypothesis that the image in the dominant focus of both eyes will...
PATIENTS AND METHODS

Twenty-nine patients with cataracts were enrolled in this prospective, nonrandomized clinical study that was performed at 2 surgical sites: Department of Ophthalmology, University of Giessen, Giessen, Germany (n = 14), and St. Johannes Hospital, Dortmund, Germany (n = 15). To be eligible for the study, patients were required to have bilateral cataracts without any other significant eye disease or abnormalities of ocular motility, and 1.5 diopters (D) or less of preoperative astigmatism. Patients were required to understand the investigational nature of the study, have a motivation to be spectacle free, and provide informed consent. No institutional review board approval was required for this study. All surgery was performed by 2 experienced surgeons (F.K.J., J.K.) using a standardized technique of sutureless, clear-corneal phacoemulsification. Before IOL implantation, 2 holes measuring 1.2 to 1.4 mm were trephined into the lens’ disc haptic by means of Elliot trephines to facilitate viscoelastic aspiration from the capsular bag. The IOLs were implanted with either an injector device or implantation forceps. There were no surgical complications.

At 1 study center, all surgery was performed on both eyes in 1 procedure. At the other center, the mean interval between surgery was 91 days. Lens selection was handled differently at each site because of the difference in the timing of the surgery in both eyes. In bilateral simultaneous surgery, the distant-dominant lens was always implanted in the right eye and the near-dominant lens in the left eye. In sequential surgery, the distant-dominant lens was always implanted in the first eye and the near-dominant lens in the second eye. Thus, 8 patients (28%) of the total study population had a distant-dominant lens implanted in the left eye. Patients were unaware of which eye had a distant- or near-dominant multifocal IOL.

The multifocal IOL used in this study was a 1-piece bifocal diffractive silicone IOL. The near addition is 4.0 D, which corresponds to approximately 3.2 D in the spectacle plane. The lens was produced in a disc haptic design (Chiron-Adatomed, Munich, Germany). There are 2 versions of the lens that use the same design and diffractive principle but differ in light distribution for the far and near focus. By assigning the appropriate dimensions to the 16 concentric rings on the posterior lens surface, 70% of incident light is focused for distance vision and 30% for near vision in the distant-dominant lens, and vice versa for the near-dominant lens. In contrast to other types of diffractive IOLs with a symmetrical light distribution, the asymmetrical multifocal IOL has a lower loss of light at higher orders of diffraction (13% instead of 18%) that are out of focus. The clinical defocus curve determined by measuring distance acuities with −3.0 D to 3.0 D of overrefraction is demonstrated for a patient who underwent binocular implantation (Figure 2). The IOL has an optic diameter of 5.5 mm (≥22 D) to 6 mm (<22 D) and a total diameter of 10 mm (Figure 3). The lens optic is biconvex and aspheric, and has a diffractive zone of 4.5 mm in diameter. The lenses supplied for this study were available in the range from 19.0 to 25.0 D in 1.0-D increments. Postoperative target refraction was emmetropia.

Measurement of the modulation transfer function (MTF), a test to quantify the image quality in an optical system, of the multifocal lenses was performed in an optical laboratory before clinical use. Measured is the modulation, or contrast, of the image formed by the system for variously sized (spatial frequencies), high-contrast targets whose luminance can be described by sinusoidal functions. Changes of in vitro MTF measurements are expected to cause reciprocal proportional changes in clinically measured contrast sensitivity. The MTF has become a standard today for evaluation of multifocal IOLs, as indicated by the Food and Drug Administration guidelines for multifocal IOL studies. The MTF of a near-dominant diffractive IOL measured through the distance and near focus is shown in Figure 4. The spatial frequency on the abscissa has been converted into normalized frequency to facilitate comparison between the diffraction-limited lens and the multifocal lens. The normalized frequency fixes the cut of frequency of the diffraction-limited lens at unity irrespective of pupil diameter and wavelength. The curve of the theoretic diffraction-limited lens has been plotted to cross the ordinate at the 0.7 and 0.3 values to account to the relative light distribution of 30% for the far and 70% for near focal point in the near-dominant lens. The MTF of the multifocal IOL closely approximates the MTF of the theoretical diffraction-limited lens, which demonstrates high image quality of the lens. The MTF for the distant-dominant lenses (not shown) corresponds to that of the near-dominant lens but switched for the far and near focal point. This high image quality be additive, thus allowing a binocular contrast sensitivity and distance and near visual acuity that are superior to the function in bilateral multifocal IOLs with symmetrical light distribution (Figure 1). The concept can be considered a combination of multifocal IOL implantation and monovision, but unlike monovision, asymmetrical bilateral multifocal IOL implantation does not induce anisometropic blur.

The objective of the study was to evaluate visual results after bilateral implantation of asymmetrical multifocal IOLs.

RESULTS

Distance and near visual acuity results are given in Table 1, Table 2, and Table 3. Distance visual acuity was better in eyes with the distant-dominant than the near-dominant multifocal IOL, both with and without distance correction. In near visual acuity testing, this tendency was reversed. We observed better near acuities more frequently in eyes with a near-dominant lens than in those with a distant-dominant lens. With distance correction, all patients achieved J1 binocularly. With near addition, we measured J1 in all eyes with a distant-dominant lens and in all but 1 eye (J2) in eyes with a near-dominant lens. Binocular distance visual acuity was improved compared with monocular distance visual acuity in eyes with the distant-dominant lens, both with and without correction. Eighteen (72%) of 25 patients were able to binocularly read 20/20 and J1 and 25 (100%), 20/25 and J2 or better with distance correction. Uncorrected, 14 (56%) of 25 patients achieved 20/25 and J2 or better.
results from the lens’ aspheric optic design, which neutralizes spherical aberration (Wilhelm Stork, PhD, Institute for Information Processing Technology, University of Karlsruhe, Karlsruhe, Germany, oral communication, September 3, 1996).

Use of the aspheric curves on IOLs to minimize spherical aberration is not common, because of lack of evidence that any particular lens design is optically superior.13 In silicone IOLs, because of the lower refractive index than that of polymethylmethacrylate IOLs, and in particular in multifocal silicone IOLs, this issue may be more likely to be of clinical importance.

To compare the optical performance of the multifocal lenses used in this study with that of a conventional monofocal lens, the Strehl ratio was calculated. The Strehl ratio is a variable in physical optics that describes the ratio of the area under the actual MTF to a diffraction-limited lens.10 A Strehl ratio of 0.58 to 0.60 in the dominant (70%) focus and 0.25 to 0.27 in the nondominant (30%) focus was determined. The measurement in the dominant focus compares well with the Strehl ratio of a monofocal lens of 0.76 as measured in the same laboratory setting.

Of the 29 eligible patients, 4 were excluded from the study. Of these, 3 patients had postoperative vision-reducing complications in 1 eye each that were not related to multifocal IOL design and not amenable to treatment. One patient had a corneal astigmatism that had increased from 1.5 D preoperatively to 2.5 D postoperatively. Angiographically confirmed cystoid macular edema was diagnosed in another patient, while the third patient had visual impairment that was attributed to a preoperatively undetected age-related maculopathy. One patient was unavailable for long-term follow-up examination because of a critical medical condition.

The 25 patients (10 men and 15 women; mean ± SD age, 73.8 ± 7.4 years; range, 60-85 years) were examined for study purposes at 3.5 to 12 months (mean ± SD, 7.8 ± 2.6 months) after the second eye surgery. Three patients had reduced visual acuity in both eyes and 2 patients, in 1 eye because of marked posterior capsule opacification. This was successfully treated by Nd:YAG laser posterior capsulotomy. No notable multifocal IOL decentration occurred either with an intact capsule or after capsulotomy.

All ocular examinations were performed by qualified ophthalmic personnel or physicians (U.G., K.W.). Monocular and binocular distance visual acuity was tested in all patients with and without correction by means of a chart projector. Subjective refraction for distance visual acuity was strictly performed through the far focus; refracting through the near focus in the near-dominant lens is expected to yield better results. Distance correction was obtained on the basis of the subjective refraction performed through the far focus. Target refraction and postoperative refraction were recorded and mean absolute error was calculated on the basis of the spherical equivalent. Near visual acuity was measured at 35 cm by means of the German Nieden cards (Nieden 1 is approximately equal to 20/27) (Oculus, Wetzlar, Germany) and converted into Jaeger values (J1 is approximately equal to 20/30). Functional vision was assessed by determining the proportion of patients who met the criteria of corrected visual acuities of 20/20 and J1, 20/25 and J2, and uncorrected acuities of 20/25 and J2. We tested contrast acuity as a measure for contrast sensitivity by means of the Regan contrast charts at 96%, 50%, 25%, and 11% contrast (Paragon Services, Lower Sackville, Nova Scotia) (n = 14). The test was administered with distance correction at 3 m (10 ft) in accordance with the manufacturer’s instructions. The obtained Regan score values were converted to Snellen line equivalents. A –3.0-D addition was used to test contrast sensitivity through the near focus. For most measurements, patients read at least 1 letter on the chart. However, in monocular testing through the nondominant focus of either lens, some patients were unable to read any letter in line 1 at the 11% contrast chart. To still obtain an acuity result, the test was repeated after halving the test distance to 1.5 m (5 ft). Half a diopter of spherical correction was added to the distance correction to adjust the refraction to the reduced testing distance. Geometric mean visual acuity scores were determined according to the method described by Holladay and Frager.14 All tests were performed with a pharmacologically unaffected pupil size.

The pupil size was not determined. Because the difference in contrast image between the 2 eyes at distance and near may influence single binocular vision, the latter was quantitatively assessed by testing the stereoscopic acuity at near with the circles of the Titmus Stereotest (n = 25) and the horizontal fusional vergence amplitudes by adjusting horizontal prism power (n = 18). To further evaluate the efficacy of the asymmetrical multifocal lens implantation, all patients were asked if they used spectacles for any task. Statistical significance of differences between data groups was determined by the Wilcoxon sign rank test (P<.05).

The visual acuity results were echoed by our findings in contrast acuity testing. Eyes with a distant-dominant lens performed better when tested at far, and eyes with a near-dominant lens, when tested with a –3.0-D addition, ie, visual performance was optimal in the dominant focus of either lens. Binocular contrast acuity results again exceeded monocular results (Figure 5).

Mean ± SD stereoscopic acuity was 74.3 ± 41.1 minutes of arc (range, 25-200 minutes of arc), with 19 (76%) of 25 patients showing values of 80 minutes of arc or less. Mean ± SD convergence amplitudes of 9.2° ± 3.0° and divergence amplitudes of –4.0° ± 1.4° were measured.

The frequency of postoperative spectacle usage was 20% (5 patients) for distance vision. Eighty percent of patients (20/25) reported no spectacle use at any time, and no one required near addition.

Refractive results are given in Table 4. Twenty-three (92%) of 25 patients had less than 1 D of refractive error from target refraction in their eye with the distant-dominant lens, compared with 18 (72%) of 25 in the eye with the near-dominant lens. Seven (28%) of 25 patients had more than 1 D of difference in spherical equivalent between both eyes.

In this study, 2 new features in the field of multifocal IOL implantation were combined to achieve simultaneous distance and near vision with improved contrast sensitivity after bilateral surgery. We used 2 versions of a foldable silicone IOL with an aspheric, diffractive bifocal optic that provide an asymmetrical light distribution for the
far and near focus of either 70%:30% or 30%:70%. These lenses were bilaterally implanted in an asymmetrical fashion: each patient received a distant-dominant IOL in 1 eye and a near-dominant IOL in the fellow eye. Furthermore, this is the first report of clinical results after implantation of foldable diffractive multifocal IOLs. The concept of bilateral implantation of asymmetrical multifocal IOLs has been previously evaluated with refractive IOLs made of polymethylmethacrylate.

Our results demonstrate a pronounced effect of the asymmetrical light distribution with statistically significant differences in distance and near visual acuity between the distant- and near-dominant multifocal IOLs. The concept of bilateral implantation of asymmetrical multifocal IOLs has been previously evaluated with refractive IOLs made of polymethylmethacrylate.

D. This implicates a safety margin in the presented concept. A slight loss in mean distance visual acuity in the eyes with the near-dominant lens can be restored by adding the proper correction, ie, −3.0-D addition. This would be indicated, for instance, when vision is lost in the distant-dominant eye because of macular degeneration.

Binocular summation in eyes with bilateral asymmetrical multifocal IOLs is clearly evidenced by improvement of binocular visual function over monocular viewing. The ideal outcome of bilateral multifocal IOLs with asymmetrical light distribution would have been an enhanced contrast sensitivity in the dominant focus without any effect on visual acuity in the nondominant focus. This
was a realistic goal based on psychophysical data, which indicate less sensitivity of visual acuity to variation of stimulus luminance compared with contrast sensitivity.\textsuperscript{16}

The asymmetrical diffractive multifocal lenses used in this study were designed after a number of earlier experimental and clinical studies were conducted.\textsuperscript{8,15} Light distributions of 70\%:30\% and 30\%:70\%, respectively, were considered the best choice on the basis of these results.

Jacobi and Eisenmann\textsuperscript{8} introduced the concept of bilateral implantation of asymmetrical multifocal IOLs in 1993 with the use of all-poly(methylmethacrylate), 3-zone refractive multifocal IOLs at various light distributions (50\%: 50\%, 60\%:40\%, 40\%:60\%, 70\%:30\%, and 30\%:70\%). They performed experimental, psychophysical studies with the use of a specially designed optical system that simulates visual perception through any type of IOL under monocular and binocular viewing conditions.\textsuperscript{17} The optical system, which is similar to an astronomical telescope, projects a real image of an IOL into the normal phakic eye of a subject. This produces a virtual IOL in the sub-

| Table 1. Distance Visual Acuity Results* 

<table>
<thead>
<tr>
<th>Snellen Visual Acuity</th>
<th>Distant-Dominant MIOL</th>
<th>Near-Dominant MIOL</th>
<th>Binocular Testing, Distant- and Near-Dominant MIOL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Correction</td>
<td>With Correction</td>
<td>No Correction</td>
</tr>
<tr>
<td>20/16</td>
<td>0 (0)</td>
<td>2 (8)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>20/20</td>
<td>3 (12)</td>
<td>11 (44)</td>
<td>3 (12)</td>
</tr>
<tr>
<td>20/25</td>
<td>9 (36)</td>
<td>11 (44)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>20/32</td>
<td>6 (24)</td>
<td>1 (4)</td>
<td>6 (24)</td>
</tr>
<tr>
<td>20/40</td>
<td>6 (24)</td>
<td>10 (40)</td>
<td>13 (52)</td>
</tr>
<tr>
<td>20/50</td>
<td>1 (4)</td>
<td>0 (0)</td>
<td>2 (8)</td>
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<tr>
<td>20/63</td>
<td>0 (0)</td>
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<tr>
<td>20/80</td>
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<td>20/100</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>20/125</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

* Data are expressed as number (percentage) of patients. MIOL indicates multifocal intraocular lens.

| Table 2. Distance Visual Acuity Results Expressed as Mean ± SD* 

<table>
<thead>
<tr>
<th>Snellen Visual Acuity</th>
<th>Decimal (Mean ± SD)</th>
<th>Snellen Visual Acuity</th>
<th>Decimal (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocular distant-dominant MIOL</td>
<td>20/30‡</td>
<td>0.67 ± 0.11</td>
<td>20/22§</td>
</tr>
<tr>
<td>Monocular near-dominant MIOL</td>
<td>20/37‡</td>
<td>0.54 ± 0.19</td>
<td>20/26§</td>
</tr>
<tr>
<td>Binocular near- and distant-dominant MIOL</td>
<td>20/27</td>
<td>0.74 ± 0.11</td>
<td></td>
</tr>
</tbody>
</table>

†Refracted through far focus.
‡P = .01.
§P = .002.

| Table 3. Near Visual Acuity Results* 

<table>
<thead>
<tr>
<th>Jaeger Visual Acuity</th>
<th>Distant-Dominant MIOL</th>
<th>Near-Dominant MIOL</th>
<th>Binocular Testing, Distant- and Near-Dominant MIOL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Correction</td>
<td>With Correction</td>
<td>+3 D</td>
</tr>
<tr>
<td>1</td>
<td>9 (36)</td>
<td>14 (56)</td>
<td>25 (100)</td>
</tr>
<tr>
<td>2</td>
<td>5 (20)</td>
<td>3 (12)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>3</td>
<td>5 (20)</td>
<td>7 (28)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>4</td>
<td>4 (16)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>5</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>6</td>
<td>1 (4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>7</td>
<td>1 (4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

* Data are expressed as number (percentage) of patients. MIOL indicates multifocal intraocular lens; D, diopters.
that spreads light over several focal points. In our lens optic design, in pupil diameters larger than 4.5 mm, relatively more light is refracted to the far than to the near focus compared with pupil diameters of 4.5 mm or less. This theoretically favors distance vision over near vision in large pupils, ie, it enhances distance dominance in the distant-dominant lens and lessens near dominance in the near-dominant lens. In our aged study population, this aspect is probably not relevant because of the already diminished pupil size in elderly patients. In young patients, who have better responsiveness to pupil reaction, enhancement of distance dominance may in fact prove advantageous under low illumination, such as at night. The significance of pupil size was not determined in our study. All tests were done with a pharmacologically unaffected pupil size.

The near addition in the foldable diffractive IOL is 4.0 D, which is adequate to provide good near vision as indicated by our results. This near addition is consistent with most other current multifocal IOL designs.

The advantage of the investigated multifocal IOL is that it can be folded and implanted through an approximately 3.5-mm-wide, self-sealing sutureless incision. The benefit of a low surgically induced astigmatism and quick visual rehabilitation in small-incision cataract surgery is well recognized with monofocal and multifocal IOL implantation. The disc haptic design in the foldable diffractive lens has a track record with good clinical results from its monofocal counterpart (model 90D, Chiron-Adatomed). One shortcoming of the multifocal lenses used in the present study was their availability in 1-D steps only. This accounts for the unsatisfactory refractive results with 1 D or more of refractive error from target refraction in some eyes. This was especially evident in eyes with a near-dominant lens (mean ± SD absolute error, 0.76 ± 0.66 D), while the results in eyes with a distant-dominant lens were within normal limits of refractive outcome data (mean ± SD absolute error, 0.37 ± 0.39 D). The former may reflect a difficulty in accurately refracting a near-dominant diffractive lens through the nondominant far focal point. To attain a higher accuracy, the multifocal IOLs will be produced in 0.5-D steps in the future, but this was not possible for technical reasons at the time the study was conducted.

It is inherent in the design of multifocal IOLs in general that they trade off a certain amount of image clarity for an increased depth of focus compared with monofocal IOLs. This is also true for both styles of the diffractive lenses.

Table 4. Refractive Data

<table>
<thead>
<tr>
<th></th>
<th>Distant-Dominant MIOL (n = 25)</th>
<th>Near-Dominant MIOL (n = 25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target refraction, D</td>
<td>Mean ± SD</td>
<td>−0.13 ± 0.22</td>
</tr>
<tr>
<td>Range</td>
<td>−0.64 to 0.25</td>
<td>−0.68 to 0.46</td>
</tr>
<tr>
<td>Postoperative refraction (spherical equivalent), D</td>
<td>Mean ± SD</td>
<td>0.14 ± 0.72</td>
</tr>
<tr>
<td>Range</td>
<td>−1.25 to 1.25</td>
<td>−2.5 to 0.75</td>
</tr>
<tr>
<td>Absolute refractive error, D</td>
<td>Mean ± SD</td>
<td>0.57 ± 0.39</td>
</tr>
<tr>
<td>Range</td>
<td>0 to 1.21</td>
<td>0 to 2.02</td>
</tr>
</tbody>
</table>

*MIOL indicates multifocal intraocular lens; D, diopters.

A diffractive optic was chosen for the present study lens because the multifocal performance is unaffected by decentration and varying pupil size and because a bifocal IOL is theoretically superior to a truly multifocal IOL.

In their studies with this “physical eye” and after clinical implantation in a series of 40 patients, they found that the 70%-30% distant-dominant lens in 1 eye and the 30%-70% near-dominant lens in the fellow eye yielded a good balance of binocular distance and near contrast acuity. Mean distance visual acuity in eyes with the 70%-30% distant-dominant lens was similar to that in eyes with a monofocal lens in both the experimental and the clinical studies. The studies also indicated that, while dominance in 1 focal point improved contrast acuity, visual acuity in the nondominant focus was compromised. On the basis of these results, an unfavorable effect of asymmetrical light distribution on visual acuity in the nondominant focus was anticipated in the present study. Optical testing of these asymmetrical multifocal IOLs in the optical laboratory (MTF, Strehl ratio, resolution efficiency) confirmed the clinical observations.

Figure 5. Mean monocular and binocular contrast acuity with distance correction (top) and an additional −3.0 diopters (bottom).
used in the present study. In combination, however, they gain an improvement in contrast sensitivity as well as distance and near visual acuity under binocular viewing conditions. Ultimately, one may assume that this gain is only at the expense of another visual modality, namely, binocular visual function. This could not be substantiated by means of clinical tests in our study. The results of stereoscopic acuity and fusional amplitude measurements suggest intact binocular vision in the majority of patients. The advanced mean age of our study population must be considered when the results are compared with normal data. The difference in image contrast between the 2 eyes does not appear to affect binocular vision to a degree that is clinically relevant. It may require more refined testing to detect subclinical deficits in binocular visual function, such as testing under low-luminance conditions. In experimental studies, a negative influence of dissimilar image contrast on stereoscopic acuity has been described. 35

The postoperative survey of spectacle usage demonstrates a high success rate with regard to spectacle independence in our study population. This is most evident for near vision, with no patient requiring near add. The need for glasses is greatly influenced by the postoperative refractive status, which is determined by the accuracy of biometry, the A-constant, and the available lens powers. The high degree of spectacle independence in our study population compares well with previous clinical studies using different styles of multifocal lenses.26,27

Eye dominance has potential importance in the concept of bilateral implantation of asymmetrical multifocal IOLs. In monovision it is well established that correcting the distant-dominant eye for distance vision and the non-dominant eye for near vision has a higher success rate in terms of patient acceptance.9 In our study, however, we were unable to define the population in terms of ocular dominance and establish an accurate assignment of the distant-dominant lens to the distant-dominant eye and the near-dominant lens to the nondominant eye, because to our knowledge there is no approved method to unerringly determine ocular dominance in patients with bilateral cataracts. Our study results are therefore potentially biased by our strategy to arbitrarily assign the distant-dominant lens to right eyes in cases of bilateral simultaneous surgery and to the first eye to be operated on in sequential surgery. The majority of our study population received the distant-dominant lens in the right eye. In the general population, the percentage of right-eye dominance is approximately 80%.28

The purpose of the reported study was to validate the feasibility of the concept of bilateral implantation of asymmetrical diffractive IOLs. It is an effective alternative to provide good simultaneous distance and near vision with improved contrast sensitivity and intact binocular vision after bilateral cataract surgery. Randomized clinical trials that compare the performance of the asymmetrical diffractive IOLs with conventional and monofocal IOLs will further elucidate the usefulness of this concept.

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