ABSTRACT

PURPOSE: To compare visual performance of the refractive Array SA40N and the diffractive CeeOn 811E multifocal intraocular lenses (IOLs) and to evaluate the potential benefits of combining both multifocal IOLs in the same patient.

METHODS: Two groups of cataract patients were unilaterally implanted with either the CeeOn diffractive (n=10) or the Array refractive multifocal IOL (n=10). Another group was bilaterally implanted with one of each multifocal IOLs (mix & match group, n=10). Visual acuity, spectacle independence, depth of focus, contrast sensitivity, presence of photic phenomena, and patient satisfaction were assessed postoperatively.

RESULTS: All eyes achieved good distance visual acuity but better uncorrected near vision was achieved with the CeeOn diffractive design. Contrast sensitivity with either multifocal IOL was at the lower limit of the normal range but when multifocal IOLs were combined in the same patient, contrast sensitivity was not significantly different from phakic controls. Defocus curves revealed a superiority of CeeOn diffractive design for near and Array refractive design for intermediate but mix & match patients performed better overall than the other patients, particularly for intermediate distances, which was reflected by total independence from spectacles in 90% of patients compared to 60% in the other groups. Visual outcomes remained unchanged over time (1 month vs 6 month vs >3 years).

CONCLUSIONS: Bilateral implantation with a diffractive multifocal IOL in one eye and a refractive multifocal IOL in the fellow eye is safe and could provide patients with better intermediate vision, increased depth of focus and contrast sensitivity, and also less dependence on spectacles. [J Refract Surg. 2008;24:233-242.]
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particular, neither of these lenses can fulfill perfectly a patient’s needs in terms of near, intermediate, and far vision. There is currently considerable debate over whether mixing and matching two different multifocal IOL technologies (refractive and diffractive) in the same patient is the best approach to provide patients with binocular vision that is satisfactory at all distances and which fulfills all patients’ expectations. In particular, there are some concerns regarding the long-term risks and side-effects that might be associated with this approach.

We report our own long-term experience with the mix & match approach using the diffractive CeeOn 811E IOL and the refractive Array IOL. Visual performance of three groups of cataract patients unilaterally implanted with either the CeeOn 811E IOL (diffractive group) or the Array IOL (refractive group) or bilaterally implanted with one of each multifocal IOL in each eye (mix & match group) was prospectively evaluated. Our data show that mixing and matching refractive and diffractive multifocal IOLs is a safe and effective approach and provides patients with improved visual performance, particularly intermediate vision and contrast sensitivity, compared to patients implanted with the refractive or the diffractive multifocal IOL only.

PATIENTS AND METHODS

Among cataract patients who were admitted to our clinic between August 2000 and September 2001, 30 patients were eligible to participate in this prospective clinical study. Exclusion criteria included previous intraocular operation, preoperative corneal astigmatism >1.50 diopters (D), corneal opacity, chronic drug myopia, iris neovascularization, macular pathology, diabetes mellitus, axial myopia, hyperopia, and glaucoma. After signing informed consent, 20 patients with unilateral cataract were randomly assigned to receive either the diffractive CeeOn 811E bifocal IOL (diffractive group, n=10) or the refractive Array SA40N (refractive group, n=10). The third group was implanted bilaterally with the diffractive CeeOn 811E IOL in the dominant eye and the refractive Array SA40N IOL in the fellow eye (mix & match group, n=10). For this group, time between the two surgeries was 10 days.

The CeeOn 811E bifocal IOL is a monobloc polymethylmethacrylate (PMMA) posterior chamber IOL with an ultraviolet-filtered biconvex optic design. Near addition (theoretically +4.00 D) is supplied by a Fresnel membrane of 20 to 30 concentric rings on the posterior surface of the optic, which is heparin-surface modified. The optic diameter is 6.0 mm, total diameter is 12.0 mm. A-constant is 117.7. Capsular C design haptics are at a 6° angle with the optic. The dioptic range is between +15.00 and +26.00 D with 0.50-D increments. Forty-one percent of incoming light is focused for distance, another 41% of incoming light is focused for near, and 18% of light is lost for the higher orders of diffraction. This distance/near focusing property is equal at any point on the IOL, thus it is thought that eccentric pupil and IOL tilt/decentration do not disturb the multifocality.

The Array SA40N IOL is a foldable posterior chamber IOL with SLM-2 ultraviolet-filtered silicone optic and PMMA haptics. The optic diameter is 6.0 mm, and total diameter is 13.0 mm. A-constant is 118.0. Modified C haptic design has a 10° angle with the optic. The central 4.7 mm of the front optic surface comprises five concentric zones of different refractive powers. This design provides +3.50 D near addition. Of the incident light, approximately 50% is focused for distance, 37% for near, and 13% for intermediate vision. The AMO Array SA40N is manufactured between +16.00 to +24.00 D in 0.50-D increments.

Operations were performed by the same surgeon (U.G.), and biometric calculations were evaluated by the same doctor (L.C.). Taking into consideration the keratometric values, axial length, and A-constant, bifocal IOL/multifocal IOL diopters were calculated using the SRK-T formula. Emmetropia was targeted during calculations.

In the eyes selected to receive the CeeOn 811E IOL, conjunctiva was dissected at the superior or temporal quadrant according to preoperative corneal astigmatism, and the sclera was cauterized. After a “frown incision” and formation of the scleral tunnel, the anterior chamber was penetrated by a 2.8-mm knife and filled with viscoelastic substance. Two side-ports were prepared. After continuous curvilinear capsulorhexis and hydrodissection, the nucleus and epinucleus were aspirated by phacoemulsification. Cortical cleaning was accomplished by the bimanual irrigation/aspiration technique. The capsular bag and anterior chamber were filled with viscoelastic substance and the incision was enlarged to 6.0 mm. The CeeOn 811E bifocal IOL was implanted into the capsular bag and the scleral incision was sutured with 10/0 monofilament. Viscoelastic substance was aspirated by bimanual irrigation/aspiration, and the conjunctiva was closed by 8/0 Vicryl sutures.

In the eyes selected to receive the Array SA40N IOL, 2.8-mm clear corneal incisions were made at the superior or temporal quadrants, depending on preoperative corneal astigmatism. After filling the anterior chamber with viscoelastic substance, two side-ports were prepared. Following the continuous curvilinear capsulorhexis and hydrodissection, the nucleus and epinucleus were
aspirated by phacoemulsification, and bimanual irrigation/aspiration for cortical cleaning was accomplished. The capsular bag and anterior chamber were filled with viscoelastic substance and the corneal incision was enlarged to 3.5 mm. The Array SA40N foldable multifocal IOL was implanted into the capsular bag using the UNFOLDER system (UNFOLDER Sapphire Series System, Allergan, Irvine, Calif). The viscoelastic substance was aspirated by bimanual irrigation/aspiration, and the operation was completed with stromal hydration. After surgery, patients received steroid eye drops six times daily and antibiotic eye drops four times daily for the first week postoperatively. Antibiotic treatment was stopped at the end of the first week and patients were advised to continue steroid drops four times daily for 2 weeks and two times daily for another week.

Patients were evaluated for the anterior segment findings at day 1 and between 3 and 5 days postoperatively. All patients were available for follow-up at 1 and 6 months, and at least 3 years postoperatively (range: 37 to 55 months; mean: 44.15 months). At every follow-up examination, patients (N=30) were assessed monocularly for uncorrected and best corrected distance vision; uncorrected, distance corrected, and best corrected near vision; spherical equivalent values; and keratometric measurements. The mix & match group was further tested for binocular visual acuity. For >3-year postoperative follow-up, intermediate visual acuity was also measured. During the two last postoperative follow-up examinations, patients were asked to answer a questionnaire including probable disturbances related to photic phenomena, spectacle dependence, and their personal satisfaction with the procedure.

**Contrast Sensitivity**

Contrast sensitivity was measured at 6-month postoperative follow-up using the Vistech VCTS 6500 System (Vistech Consultants Inc, Dayton, Ohio). Illumination was kept constant during each examination (85 cd/m²). Sitting at 3 meters distance from the chart, with the other eye closed and wearing their best spherical and cylindrical glasses, patients were asked to determine the orientation of sinusoidal gratings of different spatial frequency and contrast. Contrast sensitivity curves were drawn for each patient. Binocular contrast sensitivity curves were additionally drawn for the mix & match group. For comparison, 20 monofocal pseudophakic eyes of 20 patients (aged 46 to 82 years) and 20 phakic patients (aged 53 to 78 years) with best corrected distance vision of 20/20 were also evaluated binocularly using the same Vistech VCTS 6500 System.

**Defocus Curve**

The defocus curve, assessed at 6-month follow-up, was determined as the change of visual acuity with addition of 0.50-D increments at each step toward hyperopia and myopia after spectacles for best corrected visual acuity. Depth of focus was accepted as the range of dioptric change throughout which the patient could see 20/40 or better. The binocular defocus curve was evaluated for the mix & match group.

**Statistical Analysis**

All statistical calculations were performed by an independent statistician. Preoperative data were analyzed using the Mann-Whitney U test to evaluate any difference between groups (refractive versus diffractive eyes). For each group, Wilcoxon signed rank test was used to compare pre- versus postoperative keratometric measurements; spherical equivalent values; and distance and near visual acuities at 1 and 6 months, and 3 to 5 years postoperatively. Mann-Whitney U test was applied to compare keratometric measurements, spherical equivalents, and distance and near visual acuities between groups at all follow-up examinations and contrast sensitivity and defocus curves at 6 months postoperatively. The chi-square test was applied to evaluate the subjective data obtained from the questionnaire. Correlation analyses were done between objective results and subjective patient satisfaction at 6

**TABLE 1**

| Preoperative Data of Patients Implanted With Diffractive and Refractive IOLs* |
|---------------------------------|---------------------------------|---------------------------------|
|                                 | Diffractive Group (CeeOn 811E, n=10) | Refractive Group (Array SA40N, n=10) | Mix & Match Group (n=10) |
| Mean age (range) (y)            | 68.2 (38 to 83)                    | 64.4 (38 to 80)                    | 72.4 (40 to 81)          |
| Sex (F/M)                       | 6/4                              | 7/3                              | 4/6                      |
| Mean±SD astigmatism (D) (range) | 0.78±0.49 (0 to 1.62)             | 0.66±0.50 (0 to 1.75)             | 0.70±0.37 (0 1.25)       |

SD = standard deviation
*No statistical significant difference was noted between the diffractive, refractive, and bilaterally implanted groups (P>.05).
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RESULTS

No statistical difference was noted between the diffractive and refractive multifocal IOL implanted eyes and bilaterally implanted (mix & match group) eyes regarding preoperative data (Table 1).

SHORT-TERM FOLLOW-UP: 1 AND 6 MONTHS POSTOPERATIVELY

Mean spherical equivalent values for the diffractive group were $-0.18 \pm 0.59$ D and $-0.13 \pm 0.40$ D at 1 and 6 months postoperative, respectively. Mean spherical equivalent values for the refractive group were $-0.41 \pm 0.51$ D and $-0.32 \pm 0.37$ D at 1 and 6 months postoperative, respectively. At 6 months postoperative, the ratio of patients with $\pm 1.00$ D spherical equivalent for diffractive and refractive groups was 100% and 90%, respectively. Ratios of patients within $0.50$ D of emmetropia were 85% and 80% for the diffractive and refractive groups, respectively (Fig 1). Postoperative mean keratometric values were similar between groups with no significant changes over time (Table 2).

Visual acuity outcomes were not significantly different at 1 and 6 months postoperative, therefore only the 6-month results are presented. All eyes achieved uncorrected distance visual acuity of 20/25 or better and best corrected distance visual acuity of 20/25 or better. No statistically significant difference was noted between the refractive and diffractive IOL implanted eyes (Table 3). Patients bilaterally implanted (mix & match group) were tested for binocular vision. Seven patients achieved UCVA of 20/20, and three patients achieved 20/25. With best distance correction, nine patients achieved 20/20 and one patient achieved 20/25. The binocular performance (mix & match group) was not significantly different from the monocular performance (refractive or diffractive groups).

With regards to uncorrected near vision, the diffractive multifocal IOL eyes performed significantly bet-

months and 3 to 4½ years postoperatively. Visual outcomes from the final follow-up were compared with those of the 6-month data using the above mentioned statistical analysis methods.

TABLE 2
Mean Keratometric Readings at 1 and 6 Months Postoperatively in Patients Implanted With Diffractive and Refractive IOLs*

<table>
<thead>
<tr>
<th></th>
<th>Diffractive CeeOn 811E (n=10)</th>
<th>Refractive Array SA40N (n=10)</th>
<th>Mix &amp; Match (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>0.83±0.36</td>
<td>0.85±0.39</td>
<td>0.87±0.36</td>
</tr>
<tr>
<td>6 months</td>
<td>0.73±0.30</td>
<td>0.75±0.35</td>
<td>0.78±0.32</td>
</tr>
</tbody>
</table>

*No statistically significant difference between groups (P>.05) and no statistically significant changes over time (P>.05) were noted.

TABLE 3
Uncorrected and Best Distance Corrected Visual Acuity 6 Months Postoperatively in Patients Implanted With Diffractive and Refractive IOLs*

<table>
<thead>
<tr>
<th>Visual Acuity</th>
<th>Diffractive CeeOn 811E (n=10)</th>
<th>Refractive Array SA40N (n=10)</th>
<th>Mix &amp; Match (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20/20</td>
<td>6 (60)</td>
<td>5 (50)</td>
<td>7 (70)</td>
</tr>
<tr>
<td>20/25</td>
<td>2 (20)</td>
<td>4 (40)</td>
<td>3 (30)</td>
</tr>
<tr>
<td>20/32</td>
<td>2 (20)</td>
<td>1 (10)</td>
<td>0</td>
</tr>
<tr>
<td>20/40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Best distance corrected</td>
<td>8 (80)</td>
<td>9 (90)</td>
<td>9 (90)</td>
</tr>
<tr>
<td>20/25</td>
<td>2 (20)</td>
<td>1 (10)</td>
<td>1 (10)</td>
</tr>
<tr>
<td>20/32</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20/40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*No statistically significant difference was noted between groups (P>.05).
ter than the refractive multifocal IOL eyes ($P<.05$). All diffractive multifocal IOL eyes could read J2 or better without correction compared with four eyes with refractive multifocal IOLs. However, with near addition, both groups performed similarly ($P>.05$), with 90% of diffractive and 80% of refractive multifocal IOL eyes reading J1 (Table 4). Patients bilaterally implanted (mix & match group) were tested for their binocular vision. Nine patients were able to read J1 without correction and one patient could read J2. With near addition, 100% patients achieved J1. The binocular near visual acuity was not statistically different from those of the diffractive multifocal IOL eyes but a significant advantage over the refractive multifocal IOL eyes was observed ($P<.001$).

Contrast sensitivity measurements did not reveal any statistically significant differences between the refractive and diffractive multifocal IOL implanted eyes regarding mean Snellen equivalents and contrast sensitivities at each spatial frequency tested. As illustrated in Figure 2, contrast sensitivity curves of each group were similar, with the lower border of the shadowed area representing average values of a standard population. Patients from the mix & match group were binocularly tested and data revealed no significant difference with the binocular contrast sensitivity of our phakic and monofocal pseudophakic controls except at the spatial frequency of 18 cycles per degree (cpd). Outcomes were also significantly better than those of the diffractive and refractive eyes at each spatial frequency except at 18 cpd (see Fig 2).

Mean depth of focus of the diffractive, refractive, and mix & match groups was 5.80 D, 5.60 D, and 5.85 D, respectively, and not significantly different. However, the refractive group revealed a statistically significant superiority over the diffractive group between $-0.50$ and $-1.50$ D ($P<.05$) and vice versa, the diffractive group over the refractive group between $-2.50$ and $-3.50$ D ($P<.05$). The binocular performance (mix & match group) revealed better results at $-1.00$ and $-1.50$ D than the diffractive group and at $-2.50$ to $-5.00$ D than the refractive group, both of which were statistically significant (Fig 3).

Evaluation of the questionnaire revealed that 85% of patients in the diffractive group and 80% in the refractive group interpreted their subjective complaints resulting from halo formation as “some” or “none.” Visual disturbance due to glare formation was answered as “none” by 70% of patients in the diffractive group and 75% of the refractive group. No statistically significant difference was noted between groups regarding complaints arising from halo or glare formation. When questioning general patient satisfaction, 75% of patients in the diffractive group and 80% in

<table>
<thead>
<tr>
<th>Near Visual Acuity</th>
<th>Diffractive CeeOn 811E (n=10)</th>
<th>Refractive Array SA40N (n=10)</th>
<th>Mix &amp; Match (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrected J1</td>
<td>9 (90)</td>
<td>2 (20)</td>
<td>9 (90)</td>
</tr>
<tr>
<td>J2</td>
<td>1 (10)</td>
<td>2 (20)</td>
<td>1 (10)</td>
</tr>
<tr>
<td>J3</td>
<td>0</td>
<td>5 (50)</td>
<td>0</td>
</tr>
<tr>
<td>J4</td>
<td>0</td>
<td>1 (10)</td>
<td>0</td>
</tr>
<tr>
<td>Best corrected J1</td>
<td>9 (90)</td>
<td>8 (80)</td>
<td>10 (100)</td>
</tr>
<tr>
<td>J2</td>
<td>1 (10)</td>
<td>2 (20)</td>
<td>0</td>
</tr>
<tr>
<td>J3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>J4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* A statistically significant difference was noted between groups in favor of the diffractive and mix & match groups ($P<.05$).
the refractive group interpreted the result of the operation as “very good/perfect.” There was no statistically significant difference between groups ($P > .05$). Ninety-five percent of patients stated that they would recommend this operation to other patients. One patient in the diffractive group, despite his excellent uncorrected distance and near visual acuities, complained of halo and glare formation and stated that he was not satisfied with the result and would not recommend this operation to other patients. In terms of spectacle independence, 90% of patients from the mix & match group were able to live without spectacles compared to 60% in the other groups ($P < .05$).

**LONG-TERM FOLLOW-UP: 3 TO 4½ YEARS POSTOPERATIVELY**

Final follow-up of patients was at 37 to 55 months (mean: 44.15 months) postoperatively. Four eyes implanted with the CeeOn 811E IOL (two from diffractive group, two from the mix & match group) and six eyes with the Array SA40N IOL (four eyes from the refractive group and two eyes from the mix & match group) required Nd:YAG laser capsulotomy during the follow-up period. Mean spherical equivalent of eyes at last follow-up was $-0.23 \pm 0.44$ D with a maximum value of $-1.00$ D. Ratio of eyes within 0.50 D of emmetropia was 80%.

All patients, including those who required capsulotomy, were once more tested for their near and far vision. Data are detailed in Tables 5 and 6 and summarized in Tables 7 and 8. As observed earlier, uncorrected near visual acuity was better in the diffractive eyes compared with the refractive eyes with average values of $J1.30 \pm 0.45$ and $J1.90 \pm 0.56$, respectively ($P < .05$). In the mix & match group, all patients could read $J1.00 \pm 0.00$, a performance significantly better compared with the refractive group ($P < .05$). With best near correction, refractive eyes improved to $J1.40 \pm 0.69$ and diffractive eyes to $J1.10 \pm 0.31$ ($P < .05$). Uncorrected distance visual acuity was on average $20/27.3 \pm 4.32$ for the diffractive group, $20/23.2 \pm 3.96$ for the refractive group, and $20/22.5 \pm 2.63$ for the mix & match group with a significantly better performance of the latter compared with the diffractive group ($P < .05$). With best distance correction, all groups slightly improved with a better performance of the refractive and mix & match groups over the diffractive group ($P < .05$).

Patients were further tested for their visual acuity at 70-cm, 1.5-m, and 2-m distances. As shown in Table 9, uncorrected visual acuity at 70 cm was similar between the refractive and diffractive groups but was better in the mix & match group with average values of $J2.10 \pm 0.87$, $J2.5 \pm 0.52$, and $J1.6 \pm 0.84$, respectively. At the 1.5-m distance, only three uncorrected eyes from the diffractive group could read J5 in contrast to the refractive group and the mix & match group, which achieved an average value of $J4.50 \pm 0.70$ and $J4.00 \pm 0.94$, respectively. Vision at 2 m was poor in all groups with a slight advantage for the refractive group. There were no changes after best distance correction.

In terms of spectacles independence and patient satisfaction, outcomes were similar to those at 6-month follow-up.
The concept of mixing and matching refractive and diffractive multifocal IOLs is currently raising a lot of interest among ophthalmologists as it is believed that patients might benefit from both multifocal IOL technologies, resulting in a better quality of vision compared to a standard procedure. Our short- and long-term data show some evidence that bilateral implantation with a refractive multifocal IOL in one eye and a diffractive multifocal IOL in the fellow eye is a safe procedure and provides patients with high levels of satisfaction with a full range of vision. In particular, improved intermediate vision and contrast sensitivity can be achieved with this approach, resulting in greater freedom from spectacles.

**DISCUSSION**

The concept of mixing and matching refractive and diffractive multifocal IOLs is currently raising a lot of interest among ophthalmologists as it is believed that patients might benefit from both multifocal IOL technologies, resulting in a better quality of vision compared to a standard procedure. Our short- and long-term data show some evidence that bilateral implantation with a refractive multifocal IOL in one eye and a diffractive multifocal IOL in the fellow eye is a safe procedure and provides patients with high levels of satisfaction with a full range of vision. In particular, improved intermediate vision and contrast sensitivity can be achieved with this approach, resulting in greater freedom from spectacles.

**SHORT-TERM DATA—1- AND 6-MONTH FOLLOW-UP**

Surgery was uneventful and slit-lamp microscopy of the anterior and posterior segments revealed normal postoperative outcomes. The target refraction was emmetropia for both multifocal IOLs: 85% of the diffractive group and 80% of the refractive group were within 0.50 D of emmetropia. At 6 months postoperative, corneal astigmatism was similar in both groups with a mean of 0.78 ± 0.49 D for the diffractive CeeOn 811E eyes and 0.66 ± 0.50 D for the refractive Array SA40N eyes. Because reduction of distance visual acuity due to astigmatism is known to be greater with multifocal IOLs than with monofocal IOLs, only eyes with preoperative astigmatism <1.50 D were included in this study.

In agreement with previous literature, implantation of the diffractive CeeOn 811E bifocal IOL and the refractive Array SA40N multifocal IOL resulted in good visual outcomes and high patient satisfaction. All patients achieved good distance visual acuity with uncorrected visual acuity of 20/25 or better. However, in terms of uncorrected near vision performance, we observed a superiority of the diffractive group over the refractive group, with 100% of patients with the CeeOn 811E IOL reading J2 or better compared with 40% in the other group (P < 0.05). This difference seemed to be mainly related to the smaller near addition of the refractive design, as after best near correction 80% of the Array SA40N eyes achieved J1. These data corroborate those of a previous study showing similar visual outcomes when comparing the CeeOn 811E and Array SA40N multifocal IOLs.5 Several other laboratory and clinical studies have also reported better near visual performance with diffractive designs than with refractive designs due in part to the +4.00-D near addition of diffractive designs.
Similarly, depth of focus analyses revealed different outcomes between refractive and diffractive multifocal IOLs. Walkow et al6 reported statistically significant superiority of the refractive design at −1.50 D (intermediate reading ability) and the diffractive design beyond −2.50 D (near reading ability). Weghaupt et al11 observed better visual performance with diffractive design beyond −2.50 D but similar performance was found at other focus points. Ravalico et al12 pointed out that zonal progressive design showed a lower resolution threshold at intermediate distance and diffractive design at near by using high-pass resolution perimetry. In the present study, we found a statistically significant superiority of the refractive Array SA40N group between −0.50 and −1.50 D whereas the diffractive CeeOn 811E group performed better between −2.50 and −3.50 D. This is consistent with the design of both IOLs, with the CeeOn 811E lens having a higher addition for near than the distance dominant Array SA40N lens. Interestingly, when the lenses were combined (mix & match group), the performance improved and was significantly better than the refractive group for near vision (−2.50 to −5.00 D) and better than the diffractive group for intermediate vision (−1.00 to −1.50 D), leading us to consider that different refractive properties of these designs might be used to enhance visual performance.

In the current context, it is worth mentioning that a similar concept consisting of implanting a near dominant multifocal IOL in one eye and a far dominant multifocal IOL in the fellow eye was suggested by Jakobi and Eisenmann.13 This concept termed “asymmetrical bilateral multifocal IOL implantation” was based on the hypothesis that the image in the dominant focus of both eyes will 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. The feasibility of this concept was subsequently validated by Jacobi et al14 who reported improved contrast sensitivity as well as distance and near visual acuity with combined asymmetrical diffractive multifocal IOLs.

It is well known that multifocal IOL implantation can lead to reduced contrast sensitivity,4,6,8,9,15,16 and the reduction does not seem to differ between diffractive and refractive multifocal IOLs3,4 or to disturb patient quality of life.6,8,9,17-22 Consistent with these findings, we observed similar contrast sensitivity between diffractive and refractive designs, both of which were at the lower border of the normal range. Interestingly, the binocular performance of the mix & match patients was similar to that of monofocal pseudophakic and phakic patients except for the highest spatial frequency (18 cpd). Because control patients were tested binocularly and under the same conditions as the mix & match patients, these data strongly reinforce the idea that combining diffractive and refractive multifocal IOL designs might result in improved functional vision.

Photic phenomena are inherent to multifocal IOLs due to multiple out-of-focus images and have been extensively reported by patients,7,8,18,23 although no quantitative difference in halo size in patients implanted with a refractive multifocal IOL or a monofocal IOL was observed by Dick et al.24 However, some factors such as irregular corneal surface and/or astigmatism >1.00 D are limiting factors for multifocal IOL patients as they are accountable for the occurrence of greater halos.24 Usually, most patients are not disturbed by these visual phenomena, which disappear largely over time.24-28 In agreement with the above data, our results showed that the majority of patients (70% to 83%) were either minimally or not at all disturbed by halo or glare formation at 6-month follow-up. The significantly better visual performance achieved by our patients bilaterally implanted with one of each multifocal IOL became particularly apparent with the results of the postoperative questionnaire. When evaluating the need for spectacles, 90% of these patients declared being totally free from spectacles compared with 60% in the other groups. Although a higher proportion of spectacle independence in bilateral versus unilateral multifocal IOL individuals was anticipated,14,18,27,28 such a considerable difference between groups was unexpected.

**Long-term Data—3- to 4½-Year Follow-up**

All patients were available for final follow-up, which took place between 3 and 4½ years postoperatively.
Refractive errors remained unchanged over time with 80% of eyes within 0.50 D of emmetropia. Regarding complications, four eyes implanted with the Array SA40N IOL and six eyes with the CeeOn 811E IOL required Nd:YAG laser capsulotomy during this follow-up period.

Uncorrected visual acuity was tested for near, intermediate, and far distances and the performance was compared between the three groups. As previously observed for the early follow-up, the CeeOn 811E IOL group achieved better near uncorrected vision at 35 cm than the SA40N IOL group with 90% of eyes able to read J1 compared to only 20% in the refractive group. When intermediate vision was tested, the Array SA40N IOL group performed better than the CeeOn 811E IOL group at 70 cm and 1.5 m. However, patients from the mix & match group performed better overall than the two other groups, particularly for intermediate vision at 70 cm. Distance visual acuity at 6 months was similar between groups.

Patient satisfaction and spectacle independence were evaluated subjectively at the later follow-up examinations. Of the mix & match group, 90% stated that they did not require spectacles for daily activities. One patient used near spectacles from time to time especially in a gloomy environment. All patients were satisfied with their present visual function at the time of the ophthalmic examination.

**CONCLUSION**

Since the early launch of the Array SA40N IOL and the CeeOn 811E IOL, lens technology has significantly improved and has probably been the greatest catalyst for an upsurge in interest in multifocal IOLs. In the past few months, compelling evidence has suggested that many innovations found in this new generation of multifocal IOLs, including the apodized diffractive AcrySof ReSTOR, the diffractive Tecnis, and the refractive ReZoom, have resulted in improved visual outcomes and higher patient satisfaction compared with previous models. However, the concept of mixing and matching different multifocal IOL technologies has emerged as a result of clinical observations suggesting that diffractive multifocal IOLs might benefit from the design of refractive multifocal IOLs as the latter provide better intermediate vision. Although in its infancy, early studies on “mixing and matching” these lenses has yielded positive visual outcomes and support this concept.2,3

In the present study, although only a small number of patients were evaluated, the data strongly reinforce the argument that combining refractive and diffractive multifocal IOL technology can lead to improved visual function. However, this approach is not suitable for all patients and it is worth emphasizing again that patient selection is a critical step in multifocal IOL surgery.29

The best candidates are patients with realistic expectations, motivated to be spectacle independent, capable of understanding probable visual disturbances due to halo and glare formation, and who do not have significant corneal astigmatism or other ocular pathologies. Also, in the present study, personal bias cannot be entirely excluded as all findings were evaluated by a single observer. Designation of prospective, randomized, double-masked studies to assess bilateral diffractive, bilateral refractive, and bilateral diffractive/refractive multifocal IOL implantation would provide more definitive results.

**REFERENCES**


