Comparative Analysis of the Visual Performance After Cataract Surgery With Implantation of a Bifocal or Trifocal Diffractive IOL

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ABSTRACT

PURPOSE: To evaluate and compare the visual, refractive, contrast sensitivity, and aberrometric outcomes with a diffractive bifocal and trifocal intraocular lens (IOL) of the same material and haptic design.

METHODS: Sixty eyes of 30 patients undergoing bilateral cataract surgery were enrolled and randomly assigned to one of two groups: the bifocal group, including 30 eyes implanted with the bifocal diffractive IOL AT LISA 801 (Carl Zeiss Meditec, Jena, Germany), and the trifocal group, including eyes implanted with the trifocal diffractive IOL AT LISA tri 839 MP (Carl Zeiss Meditec). Analysis of visual and refractive outcomes, contrast sensitivity, ocular aberrations (OPD-Scan III; Nidek, Inc., Gagamori, Japan), and defocus curve were performed during a 3-month follow-up period.

RESULTS: No statistically significant differences between groups were found in 3-month postoperative uncorrected and corrected distance visual acuity ($P \geq .21$). However, uncorrected, corrected, and distance-corrected near and intermediate visual acuities were significantly better in the trifocal group ($P < .01$). No significant differences between groups were found in postoperative spherical equivalent ($P = .22$). In the binocular defocus curve, the visual acuity was significantly better for defocus of -0.50 to -1.50 diopters in the trifocal group ($P \leq .04$) and -3.50 to -4.00 diopters in the bifocal group ($P \leq .03$). No statistically significant differences were found between groups in most of the postoperative corneal, internal, and ocular aberrations ($P \geq .31$), and in contrast sensitivity for most frequencies analyzed ($P \geq .15$).

CONCLUSIONS: Trifocal diffractive IOLs provide significantly better intermediate vision over bifocal IOLs, with equivalent postoperative levels of visual and ocular optical quality.

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Multifocal diffractive intraocular lenses (IOLs) use a platform based on scattered waves that interfere constructively if they are in phase and destructively if they are out of phase.[1] With this type of IOL platform, light can be distributed to different foci by assigning appropriate dimensions to the diffractive pattern on the lens surface.[1] Until recently, the optics of diffractive multifocal IOLs consisted of concentric rings that formed two primary focal points providing functional distance and near vision.[2-6] However, a limitation of the visual function at intermediate distance has been shown to be a potential inconvenience of these bifocal diffractive IOLs.[5-7] For this reason, a new concept of IOL based on 100% diffractive technology, providing three useful focal distances (far, intermediate, and near), was recently developed: the trifocal diffractive IOL.[8-10] The initial in vivo outcomes with some trifocal IOLs confirms that functional far, intermediate, and near vision can be achieved with this technology.[8,11-14] However, there is no comparative study to date of the visual performance achieved with a bifocal and trifocal diffractive IOL to confirm whether the potential limitations of the bifocal design are overcome with diffractive trifocality. The current study aimed to evaluate and compare the visual, refractive, contrast sensitivity, and aberrometric outcomes with a diffractive bifocal and trifocal IOL of the same material and haptic design.

PATIENTS AND METHODS

PATIENTS

In this prospective comparative study, 60 eyes of 30 patients were enrolled. Each eye was randomly assigned to one

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type of implant (bifocal or trifocal). Accordingly, two groups of 30 eyes of 15 patients were differentiated: the bifocal group, including eyes implanted with the bifocal diffractive IOL with C-loop haptics AT LISA 801 (Carl Zeiss Meditec, Jena, Germany), and the trifocal group, including eyes implanted with the trifocal diffractive plate-haptic IOL AT LISA tri 839 MP (Carl Zeiss Meditec). The same type of IOL was implanted in both eyes of each patient (bilateral implantation). Inclusion criteria were patients with cataract or presbyopia/pre-presbyopia suitable for refractive lens exchange seeking spectacle independence. Exclusion criteria were patients with a history of glaucoma or retinal detachment, corneal disease, irregular corneal astigmatism, abnormal iris, macular degeneration or retinopathy, neuro-ophthalmic disease, ocular inflammation, or previous ocular surgery.

Examination Protocol

Before surgery, a complete ophthalmological examination was performed, including refraction, keratometry, uncorrected (UDVA) and corrected distance visual acuity (CDVA) (Early Treatment Diabetic Retinopathy Study [ETDRS] charts), uncorrected (UIVA) and corrected intermediate visual acuity (CIVA) at 66 cm (Modified ETDRS for European-wide use for near and intermediate distance recordings; Precision Vision, La Salle, IL) and 80 cm (Logaritmic Visual Acuity Charts, calibrated for testing at 80 cm; Precision Vision), uncorrected (UNVA) and corrected near visual acuity (CNVA) at 33 cm (Modified ETDRS for European-wide use for near and intermediate distance recordings; Precision Vision) and 40 cm (Logaritmic Visual Acuity Chart–ETDRS 2000, calibrated for testing at 40 cm; Precision Vision), distance-corrected near (DCNVA) (33 and 40 cm) and intermediate visual acuity (DCIVA) (66 and 80 cm), Goldmann applanation tonometry, slit-lamp examination, ocular aberrometry (OPD-Scan III; Nidek, Inc., Gagamori, Japan), corneal topography (OPD-Scan III; Nidek, Inc.), biometry (IOLMaster, version 4.3; Carl Zeiss Meditec), and funduscopy. The analysis of optical aberrations was performed under pupil dilation and considered a pupil aperture of analysis of 5.0 mm. The following parameters were calculated and recorded for the corneal, internal, and ocular optics: trefoil (Z^3_{-3}, Z^3_3), coma (Z^3_{-1}, Z^3_1), and tetrafoil (Z^4_{-4}, Z^4_4) root mean square (RMS), and the Zernike coefficient for spherical aberration (Z^0_4).

In all cases, the SRK-T formula was used for the calculation of the IOL power to implant according to the measurements of corneal power, axial length, and anterior chamber depth obtained with the IOLMaster. Target refraction was emmetropia in all cases.

The postoperative examination protocol at 3 months was identical to the preoperative protocol, with the additional evaluation of the contrast sensitivity measurements under photopic conditions (CSV-1000; Vector Vision, Greenville, OH). In addition, defocus curves were also obtained to evaluate the range of functional vision. For this test, the patient wore the correction providing the best distance visual acuity in both eyes and the ETDRS charts were used at a distance of 4 m. Different levels of defocus were introduced in 0.5-diopter (D) steps from +1.00 to -4.00 D, and visual acuity values were then recorded. All of the data were then represented in a Cartesian graphic display, with the x-axis showing the levels of defocus and the y-axis showing the visual acuity achieved.

All patients were informed about the study and signed a consent form. The study adhered to the tenets of the Declaration of Helsinki and was approved by the local ethics committee.

Surgery

All surgeries were performed by the same experienced surgeon (PM) using a standard technique of sutureless micro-coaxial 2.2-mm phacoemulsification in the bifocal group (AT LISA 801) and a technique of microincision (1.6 mm) phacoemulsification in the trifocal group (AT LISA tri 839 MP). All incisions were made at the temporal area. Topical anesthesia and mydriatic drops were instilled in all cases prior to surgery. After capsulorhexis creation and phacoemulsification, the IOLs were inserted into the capsular bag using the AT.Shooter A1-2000 injector (Carl Zeiss Meditec) and Viscoject 2.2 cartridge (Carl Zeiss Meditec) (bifocal group) and BLUEMIXS 180 injector (Carl Zeiss Meditec) (trifocal group) through the main incisions. A postoperative topical therapy based on a combination of topical antibiotic and steroid was prescribed to be applied four times daily for 1 week.

IOLs

The AT LISA 801 (formerly Acri.LISA 376D) is a single-piece C-loop diffractive bifocal IOL with a 6.0-mm biconvex optic, an overall length of 12.5 mm, a posterior surface with asphericity of -0.18, and haptic angulation of 0° (**Figure A**, available in the online version of this article). It is made of a foldable hydrophilic acrylate with a water content of 25% that has hydrophobic surface properties and a refractive index of 1.46. The IOL is available in spherical powers from 0 to 10 D in 1-diopter increments, and from 10 to 30 D in 0.50-diopter increments, although powers from 31 to 40 D in 1-diopter increments can also be obtained by request. This IOL provides a theoretical addition

of +3.75 D at the IOL plane. The company labelled A-constant for this IOL is 118.0.

The AT LISA tri 839 MP is a diffractive trifocal preloaded IOL with a 6.0-mm biconvex optic, an overall length of 11.0 mm, and a posterior surface with asphericity of -0.18 (**Figure A**). It has a four-haptic design with an angulation of 0° and a new 360° square edge to prevent posterior capsule opacification. It is made of foldable hydrophilic acrylate with a water content of 25%, a hydrophobic surface, and a refractive index of 1.46. This IOL is trifocal within an IOL diameter of 4.3 mm, whereas it is bifocal between 4.3 and 6 mm. In the central 4.3-mm diameter, the IOL provides a near addition of +3.33 D and an intermediate addition of +1.66 D, both calculated at the IOL plane. The addition power between the diameters of 4.3 and 6 mm is +3.75 D (bifocal AT LISA model). The IOL is available in spherical powers from 0 to 32 D in 0.5-diopter increments. The company labelled A-constant for this IOL is 118.6.

Statistical Analysis

SPSS software (version 15.0.1; SPSS, Inc., Chicago, IL) was used for statistical analysis. The Kolmogorov–Smirnov test was used to check the normality of the data distribution. When parametric analysis was possible, Student's *t* test for paired data was performed for all parameter comparisons between preoperative and postoperative examinations and between consecutive postoperative visits, whereas Student's *t* test for unpaired data was used for the comparison between the bifocal and trifocal groups. Otherwise, when parametric analysis was not possible, the Wilcoxon signed rank test was applied to assess the significance of differences between examinations, and the Mann–Whitney test was used for the comparison between groups. In all cases, the same level of significance ($P < .05$) was considered.

RESULTS

The study enrolled a total of 60 eyes of 30 patients with ages ranging from 44 to 70 years (mean age: 58.7 years). This sample was divided into two groups of 30 eyes of 15 patients according to the IOL implanted (bifocal or trifocal). **Table A** (available in the online version of this article) shows a comparative analysis of the preoperative data of the two groups of eyes of the current series. No statistically significant differences between groups were found in refraction, mean keratometry, axial length, or anterior chamber depth ($P > .12$). In contrast, IOL power was significantly higher in the trifocal group compared to the bifocal group ($P = .01$). Likewise, the analyzed sample in the trifocal group was significantly younger ($P = .01$).

Visual Acuity and Refractive Outcomes

Table B (available in the online version of this article) summarizes the 3-month postoperative visual acuity and refraction data in the two groups of eyes of the current sample. No statistically significant differences between groups were found in postoperative UDVA ($P = .21$) and CDVA ($P = .37$). In contrast, UNVA, CNVA, and DCNVA measured at 33 and 40 cm were significantly better in the trifocal group compared to the bifocal group ($P < .01$) (**Table B**). Likewise, UIVA, CIVA, and DCIVA measured at 66 cm were also found to be significantly better in the trifocal group compared to the bifocal group ($P \leq .03$) (**Table B**). Regarding intermediate visual acuity measured at 80 cm, significantly better values of UIVA and DCIVA were found in the trifocal group ($P < .01$), but no statistically significant differences were found between the trifocal and bifocal groups in CIVA ($P = .21$) (**Table B**). No significant differences between groups were found in postoperative sphere ($P = .85$) and spherical equivalent ($P = .22$). Furthermore, a small but statistically significant difference was found in postoperative manifest cylinder ($P < .01$), with a larger magnitude of cylinder for the bifocal group.

In the bifocal group, a significant improvement with surgery was observed in UDVA, CDVA, UNVA (33 and 40 cm), DCNVA (33 and 40 cm), UIVA (66 and 80 cm), and DCIVA (80 cm) (all $P < .01$). In contrast, no significant changes were detected in CNVA (33 and 40 cm) ($P = .13$ and .49, respectively), CIVA (66 cm, $P = .31$), DCIVA (66 cm, $P = .07$), sphere ($P = .28$), cylinder ($P = .62$), and spherical equivalent ($P = .27$). In the trifocal group, UDVA, UNVA (33 and 40 cm), DCNVA (33 and 40 cm), CNVA (40 cm), UIVA (66 and 80 cm), CIVA (66 cm), and DCIVA (66 and 80 cm) were found to improve significantly 3 months after surgery. No significant changes with surgery were detected in CDVA ($P = .38$), CNVA (33 cm, $P = .12$), and CIVA (80 cm, $P = .09$). Likewise, a significant reduction was found in sphere ($P = .01$) and spherical equivalent ($P = .02$). The change in manifest cylinder in this group was in the limit of statistical significance ($P = .05$).

Defocus Curve

Figure 1 shows the mean defocus curves obtained in the two groups of eyes of the current study. Significant differences between groups were obtained in the visual acuities corresponding to levels of defocus simulating the intermediate vision. Specifically, the visual acuity was significantly better in the trifocal group compared to the bifocal group for the defocus levels of -0.50 ($P = .01$), -1.00 ($P < .01$), and -1.50 D ($P = .04$) (**Figure 1**). In contrast, the visual acuity for

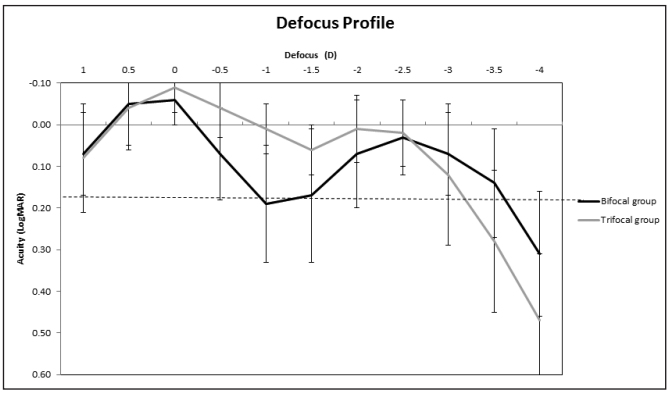

Figure 1. Mean defocus curve in the bifocal (black line) and trifocal (gray line) groups.

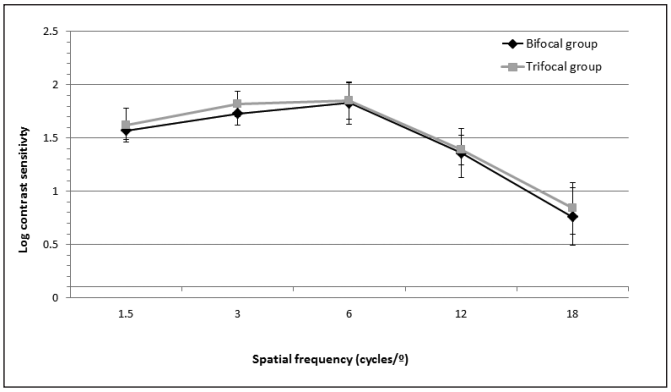

Figure 2. Mean contrast sensitivity function in the bifocal (black line) and trifocal (gray line) groups.

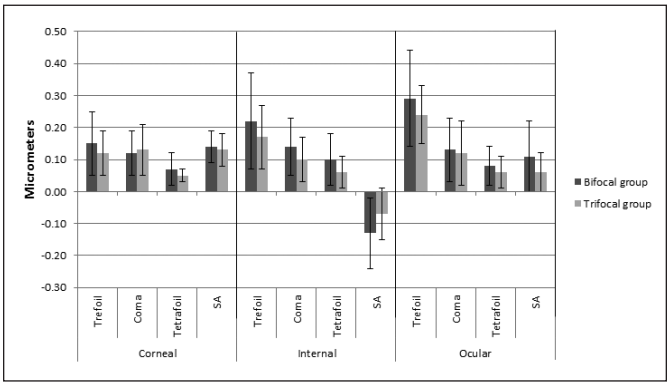

Figure 3. Distribution of preoperative ocular, corneal, and internal aberrometric data in the bifocal (dark gray bars) and trifocal (light gray bars) groups.

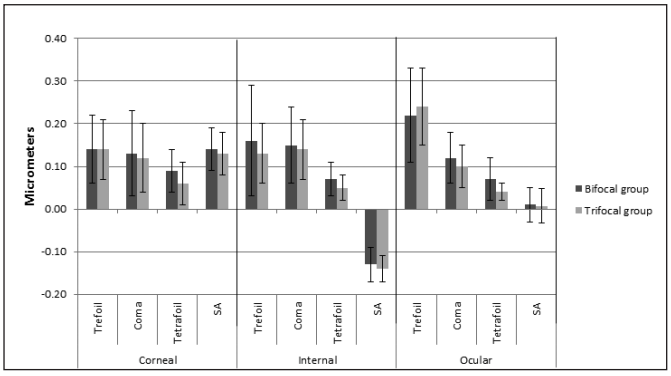

Figure 4. Distribution of postoperative ocular, corneal, and internal aberrometric data in the bifocal (dark gray bars) and trifocal (light gray bars) groups.

the defocus of -3.50 (P = .03) and -4.00 D (P = .01) was significantly better in the bifocal group compared to the trifocal group.

Contrast Sensitivity Outcomes

Figure 2 shows the mean contrast sensitivity function obtained in the two groups of eyes in the current study. No statistically significant differences in contrast sensitivity were found between groups for 1.5 (P = .21), 6 (P = .63), 12 (P = .50), and 18 (P = .15) cycles per degree. However, a significantly higher level of contrast sensitivity was found for 3 cycles per degree in the trifocal group compared to the bifocal group (P = .01).

Aberrometric Outcomes

Figures 3-4 display the preoperative and 3-month postoperative aberrometric data for corneal, internal, and global ocular optics in the two groups of eyes of the current study. Preoperatively, no statistically significant differences in any corneal, internal, and ocular aberrometric term were found ($P \geq .063$), except for internal spherical aberration Zernike term (P = .03) and RMS for ocular tetrafoil (P = .040) (**Figure 3**). Specifically, the magnitude of these two aberrometric parameters was significantly higher in the bifocal group. Postoperatively, no statistically significant differences in any corneal, internal, and ocular aberrometric term were found ($P \geq .31$), except for the RMS for ocular (P = .01) and corneal tetrafoil (P = .03) that was significantly higher in the bifocal group compared to the trifocal group (**Figure 4**).

DISCUSSION

In the current study, two groups of eyes implanted with a diffractive multifocal IOL (one with a bifocal and the other with a trifocal IOL) were compared. Preoperatively, both groups were comparable in terms of refraction, mean keratometry, axial length, or anterior chamber depth. However, a significant difference of approximately 2 D on average in IOL power was present between groups. Despite this difference, excellent distance and near visual outcomes were obtained in both groups after surgery, with a significant improvement in UDVA, UIVA, and UNVA in both groups. The level achieved in postoperative UDVA in the bifocal

and trifocal groups was of the same magnitude or better than the outcomes reported by previous studies with other models of diffractive bifocal and trifocal IOLs (**Table 1**).[2,4-8,11,12,14] Regarding UNVA, our results with the bifocal IOL were of the same magnitude as those reported in previous series,[2] but slightly worse than those reported by other studies using the same models of multifocal IOLs.[4-8,14] The variability between studies in terms of sample size, clinical protocol to obtain the visual acuity measurements, postoperative follow-up, or patient's features may play a major role in the discrepancies among studies. Indeed, previous comparative studies evaluating some bifocal diffractive IOLs have not found significant differences in distance and near visual outcomes between different IOL models.[4,7] Comparing the bifocal and trifocal groups of the current series, no significant differences were found in UDVA and CDVA, which confirms that the generation of a third focal point with the trifocal diffractive IOL evaluated did not result in a detriment of the distance focal point. In contrast, UNVA measured at 33 and 40 cm was significantly better in the trifocal group from our series compared to the bifocal group. Considering that no significant differences were present between groups in spherical equivalent refraction, the IOL optical behavior seems to be the main factor for this finding. Indeed, the CNVA measured at 33 and 40 cm was found to also be significantly better in the trifocal group compared to the bifocal group. Therefore, the visual performance achieved at 33 to 40 cm with the trifocal IOL evaluated was significantly better than that achieved with the bifocal diffractive IOL of the same manufacturer.

As expected, the intermediate vision was significantly better in our series with the trifocal IOL, with similar UIVA and CIVA to those reported for another model of trifocal IOL [11,12] and even for the same model of trifocal IOL.[14] In any case, a significant improvement in UIVA measured at 66 and 80 cm was found after surgery with the implantation of both bifocal and trifocal IOLs. Therefore, the trifocal IOL evaluated has a clear advantage over the bifocal IOL because a better intermediate and even near visual acuity can be obtained. Furthermore, the UIVA and CIVA outcomes obtained with the trifocal IOL evaluated in the current study are also better than those reported by previous studies for other modalities of bifocal IOLs (**Table 1**).[4-7] This is the first study to date comparing clinically the visual outcomes obtained with a bifocal and a trifocal IOL, and then showing the realistic benefit of the recently developed trifocal IOL technology. Recently, Gatinel and Houbrechts[15] evaluated the differences in optical performance of nine multifocal IOLs, including one trifocal (FineVision; PhysIOL, Liège, Belgium) and several bifocal IOLs (one of them the AT LISA bifocal), using the same optical bench. In agreement with our clinical outcomes, these studies found that intermediate vision was more prominent with the trifocal IOL compared to the bifocal IOLs.[15]

The superiority of the trifocal IOL over the bifocal IOL in terms of visual outcome was also found in the analysis of the binocular defocus curve, which confirms the achievement of significantly better levels of binocular distance-corrected visual acuity with the trifocal IOL for different levels of defocus simulating the range of intermediate vision. However, in contrast to the monocular outcomes, no significant differences between bifocal and trifocal IOLs were found in binocular distance and near visual acuity. Only significantly better binocular DCNVA was obtained with the bifocal IOL compared to the trifocal IOL for levels of defocus simulating reading and work distances close to the eye. Therefore, the bifocal IOL provides a better distance-corrected vision than the trifocal IOL at near distances closest to the eye (approximately 30 to 25 cm).

Contrast sensitivity and ocular higher-order aberrations were also evaluated and compared between groups in the current study to see the potential effect of trifocality on the visual and ocular optical quality. Equivalent levels of contrast sensitivity with both types of IOLs were obtained and no significantly different levels in most ocular and intraocular higher-order aberrations. Only significantly higher levels of tetrafoil were observed in the bifocal groups that were consistent with the significantly higher levels of corneal tetrafoil that were present postoperatively and even preoperatively. Therefore, the generation of a third focal point does not seem to be associated with a decrease of the postoperative ocular optical quality. Indeed, the values obtained are comparable or even better than those reported by previous studies evaluating different multifocal IOLs with different wavefront sensors.[16] The aberrometric analysis shown in the current study should be considered with caution because the accuracy of wavefront aberration measurements has been demonstrated to be limited in some eyes implanted with diffractive bifocal and multifocal IOLs.[17] Indeed, a more significant aberrometric component may be expected with the evaluated IOL due to its diffractive component. More studies evaluating the ocular aberrations after implantation of diffractive bifocal and trifocal IOLs should be performed using other devices for their characterization.

Because of potential limitations of the study, it should be mentioned that an intraindividual comparison may have been a better design for our study, which

TABLE 1

Comparison of Monocular Outcomes of the Current Study to Those Obtained by Previous Studies With Other Modalities of Multifocal IOLs

Study (y)	Eyes	AL (mm) (SD)	IOL (Follow-up)	logMAR UDVA (SD)	logMAR CDVA (SD)	logMAR UNVA (SD)	logMAR CNVA (SD)	logMAR UIVA (SD)	logMAR CIVA (SD)
Alfonso et al. (2007)[5]	162	25.01 ± 3.05	Acri.LISA 366D (3 months)	0.225 ± 0.234	0.102 ± 0.191	0.048 ± 0.150; 33 cm	0.031 ± 0.125; 33 cm	–	0.265 ± 0.099; Binocular 70 cm
Alfonso et al. (2007)[6]	650 670	–	ReSTOR SA60D3, ReSTOR SN60D3 (6 months)	0.095 ± 0.016; 0.122 ± 0.038	0.054 ± 0.005; 0.039 ± 0.006	0.015 ± 0.011; 0.057 ± 0.010; 33cm	0.014 ± 0.013; 0.049 ± 0.011; 33 cm	–	0.352 ± 0.040; 0.401 ± 0.042; Binocular 70 cm
Alfonso et al. (2009)[4]	36 40	24.36 ± 2.71; 23.54 ± 0.98	ReSTOR SN6AD3, Acri.LISA 366D (6 months)	0.02 ± 0.13; 0.01 ± 0.18, Binocular	-0.05 ± 0.09; -0.08 ± 0.08, Binocular	-0.04 ± 0.18; -0.05 ± 0.07; Binocular 40 cm	-0.01 ± 0.06; -0.05 ± 0.07; Binocular 40 cm	0.21 ± 0.14; 0.19 ± 0.14; Binocular 60 cm	0.16 ± 0.16; 0.18 ± 0.13; Binocular 60 cm
Alfonso et al. (2010)[7]	20 20 20 20	24.21 ± 2.56; 24.36 ± 2.71; 23.81 ± 1.79; 23.54 ± 0.98	ReSTOR SN60D3, ReSTOR SN6AD3, ReSTOR SN6AD1, Acri.LISA 366D (6 months)	–	-0.04 ± 0.10; -0.08 ± 0.10; -0.06 ± 0.05; -0.08 ± 0.04, Binocular	–	0.03 ± 0.05; -0.05 ± 0.06; 0.03 ± 0.05; -0.02 ± 0.08; Binocular 40 cm	–	0.38 ± 0.14; 0.14 ± 0.17; 0.02 ± 0.13; 0.15 ± 0.15; Binocular 60 cm
Voskresenskaya et al. (2010)[8]	36	–	MIOL-Record (6 months)	0.74 ± 0.21, decimal	0.86 ± 0.23, decimal	0.85 ± 0.13; decimal; Patient preferred distance	0.89 ± 0.12; decimal; Patient preferred distance	0.58 ± 0.16; decimal; 50 cm	0.60 ± 0.20; decimal; 50 cm
Alió et al. (2011)[2]	48	22.83 ± 1.18	Acri.LISA 366D (6 months)	0.12 ± 0.16	0.03 ± 0.09	0.16 ± 0.13; 40 cm	0.13 ± 0.13; 40 cm	–	–
Cochener et al. (2012)[12]	94	23.13 ± 1.17	FineVision (6 months)	0.08 ± 0.12	0.03 ± 0.16	0.01 ± 0.06; 35 cm	0.00 ± 0.05; 35 cm	0.08 ± 0.12; 65 cm	0.08 ± 0.10; 65 cm
Sheppard et al. (2013)[11]	30	–	FineVision (2 months)	0.19 ± 0.09	0.08 ± 0.08	–	–	–	–
Mojzis et al. (2014)[14]	60	–	AT LISA tri 839 MP (6 months)	-0.03 ± 0.09	-0.05 ± 0.08	0.20 ± 0.12; 33 cm	0.13 ± 0.10; 33 cm	0.08 ± 0.10; 66 cm	0.06 ± 0.11; 66 cm
Current study (2014)	30 30	23.26 ± 1.29; 23.21 ± 0.90	AT LISA 801, AT LISA tri 839 MP (3 months)	0.00 ± 0.13; -0.05 ± 0.08	-0.03 ± 0.11;- 0.06 ± 0.07	0.21 ± 0.12; 0.07 ± 0.09; 33 cm	0.16 ± 0.11; 0.06 ± 0.07; 33 cm	0.29 ± 0.18; 0.06 ± 0.07; 66 cm	0.10 ± 0.11; 0.05 ± 0.05; 66 cm

AL = axial length; SD = standard deviation; IOL = intraocular lens; UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; UNVA = uncorrected near visual acuity; CNVA = corrected near visual acuity; UIVA = uncorrected intermediate visual acuity; CIVA = corrected intermediate visual acuity
The Acri.LISA 366D, AT LISA tri 839 MP, and AT LISA 801 are manufactured by Carl Zeiss Meditec, Jena, Germany. The ReSTOR SA60D3, SN6AD3, and SN6AD1 are manufactured by (Alcon Laboratories, Inc., Fort Worth, TX). The MIOL-Record is manufactured by (Reper-NN, Nizhegorodskaya, Russia). The FineVision is manufactured by PhysIOL, Liège, Belgium.

would have increased the statistical power and relevance of the conclusions of the study. Likewise, the relevance of the comparison may have been increased if the bifocal plate-haptic IOL AT LISA with the same IOL body design and injection protocol had been used. These limitations must be considered for the design of future comparative studies evaluating bifocal and trifocal IOLs.

Trifocal diffractive IOL technology is able to provide an effective distance, intermediate, and near visual restoration after cataract surgery with postoperative levels of visual and ocular optical quality equivalent to those that can be obtained with the bifocal diffractive IOL technology. Therefore, the trifocal IOL seems to be a better option over the bifocal diffractive IOL in terms of visual outcome. The generation of a third focal point with a diffractive trifocal design does not imply a detriment in the distance and near visual acuity or in the visual and ocular optical quality.

AUTHOR CONTRIBUTIONS

Study concept and design (PM, DPP); data collection (PM, LK, KM, KL); analysis and interpretation of data (DPP); drafting of the manuscript (DPP); critical revision of the manuscript (PM, LK, KM, KL); statistical expertise (DPP); administrative, technical, or material support (PM, LK, KM, KL); supervision (PM, LK, KM, KL)

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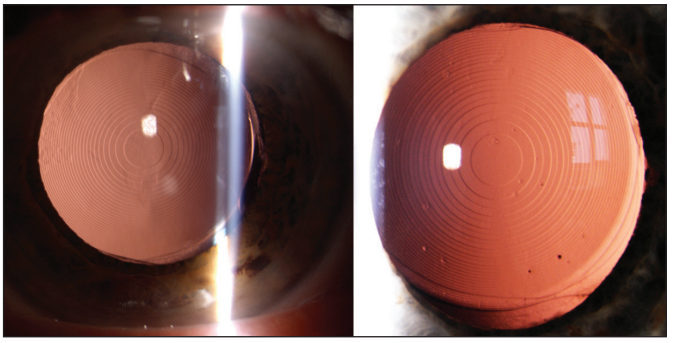

Figure A. Intraocular lenses used in the study: (A) the bifocal diffractive IOL AT LISA 801 (Carl Zeiss Meditec, Jena, Germany) and (B) the trifocal diffractive IOL AT LISA tri 839 MP (Carl Zeiss Meditec).

TABLE A

Preoperative Clinical Data of Eyes Included in the Two Groups[a]

Parameter	Bifocal Group	Trifocal Group	*P*
Age (y) (SD) Median (range)	62.3 ± 5.7 64.0 (range: 45.0 to 70.0)	55.2 ± 7.0 55.0 (range: 44.0 to 67.0)	.01[b]
logMAR UDVA (SD) Median (range)	0.61 ± 0.38 0.60 (range: 0.10 to 1.50)	0.53 ± 0.39 0.40 (range: 0.00 to 1.30)	.40[c]
logMAR CDVA (SD) Median (range)	0.21 ± 0.33 0.10 (range: -0.20 to 1.00)	-0.01 ± 0.21 -0.10 (range: -0.20 to 1.00)	< .01[c]
logMAR UNVA (33 cm) (SD) Median (range)	0.75 ± 0.33 0.75 (range: 0.30 to 1.40)	0.80 ± 0.21 0.85 (range: 0.20 to 1.20)	.46[c]
logMAR CNVA (33 cm) (SD) Median (range)	0.25 ± 0.28 0.20 (range: -0.20 to 1.10)	0.05 ± 0.17 0.00 (range: -0.20 to 0.80)	< .01[c]
logMAR DCNVA (33 cm) (SD) Median (range)	0.64 ± 0.26 0.65 (range: 0.10 to 1.40)	0.56 ± 0.21 0.55 (range: 0.20 to 1.10)	.12[c]
logMAR UNVA (40 cm) (SD) Median (range)	0.78 ± 0.36 0.70 (range: 0.30 to 1.50)	0.78 ± 0.25 0.80 (range: 0.00 to 1.10)	.97[b]
logMAR CNVA (40 cm) (SD) Median (range)	0.28 ± 0.33 0.20 (range: 0.00 to 1.50)	0.05 ± 0.11 0.00 (range: -0.10 to 0.40)	< .01[c]
logMAR DCNVA (40 cm) (SD) Median (range)	0.63 ± 0.30 0.60 (range: 0.10 to 1.50)	0.53 ± 0.21 0.55 (range: 0.00 to 0.90)	.21[c]
logMAR UIVA (66 cm) (SD) Median (range)	0.63 ±0.36 0.60 (range: 0.00 to 1.50)	0.68 ± 0.32 0.70 (range: 0.20 to 1.30)	.52[b]
logMAR CIVA (66 cm) (SD) Median (range)	0.17 ± 0.29 0.10 (range: -0.20 to 1.13)	-0.01 ± 0.19 -0.10 (range: -0.20 to 0.80)	< .01[c]
logMAR DCIVA (66 cm) (SD) Median (range)	0.41 ± 0.29 0.30 (range: 0.00 to 1.40)	0.26 ± 0.23 0.30 (range: -0.10 to 0.90)	.03[c]
logMAR UIVA (80 cm) (SD) Median (range)	0.61 ± 0.34 0.65 (range: 0.10 to 1.20)	0.62 ± 0.29 0.60 (range: 0.10 to 1.10)	.90[b]
logMAR CIVA (80 cm) (SD) Median (range)	0.19 ± 0.29 0.10 (range: -0.10 to 1.10)	0.01 ± 0.17 0.00 (range: -0.20 to 0.80)	< .01[c]
logMAR DCIVA (80 cm) (SD) Median (range)	0.39 ± 0.26 0.40 (range: 0.00 to 1.10)	0.18 ± 0.21 0.20 (range: -0.10 to 1.00)	< .01[c]
Sphere (D) (SD) Median (range)	0.34 ± 3.39 0.75 (range: -7.25 to 9.00)	0.81 ± 2.27 1.38 (range: -5.50 to 3.25)	.11[c]
Cylinder (D) (SD) Median (range)	-0.54 ± 0.59 -0.50 (range: -2.25 to 0.00)	-0.32 ± 0.33 -0.25 (range: -1.50 to 0.00)	.12[c]
Spherical equivalent (D) (SD) Median (range)	0.11 ± 3.37 0.50 (range: -7.25 to 8.13)	0.68 ± 2.28 1.31 (range: -5.50 to 3.13)	.14[c]
Mean keratometry (D) (SD) Median (range)	43.62 ± 1.84 43.34 (range: 40.59 to 47.64)	43.27 ± 1.52 43.01 (range: 40.53 to 46.88)	.42[b]
Corneal astigmatism (D) (SD) Median (range)	0.60 ± 0.32 0.55 (range: 0.18 to 1.29)	0.71 ± 0.25 0.72 (range: 0.34 to 1.37)	.14[b]
Axial length (mm) (SD) Median (range)	23.26 ± 1.29 23.37 (range: 19.23 to 25.31)	23.21 ± 0.90 23.18 (range: 21.83 to 25.25)	.56[c]
Anterior chamber depth (mm) (SD) Median (range)	3.33 ± 0.31 3.37 (range: 2.67 to 3.85)	3.23 ± 0.34 3.22 (range: 2.55 to 4.05)	.24[b]
Intraocular lens power (D) (SD) Median (range)	20.83 ± 4.09 20.50 (range: 12.50 to 33.00)	22.25 ± 3.79 22.25 (range: 11.50 to 27.00)	.01[c]

SD = standard deviation; UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; UNVA = uncorrected near visual acuity; CNVA = corrected near visual acuity; DCNVA = distance-corrected near visual acuity; UIVA = uncorrected intermediate visual acuity; CIVA = corrected intermediate visual acuity; DCIVA = distance-corrected intermediate visual acuity; D = diopters

[a]*The corresponding* P *values for the comparison between groups are shown for each parameter evaluated.*

[b]*Unpaired Student's* t *test.*

[c]*Wilcoxon test.*

TABLE B

3-Month Postoperative Clinical Data of Eyes Included in the Two Groups[a]

Parameters	Bifocal Group	Trifocal Group	*P*
logMAR UDVA (SD) Median (range)	0.00 ± 0.13 0.00 (range: -0.10 to 0.40)	-0.05 ± 0.08 -0.10 (range: -0.20 to 0.10)	.21[b]
logMAR CDVA (SD) Median (range)	-0.03 ± 0.11 0.00 (range: -0.20 to 0.40)	-0.06 ± 0.07 -0.10 (range: -0.20 to 0.10)	.37[b]
logMAR UNVA (33 cm) (SD) Median (range)	0.21 ± 0.12 0.20 (range: 0.00 to 0.60)	0.07 ± 0.09 0.10 (range: -0.10 to 0.40)	< .01[b]
logMAR CNVA (33 cm) (SD) Median (range)	0.16 ± 0.11 0.10 (range: -0.10 to 0.40)	0.06 ± 0.07 0.10 (range: -0.10 to 0.20)	< .01[b]
logMAR DCNVA (33 cm) (SD) Median (range)	0.21 ± 0.13 0.20 (range: 0.00 to 0.60)	0.07 ± 0.09 0.10 (range: -0.10 to 0.40)	< .01[b]
logMAR UNVA (40 cm) (SD) Median (range)	0.30 ± 0.15 0.30 (range: 0.10 to 0.60)	0.15 ± 0.09 0.10 (range: 0.00 to 0.40)	< .01[b]
logMAR CNVA (40 cm) (SD) Median (range)	0.27 ± 0.12 0.30 (range: 0.10 to 0.50)	0.12 ± 0.07 0.10 (range: 0.00 to 0.30)	<.01[b]
logMAR DCNVA (40 cm) (SD) Median (range)	0.32 ± 0.16 0.30 (range: 0.10 to 0.70)	0.14 ± 0.10 0.10 (range: 0.00 to 0.40)	< .01[b]
logMAR UIVA (66 cm) (SD) Median (range)	0.29 ± 0.18 0.30 (range: -0.10 to 0.60)	0.06 ± 0.07 0.05 (range: 0.00 to 0.30)	< .01[b]
logMAR CIVA (66 cm) (SD) Median (range)	0.10 ± 0.11 0.10 (range: -0.10 to 0.40)	0.05 ± 0.05 0.00 (range: 0.00 to 0.10)	.03[b]
logMAR DCIVA (66 cm) (SD) Median (range)	0.30 ± 0.17 0.30 (range: 0.00 to 0.60)	0.06 ± 0.07 0.05 (range: 0.00 to 0.30)	< .01[b]
logMAR UIVA (80 cm) (SD) Median (range)	0.24 ± 0.16 0.20 (range: -0.10 to 0.60)	0.03 ± 0.08 0.00 (range: -0.20 to 0.20)	< .01[b]
logMAR CIVA (80 cm) (SD) Median (range)	0.06 ± 0.10 0.10 (range: -0.10 to 0.40)	0.03 ± 0.08 0.00 (range: -0.20 to 0.20)	.21[b]
logMAR DCIVA (80 cm) (SD) Median (range)	0.24 ± 0.15 0.20 (range: -0.10 to 0.60)	0.03 ± 0.08 0.00 (range: -0.20 to 0.20)	< .01[b]
Sphere (D) (SD) Median (range)	-0.18 ± 0.38 -0.25 (range: -1.00 to +0.75)	-0.19 ± 0.35 -0.25 (range: -1.00 to +0.75)	.85[b]
Cylinder (D) (SD) Median (range)	-0.46 ± 0.33 -0.50 (range: -1.00 to 0.00)	-0.20 ± 0.21 -0.25 (range: -0.75 to 0.00)	< .01[b]
Spherical equivalent (D) (SD) Median (range)	-0.40 ± 0.42 -0.38 (range: -1.38 to +0.25)	-0.29 ± 0.33 -0.25 (range: -1.25 to +0.38)	.22[c]
Corneal astigmatism (D) (SD) Median (range)	0.81 ± 0.42 0.76 (range: 0.15 to 1.59)	0.71 ± 0.27 0.74 (range: 0.19 to 1.18)	.27[c]

UDVA = uncorrected distance visual acuity; SD = standard deviation; CDVA = corrected distance visual acuity; UNVA = uncorrected near visual acuity; CNVA = corrected near visual acuity; DCNVA = distance-corrected near visual acuity; UIVA = uncorrected intermediate visual acuity; CIVA = corrected intermediate visual acuity; DCIVA = distance-corrected intermediate visual acuity; D = diopters

[a]*The corresponding* P *values for the comparison between groups are shown for each parameter evaluated.*

[b]*Wilcoxon test.*

[c]*Unpaired Student's* t *test.*