ARTICLE

Long-term performance of a diffractive–refractive trifocal IOL with centralized diffractive rings: 5-year prospective clinical trial

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Purpose: To report the 5-year visual, refractive, and patient-reported outcomes following implantation of a trifocal intraocular lens (IOL) during cataract surgery.

Setting: Csolnoky Ferenc University Hospital, Veszprém, Hungary.

Design: Prospective, longitudinal, single-center, interventional study.

Methods: 100 eyes of 50 patients underwent bilateral implantation of a trifocal IOL during cataract surgery. Preoperative corrected distance (CDVA) and postoperative uncorrected distance visual acuity (UDVA), CDVA, uncorrected (UIVA) and corrected (CIVA) intermediate and uncorrected (UNVA) and corrected (CNVA) near visual acuity were collected. All subjects were seen at day 1, 1 month, 3 months, 6 months, 12 months, and 24 months, and at year 5. Contrast sensitivity, slitlamp photography, and quality of vision questionnaire were performed at months 3, 6, 12, and 24 and at year 5. Of these 50 patients, 41 completed their 5-year follow-up.

Results: At year 5, 74 eyes of 37 patients were analyzed. The mean postoperative UDVA was 0.02 ± 0.10 (logMAR). The mean CDVA was −0.04 ± 0.07. The mean UIVA was 0.04 ± 0.09. The mean CIVA was 0.00 ± 0.08. The mean UNVA was 0.09 ± 0.09. The mean CNVA was 0.05 ± 0.07. Mesopic and photopic contrast sensitivity values were in the upper third range of the age-matched normal values.

Conclusions: 5-year prospective study data showed that bilateral implantation of a diffractive–refractive trifocal IOL with centralized diffractive rings provided good functional vision at all distances. There was high level of spectacle independence and patient satisfaction with minimal levels of dysphotopsia.

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Cataract surgery is one of the most common surgical procedures performed worldwide, with more than 26 million surgeries performed in 2019.[1] It has also been shown to be cost-effective in the long term with improvements in the quality of life in patients of all ages.[2,3] The visual performance of patients after cataract extraction is greatly dependent on the choice of intraocular lens (IOL). Monofocal IOLs are the most common type of IOLs implanted during cataract surgery. These IOLs provide excellent long-term objective and subjective visual outcomes.[4,5] Although monofocal IOLs provide excellent visual function, for many patients, the limited depth of focus does not allow clear vision at both distance and near. With modern lifestyle, patients expect and demand good functional range of uncorrected vision following cataract surgery. Multifocal IOLs implanted during cataract surgery have become an important tool in rehabilitating and meeting the visual needs of our patients.

Currently, the choices of presbyopia-correcting IOLs include diffractive bifocal, segmental bifocal, trifocal, and extended depth of focus. Two recent reviews and meta-analysis reported that multifocal IOLs are effective in improving the near vision, and patients receiving multifocal lenses were less likely to be spectacle dependent compared with monovision.[6,7] Despite increasing demand and popularity of presbyopia-correcting IOLs, there is paucity of long-term follow-up data. We had earlier reported on the prospective 2-year data on the diffractive–refractive trifocal IOL with centralized diffractive rings (Liberty Bi-Flex 677MY, Medicontur Medical Engineering Ltd.; Table 1).[8] The Liberty trifocal lens is a hydrophilic IOL made from a hydrophilic – hydrophobic

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Table 1. Optical Details of the Liberty Trifocal IOL.

Description	Value
Optic and haptics material	Hydrophilic–hydrophobic acrylic copolymer with UV absorber and blue-light filter
Optic design	Biconvex, aspheric, diffractive–refractive, apodized
Refractive index	1.46 (at 589 nm when hydrated)
Abbe number	58
Optic diameter	6.0 mm
Overall diameter	13.0 mm
Type of haptics	Double C-loop
Haptic angulation	0°—asymmetrical design with posterior vaulting
Available power	+8.00 to +35.0 D (increment 0.50 D)
Addition	+3.50 D (near) and +1.75 D (intermediate)
Incision	2.2 mm
A-constant SRK-T (IOLMaster)	118.9
Haigis constants (IOLMaster)	a0 = 0.19; a1 = 0.192; a2 = 0.173

copolymer, Benz-25, that has been commercially available for over 2 decades.

The highly hydrophilic monomer, hydroxyethyl methacrylate, which gives 64% of the copolymer, has 38% water content and is responsible for biocompatibility, whereas the hydrophobic monomer (36%), EOEMA, has a 2% water content and ensures the elastic properties and the softness of the material. The final copolymer has a water content of 25%.

The purpose of this study was to assess the visual and refractive outcomes, and contrast sensitivity (CS) 5 years following cataract surgery with bilateral implantation of the Liberty Bi-Flex 677 trifocal IOL.

METHODS

In this prospective single-center trial, 100 eyes of 50 patients underwent cataract surgery with bilateral implantation of an apodized diffractive–refractive trifocal IOL. The procedure was performed by a single surgeon (J.F.G.) between February and May 2015. Details of the patient selection criteria and results of the 2-years follow-up have been previously published.[8] Only patients with preexisting corneal astigmatism of less than 1.25 diopters (D) were included in this study. All patients had detailed informed consent preoperatively. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Health Science and Research Ethical Board Committee of Hungary (OGYEI, Hungarian Health Authority, ref: 032802/2014/OTIG). The study was registered at ClinicalTrials.gov under number: NCT04220255. Forty-one (82 eyes) of the 50 patients completed the 5-year follow-up. Sample size calculation was not performed. But the study was designed with the clear goal of recruiting 100 eyes of 50 patients with a prospective follow-up till year 5.

Preoperative and Postoperative Follow-Up Examinations

At each visit, uncorrected (UDVA) and corrected distance visual acuity (CDVA) at 6 m, uncorrected (UIVA) and corrected intermediate (CIVA) visual acuity at 67 cm, and uncorrected (UNVA) and corrected (CNVA) near visual acuities at 40 cm were recorded using the Early Treatment Diabetic Retinopathy Study (ETDRS) charts. Binocular defocus curve was assessed after best distance correction under photopic light conditions by adding lenses in 0.50 D increments from +2.00 to −4.00 D. Visual acuity values were measured with varying ETDRS charts to avoid the learning effect at a viewing distance of 4 m. Binocular CS was measured at spatial frequencies of 3, 6, 12, and 18 with a standard CS chart CSV-1000 (Vector Vision) under photopic, mesopic, and photopic with backlight conditions at 2.50 m. CS was measured preoperatively and postoperatively at 1, 2, and 5 years after cataract surgery. Measured scores were converted to log values. Intraocular straylight was determined using a computerized straylight meter, according to the compensation comparison principle (Oculus C-Quant, Oculus GmbH). Measurements were performed at 1 year and 5 years postoperatively. Values were compared with the normal straylight values of age-matched noncataractous subjects of the database as developed by van der Berg et al.[9] Subjects completed a modified Visual Function Questionnaire (VFQ-25, National Eye Institute). Overall patient satisfaction was scored from 1 to 10. All follow-ups were performed by 2 trained optometrists (E.M. and L.B.) trained and certified in good clinical practice.

Statistical Analysis

Collected data were registered in Microsoft Excel (Microsoft Corp.) and were analyzed with the GraphPad Prism 8.2 statistical analysis software. Descriptive statistics (mean, SD, minimum, and maximum) were calculated in all cases. Measured decimal visual acuities were converted to logMAR. Pairwise comparison for defocus and CS groups was performed with 2-way analysis of variance followed by Tukey multiple comparison test. The comparison between straylight log values of the first and fifth postoperative years was made by using the *t* test. Of the 50 subjects (100 eyes) enrolled, 41 subjects (82 eyes) completed their 5-year follow-up. Four subjects (8 eyes) were excluded from data analysis due to macular degeneration (n = 3) and severe dry eye (n = 1).

RESULTS

The data are presented on 37 patients (74 eyes). The mean age was 67 ± 8.97 years (range 35 to 85 years). There was no significant difference in sex or age between the participants (16 men [43.24%], mean age 68.3 years, and 21 women [56.7%], mean age 66 years).

Visual and Refractive Outcomes

At 5 years, the mean postoperative UDVA was 0.02 ± 0.10 (logMAR). The mean CDVA was −0.04 ± 0.07. The mean UIVA was 0.04 ± 0.09, whereas the mean CIVA was 0.00 ± 0.08. The mean UNVA at year 5 was 0.09 ± 0.09. The mean CNVA was 0.05 ± 0.07. The uncorrected visual acuities of 0.00 logMAR were achieved for 66% of the subjects for distance (6 m), 67% for intermediate (60 cms), and 32.4% for near vision (40 cms). Ninety percent of the eyes reached 0.1 logMAR without correction at far and intermediate, whereas at near, 77% of the eyes had 0.1 logMAR without correction. Figure 1 shows the cumulative postoperative UDVA compared with post-operative CDVA at year 5 for distance, intermediate, and near vision. The change in uncorrected and corrected visual acuities over the first 5 postoperative year is illustrated in Figure 2.

Five years after surgery, the mean UDVA was found to be practically unchanged compared with the 0.01 ± 0.07 logMAR measured at year 2 (*P* > .9999). The CDVA improved over time from −0.02 ± 0.03 logMAR at month 3 to −0.04 ± 0.07 logMAR at year 5, although these changes are not clinically or statistically significant (*P* > .9999). The UIVAs were stable throughout the study period. These were 0.05 ± 0.67 logMAR

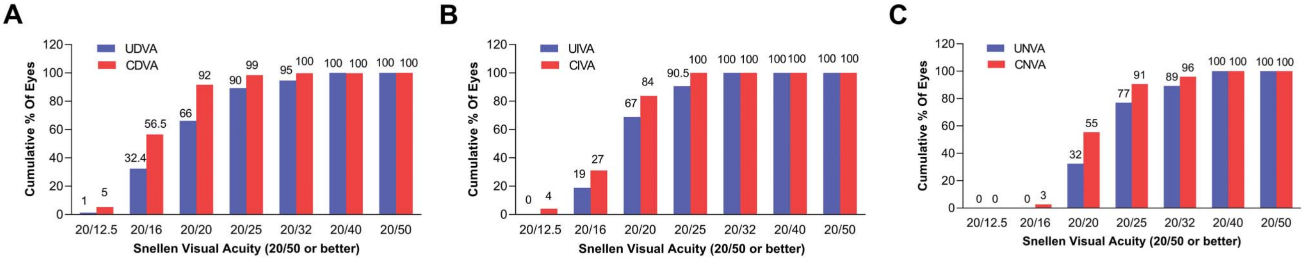

Figure 1. *A*: Cumulative postoperative UDVA compared with postoperative CDVA. *B*: Cumulative postoperative UIVA compared with postoperative CIVA. *C*: Cumulative postoperative UNVA compared with postoperative.

at month 3, 0.06 ± 0.10 logMAR at year 2, and 0.04 ± 0.09 logMAR at year 5, whereas the CIVAs were −0.02 ± 0.68 logMAR at month 3, −0.01 ± 0.07 at year 2, and 0.00 ± 0.08 logMAR, respectively ($P > .9999$).

In the near VA, there was a negligible difference of 0.01 and 0.02 logMAR both at the uncorrected and corrected VA, respectively (the UNVA from 0.08 ± 0.08 logMAR at month 3 changed to 0.09 ± 0.09 logMAR at year 5 ($P > .9999$), whereas the CNVA was 0.03 ± 0.06 logMAR at month 3 and 0.05 ± 0.07 at year 5 ($P > .9999$).

The majority of eyes (69 eyes, 93.24%) achieved a spherical equivalent refraction within ± 0.50 D from the target refraction, emmetropia. Four eyes (5.40%) resulted between +0.51 D and +1.00 D from the intended target, while only one eye (1.35%) had a residual spherical equivalent of +1.50 D. The refractive cylinder at year 5 was below 0.25 D in 71 eyes (96%) and less than 0.51 D in 3 eyes (4%) (Figure 3).

Posterior Capsule Opacification

All study patients underwent slitlamp photography with dilated pupils to evaluate the posterior capsule opacification at 1 year, 2 years, and 5 years. YAG laser posterior capsulotomy was considered and offered when patients become symptomatic or if it affected the CDVA. Over the study period, the rates of YAG laser posterior capsulotomies were as follows: 0% at year 1, 9% (n = 9 out of 100 eyes) at year 2, and 21.9% (n = 18 out of 81 eyes) at year 5.

Defocus Curves

Distance-corrected defocus curves were performed postoperatively at years 1, 2, and 5 (Figure 4). At all the above timepoints tested, the binocular visual acuities were below 0.3 logMAR except for the defocus lenses of −4.00 D and +2.00 D. Although not statistically significant, visual acuities at year 5 were slightly better when compared with years 1 and 2 when tested with test lenses between +2.0 D and −2.50 D. Table 2 shows the mean VA values ± SD recorded with each defocus lens at 1-, 2-, and 5-year follow-up visits.

Contrast Sensitivity and Straylight

Figure 5 shows the mean monocular preoperative and postoperative CS at 1 year, 2 years, and 5 years. In all the 3 different light conditions measured (photopic, mesopic, and with backlight), CS improved significantly ($P > .0001$) at all spatial frequencies compared with the preoperative state with the highest values at 1 year after surgery. A slight and statistically nonsignificant deterioration was detected during the second follow-up year; then, the scores stabilized and remained constant during the fifth-year follow-up. The only statistically significant decrease in the CS score was detected 5 years postoperatively when CS was tested with backlight, at the spatial frequency of 12 cycles/degree ($P = .03$). The CS values of the studied IOL were in the upper third range within the age-matching normal values.

Straylight measurements were performed 1 year and 5 years postsurgery. The mean straylight level was 1.121 ± 0.207 after the first year and significantly increased and reached 1.213 ± 0.230 at 5 years ($P = .01$). Of the 84 eyes tested, only 8 eyes (9.5%) had higher values and 17 eyes (20.2%) had lower straylight values than their age-matched counterparts. Figure 6 illustrates the straylight data (absolute

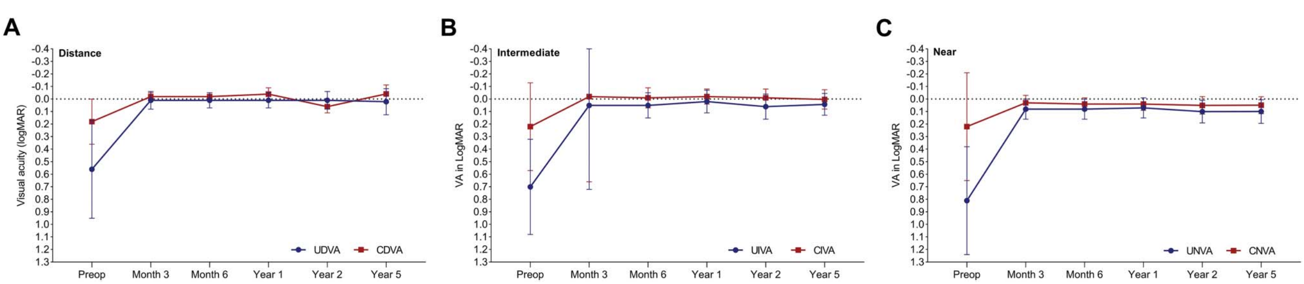

Figure 2. *A*: Cumulative preoperative and postoperative UDVA compared with postoperative CDVA over 5 years. *B*: Cumulative preoperative and postoperative UIVA compared with postoperative CIVA over 5 years. *C*: Cumulative preoperative and postoperative UNVA compared with postoperative. CNVA over 5 years.

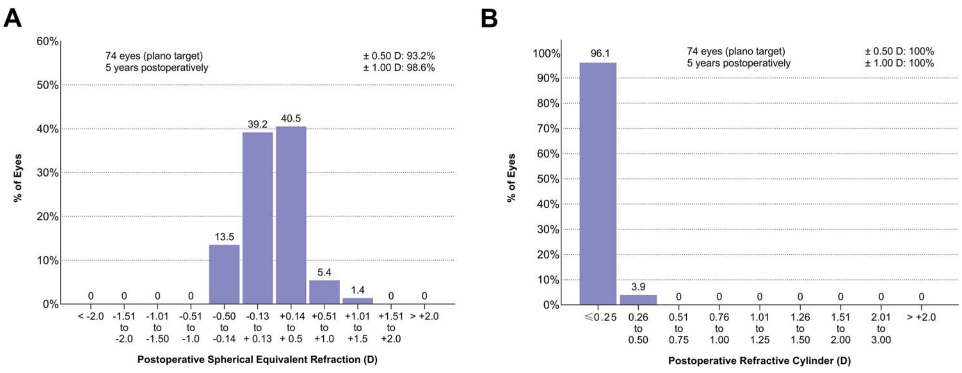

Figure 3. *A*: Spread of postoperative mean spherical equivalent. *B*: Postoperative refractive cylinder.

value as log(s)) 5-year after surgery plotted together with the phakic norm curve as defined by van der Berg et al.[9]

Patient-Reported Outcome Measures

All the patients enrolled in the study completed a modified VFQ-25 questionnaire. A classification was performed according to the patient's response on the degree of difficulty performing different tasks: cannot accomplish, severe, moderate, mild, and none. The results are summarized in Table 3.

DISCUSSION

Cataract surgery is one of the most cost-effective surgical interventions compared with other surgical procedures performed across medical subspecialties.[2] Small-incision phacoemulsification with monofocal IOL implantation has become the gold standard surgical technique for cataract surgery in most parts of the world. Long-term follow-up is an important step in evaluating cataract surgery results because many patients have a remaining lifespan of several years or decades. In the Western world, an increasing number of persons are projected to reach their ninth and 10th decades of life.[10] Monestam et al. analyzed the long-term outcomes following cataract surgery with a monofocal IOL in a Swedish cohort and demonstrated with these longitudinal studies that patients enjoyed excellent subjective visual function and the CDVA was retained in the operated eye 20 years after cataract surgery.[4,5,11]

Multifocal IOLs were developed to meet the patients demand for good functional vision at various focal points. A Cochrane review reported that multifocal IOLs are effective in improving the near vision and patients receiving multifocal IOLs are less likely to be spectacle dependent than patients receiving monovision IOLs.[6] Cao et al. in a recent review and meta-analysis of 2951 subjects demonstrated no statistical difference between UDVA and CDVA. Compared with monofocal IOLs, MFIOLs showed a better performance on UIVA measured at 60 cm and UNVA at 40 cm.[7]

Presbyopia-correcting IOLs are gaining popularity in providing good functional range of distance, intermediate, and near vision following cataract surgery. The optics of the presbyopia-correcting IOLs have advanced in the last 3 decades. The earlier version of bifocal IOLs failed to provide intermediate vision, which led the IOL manufacturers to develop trifocal optics that could provide uninterrupted distance, intermediate, and near vision. At present, outside the United States, in addition to the Liberty trifocal IOL (Liberty Bi-Flex 677MY), several other trifocal IOLs are available from different manufacturers (AT Lisa tri 839 MP, Carl Zeiss Meditec; FineVision Micro F PhysIOL, BVI; PanOptix, Alcon Laboratories Inc., RayOne Trifocal, Rayner Intraocular lenses Ltd.; Versario Multifocal 3F IOL (Valeant Med Sp.zo.o.). Previous short-term studies have shown that trifocal IOLs provide good functional vision at all distances

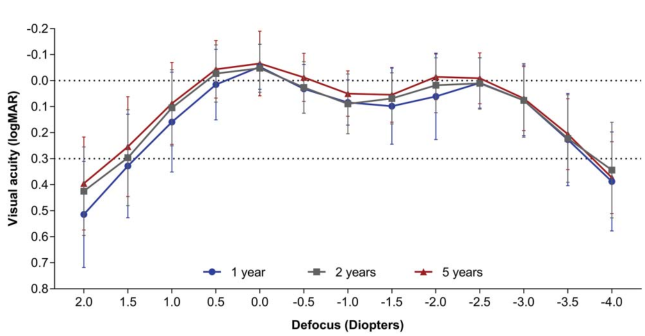

Figure 4. Binocular defocus curve (mean ± SD).

Table 2. Binocular Visual Acuity With the Corrected Distance Refraction at Different Defocus Steps.

Defocus/ follow-up	1 year	2 years	5 years
2.00 D	0.51 ± 0.2	0.42 ± 0.17	0.39 ± 0.18
1.50 D	0.32 ± 0.2	0.30 ± 0.18	0.25 ± 0.19
1.00 D	0.15 ± 0.19	0.10 ± 0.15	0.09 ± 0.16
0.50 D	0.01 ± 0.14	-0.03 ± 0.11	−0.04 ± 0.11
0.00 D	−0.05 ± 0.09	−0.05 ± 0.09	−0.07 ± 0.12
−0.50 D	0.03 ± 0.09	0.03 ± 0.10	−0.01 ± 0.09
−1.00 D	0.08 ± 0.09	0.09 ± 0.11	0.05 ± 0.09
−1.50 D	0.09 ± 0.15	0.07 ± 0.10	0.05 ± 0.11
−2.00 D	0.05 ± 0.17	0.02 ± 0.11	−0.01 ± 0.09
−2.50 D	0.01 ± 0.10	0.01 ± 0.10	−0.01 ± 0.10
−3.00 D	0.07 ± 0.14	0.08 ± 0.14	0.07 ± 0.12
−3.50 D	0.22 ± 0.18	0.22 ± 0.17	0.21 ± 0.14
−4.00 D	0.38 ± 0.19	0.34 ± 0.18	0.37 ± 0.14

Results are displayed in logMAR as mean ± SD

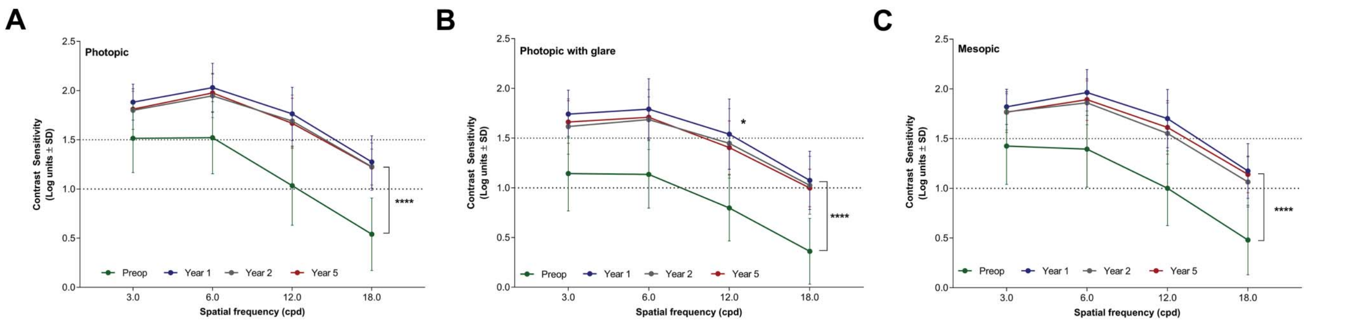

Figure 5. Contrast sensitivity measured with the CSV-1000 contrast sensitivity chart in *A*: photopic, *B*: photopic with glare, and in *C*: mesopic light conditions.

(including intermediate) with high levels of spectacle independence and patient satisfaction.[12–19]

However, there is paucity of published literature with regard to long-term (>3 years) data following trifocal IOL implantation.[20] We had previously published the prospective 2-year data on the outcomes of the Liberty trifocal IOL.[8] In this report, we present the prospective, longitudinal data on the visual, refractive outcomes, CS, and patient-reported outcomes on 74 eyes on 37 patients who had completed the 5-year follow-up. The optical principle and structural arrangement of the diffractive rings of the trifocal IOL used in this study differ from those of other commercially available trifocal IOLs. The IOL uses an elevated phase shift technology that causes constructive interference in the wavefront, providing an intermediate peak for intermediate vision. Moreover, the Liberty trifocal IOL has 7 diffractive rings that are progressively apodized and located in the central 3.00 mm of the 6.00 mm optic, with the rest of the optic being a refractive surface. In our cohort, the mean postoperative binocular UDVA was 0.01 ± 0.07 logMAR at 2 years and 0.02 ± 0.10 logMAR at 5 years. The mean UIVA was 0.06 ± 0.10 logMAR at 2 years and 0.04 ± 0.09 logMAR at 5 years. The mean UNVA was 0.10 ± 0.09 logMAR and 0.09 ± 0.09 logMAR, respectively. The visual outcome results are presented according to the recommendations of a joint editorial by the editors of the *Journal of Cataract & Refractive Surgery* and the *Journal of Refractive Surgery*.[21] The postoperative UDVA was the same as or better than the postoperative CDVA in 46% of cases and within 1 line in 88%.

To our knowledge, this prospective study is among the first to report longitudinal data on such a large cohort of patients with trifocal IOLs. Oliveira et al. recently published 5 years data on 24 eyes of 12 patients with PhysIOL (FineVision Micro F, BVI) diffractive trifocal.[20] In their cohort, the mean UDVA, UIVA, and UNVA were 0.19, 0.15, and 0.17 logMAR, which compare favorably to our results of 0.02, 0.09, and 0.04 logMAR of distance, intermediate, and near vision, respectively. A more robust and objective clinical measurement of the presbyopia-correcting IOL is the defocus curve, which indicates the range of vision of the IOL performance. The binocular defocus curve obtained with the Liberty 677MY lens under photopic conditions showed the best visual acuity without (far), and with −1.50 D (intermediate) and −2.50 D (near) addition. The functional vision at these distances remained consistent over a 5-year follow-up period. Bianchi reported the binocular defocus curve for 480 eyes of 240 patients implanted with FullRange multifocal IOL (Hanita Lenses). One year postoperatively, the best outcomes were 0.04 logMAR for −3.0 D and 0.09 logMAR for −1.5 D.[22] The defocus curves for the Liberty trifocal IOL at 5 years are more favorable when compared with 5-year defocus curves on the FineVision IOL.[20]

In the present study, we report the CS function of the Liberty 677MY, diffractive–refractive trifocal IOL measured at 1 year, 2 years, and 5 years postoperatively. To our knowledge, this is the first study to publish CS evaluation of a trifocal IOL 5 years after implantation. The only prospective, long-term follow-up study addressing CS functioning of MIOL published by Mesci et al. reports the results of 18-month postoperative measurements.[23] One of the limitations of our present study is that we did not include control group, and the direct comparison of our data with the other published results is difficult not only due to variable follow-up intervals but also due to different testing methods used in either monocular or binocular measurements, the mean age of the cohort, and the different outcome variables. By using the CSV-1000, we have found that the monocular CS reached with Liberty 677MY was statistically significantly better at each follow-up visit across all spatial frequencies and at all light conditions than that measured preoperatively.

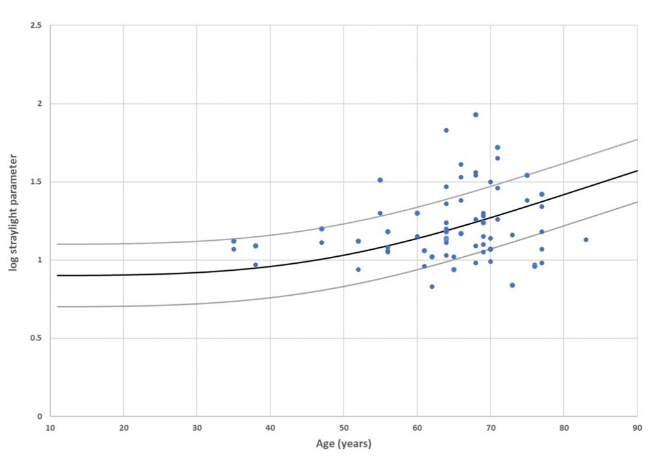

Figure 6. Straylight data (absolute value as log(s)) 5 years after surgery plotted together with the phakic norm curve.

Table 3. National Eye Institute VFQ (N = 37).

Items	Responses 1 No difficulty	2 Mild difficulty	3 Moderate difficulty	4 Severe difficulty	5 Cannot accomplish	6 Not applicable
Glare/flare (trouble seeing street signs due to bright light or oncoming headlight)	22	11	3	1	—	—
Night vision	32	4	—	—	1	—
Recognizing specific colors (color perception)	34	1	2	—	—	—
Rings around light sources (halos)	32	3	1	1	—	—
Lining things up, pouring liquids, or going down stairs (depth perception)	35	1	1	—	—	—
Distorted near vision (straight lines looked crooked close up)	37	—	—	—	—	—
Distorted distance vision (straight lines looked crooked at distance)	37	—	—	—	—	—
Blurred near vision	35	1	1	—	—	—
Blurred far vision	33	1	3	—	—	—
Double vision	35	1	1	—	—	—
Watching TV or movies	34	—	2	1	—	—
Playing or working outdoors	36	1	—	—	—	—
Caring for/playing with children	36	1	—	—	—	—
Reading the time on at alarm clock	35	1	1	—	—	—
Seeing clearly when waking up	30	5	2	—	—	—
Reading the time on a wall clock	35	1	1	—	—	—
Performing jobs/hobbies	35	1	—	1	—	—
Participating in sports/recreation activities	35	1	—	1	—	—
Participating in social events	34	—	2	1	—	—
Reading and near work activities	32	2	3	—	—	—
Driving at night	17	7	11	2	—	—
Driving when it is raining	21	6	7	2	1	—
Using a computer	31	3	2	—	—	1
Cooking	35	—	—	2	—	—
Shopping	35	1	—	1	—	—

VFQ = Visual Function Questionnaire

Furthermore, the level of CS was maintained over the years, and only a slight decrease could be detected in the second follow-up year, whereas the CS scores of the fifth year were between the scores of the first and second years. The decrease in CS in patients implanted with multifocal IOL is due to the dispersed distribution of light energy within the surface of the optic.[24] Our results compare favorably with the CS functions obtained by other trifocal diffractive lens types and even outperform some of the MIOLs both in photopic and the low light, mesopic conditions.[25,26]

Compared with the 1-year follow-up, where 44% reported mild to moderate symptoms of glare and 60% reported halos, the percentage of patients reporting positive dysphotopsia at 5-year follow-up was reduced to 37% for glare perception and 11% for halos.[8] These results are in line with the concept of neuroadaptation, which diminishes the patients' ability to notice or to be bothered by these photic phenomena. The results obtained by ray-tracing simulations demonstrate that the amount and intensity of the out-of-focus light at both near and far distances were reduced (Figure 7). We assume

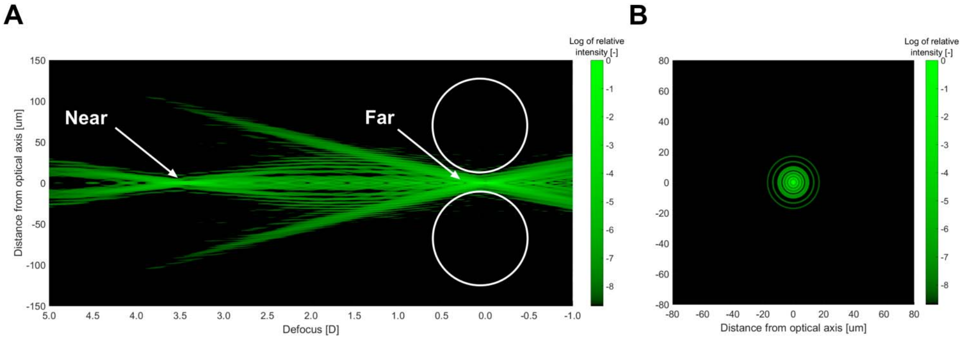

Figure 7. *A*: Optical bench simulation of a through-focus point-spread function. Simulated data acquired with a custom made. The longitudinal section of the irradiance distribution near the focus spots. *B*: Optical bench simulation of a through-focus point-spread function.

that by minimizing the amount of out-of-focus light, the diffractive design of the Liberty 677MY IOL was associated with small halo diameter, which would not be perceived or found bothersome by the patients.

In our cohort, at 5 years, the Liberty trifocal IOL conferred complete spectacle independence for almost the whole group enrolled in the study except 3 patients (8%). One of these patients had a residual refractive error of SE = 1.5 D, while the other 2 reported occasional need for spectacles while performing some activities requiring good far or intermediate vision. Three of the 41 patients (7.3%) at 5-year follow-up went on to develop age-related macular degeneration. Each patient had been informed preoperatively, that future comorbidities like age-related macular degeneration might compromise their visual outcomes achieved after cataract surgery. Finally, patients were asked to rate their satisfaction with vision on a scale of zero to 10. Five years postoperatively, 70% of patients reported that they were highly satisfied with their postoperative functional vision. Nine patients (24%) were moderately satisfied, while 2 patients (5%) were less satisfied. Our data, based on prospective, 5-year follow-up clinical study, provide evidence regarding the refractive stability and trifocal performance of Liberty 677MY. The lens confers good CS and maintains CS. Spectacle independency was achieved at most of the patients; dysphotopic phenomena were rarely reported and easy to tolerate.

WHAT WAS KNOWN

- Trifocal lenses provide good functional distance, intermediate, and near vision, thereby providing greater spectacle independence. There are different types and designs of trifocal lenses available in the market.
- A new design of a hydrophilic diffractive–refractive trifocal IOL with centralized diffractive rings seems to provide good functional vision across all distances at 2-year follow-up.

WHAT THIS PAPER ADDS

- A new design of a hydrophilic diffractive–refractive trifocal IOL provides good functional vision across all distances at 5-year follow-up.
- The centralized apodized diffractive rings seem to reduce patient symptoms of postoperative glare and halos while providing high level of patient satisfaction at 5-year follow-up.

REFERENCES

1. Market scope. 2020 IOL Market Report: A Global Analysis for 2019 to 2025. 2020. Available at: https://www.market-scope.com/pages/reports/181/2020-iol-market-report#reports. Accessed January 6, 2021
2. Busbee BG, Brown MM, Brown GC, Sharma S. Incremental cost-effectiveness of initial cataract surgery. Ophthalmology 2002;109:606–613
3. Busbee BG, Brown MM, Brown GC, Sharma S. Cost-utility analysis of cataract surgery in the second eye. Ophthalmology 2003;110:2310–2317
4. Monestam E. Long-term outcomes of cataract surgery: 15-year results of a prospective study. J Cataract Refract Surg 2016;42:19–26
5. Mönestam E. Long-term outcome of cataract surgery: 20-year results from a population-based prospective study. J Cataract Refract Surg 2019;45:1732–1737
6. De Silva SR, Evans JR, Kirthi V, Ziaei M, Leyland M. Multifocal versus monofocal intraocular lenses after cataract extraction. Cochrane Database Syst Rev 2016;12:CD003169
7. Cao K, Friedman DS, Jin S, Yusufu M, Zhang J, Wang J, Hou S, Zhu G, Wang B, Xiong Y, Li J, Li X, He H, Chai L, Wan XH. Multifocal versus monofocal intraocular lenses for age-related cataract patients: a system review and meta-analysis based on randomized controlled trials. Surv Ophthalmol 2019;64:647–658
8. Gyory JF, Madár E, Srinivasan S. Implantation of a diffractive-refractive trifocal intraocular lens with centralized diffractive rings: two-year results. J Cataract Refract Surg 2019;45:639–646
9. Van Den Berg TJ, Van Rijn LJ, Michael R, Heine C, Coeckelbergh T, Nischler C, Wilhelm H, Grabner G, Emesz M, Barraquer RI, Coppens JE, Franssen L. Straylight effects with aging and lens extraction. Am J Ophthalmol 2007;144:358–363
10. Klein R, Lee KE, Gagnon RE, Klein BEK. Incidence of visual impairment over a 20-year period: the Beaver Dam study. Ophthalmology 2013;120:1210–1219
11. Mönestam EI, Lundqvist B. Extended long-term outcomes of cataract surgery. Acta Ophthalmol 2012;90:651–656
12. Mendicute J, Kapp A, Lévy P, Krommes G, Arias-Puente A, Tomalla M, Barraquer E, Rozot P, Bouchut P. Evaluation of visual outcomes and patient satisfaction after implantation of a diffractive trifocal intraocular lens. J Cataract Refract Surg 2016;42:203–210
13. Bilbao-Calabuig R, Llovet-Rausell A, Ortega-Usobiaga J, Martínez-DelPozo M, Mayordomo-Cerda F, Segura-Albentosa C, Baviera J, Llovet- Osuna F. Visual outcomes following bilateral implantation of two diffractive trifocal intraocular lenses in 10 084 eyes. Am J Ophthalmol 2017;179:55–66
14. Kim M, Kim JH, Lim TH, Cho BJ. Comparison of reading speed after bilateral bifocal and trifocal intraocular lens implantation. Korean J Ophthalmol 2018;32:77–82
15. Lee S, Choi M, Xu Z, Zhao Z, Alexander E, Liu Y. Optical bench performance of a novel trifocal intraocular lens compared with a multifocal intraocular lens. Clin Ophthalmol 2016;10:1031–1038
16. Kohnen T, Titke C, Böhm M. Trifocal intraocular lens implantation to treat visual demands in various distances following lens removal. Am J Ophthalmol 2016;161:71–e1
17. Jonker SMR, Bauer NJC, Makhotkina NY, Berendschot TTJM, van den Biggelaar FJHM, Nuijts RMMA. Comparison of a trifocal intraocular lens with a + 3.0 D bifocal IOL: results of a prospective randomized clinical trial. J Cataract Refract Surg 2015; 41:1631–1640; erratum. J Cataract Refract Surg 2017;43:148–150
18. Ribeiro F, Ferreira TB. Comparison of clinical outcomes of 3 trifocal IOLs. J Cataract Refract Surg 2020;46:1247–1252
19. Fernández J, Rodríguez-Vallejo M, Martínez J, Tauste A, Piñero DP. Standard clinical outcomes with a new low addition trifocal intraocular lens. J Refract Surg 2019;35:214–221
20. Oliveira RF, Vargas V, Plaza-Puche AB, Alió JL. Long-term results of a diffractive trifocal intraocular lens: visual, aberrometric and patient satisfaction results. Eur J Ophthalmol 2020;30:201–208
21. Reinstein DZ, Archer TJ, Srinivasan S, Mamalis N, Kohnen T, Dupps WJ Jr, Randleman JB. Standard for reporting refractive outcomes of intraocular lens–based refractive surgery [editorial]. J Cataract Refract Surg 2017;3:435–439
22. Bianchi GR. Spectacle independence after cataract surgery: a prospective study with a multifocal intraocular lens. Med Hypothesis Discov Innov Ophthalmol 2020;9:38–46
23. Mesci C, Erbil HH, Olgun A, Aydin N, Candemir B, Akçakaya AA. Differences in contrast sensitivity between monofocal, multifocal and accommodating intraocular lenses: long-term results. Clin Exp Ophthalmol 2010;38:768–777
24. Montes-Mico R, España E, Bueno I, Charman WN, Menezo JL. Visual performance with multifocal intraocular lenses:mesopic contrast sensitivity under distance and near conditions. Ophthalmology 2004;111:85–96
25. Dexl AK, Zaluski S, Rasp M, Grabner G. Visual performance after bilateral implantation of a new diffractive aspheric multifocal intraocular lens with a 3.5 D addition. Eur J Ophthalmol 2014;24:35–43
26. Mencucci R, Favuzza E, Caporossi O, Rizzo S. Visual performance, reading ability and patient satisfaction after implantation of a diffractive trifocal intraocular lens. Clin Ophthalmol 2017;11:1987–1993

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