Original Article

A Comparative Evaluation of Visual, Refractive, and Patient-Reported Outcomes of Three Diffractive Trifocal Intraocular Lenses

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ABSTRACT

Objective: To compare the visual, refractive, and patient-reported outcomes of eyes implanted with one of 3 trifocal intraocular lenses (IOLs).

Methods: This is a cross-sectional, comparative, non-interventional study wherein subjects implanted with FineVision Micro F, AT LISA tri 839MP or AcrySof IQ PanOptix trifocal IOL after phacoemulsification were recruited. Manifest refraction, uncorrected and corrected visual acuity (VA) at distance, intermediate and near vision, contrast sensitivity, modulated transfer function (MTF) values and questionnaire answers were compared among the 3 groups using analysis of variance (ANOVA).

Results: Fifty-seven (57) eyes were included in the study: 21 eyes with FineVision (group A), 21 eyes with LISA tri (group B), and 15 eyes with PanOptix IOL (group C). The post-operative mean manifest spherical equivalent was -0.01D, -0.07D, and 0.05D, respectively (p=0.083). Uncorrected distance VA and best-corrected distance VA were similar among the groups. Groups A and C had better uncorrected and corrected intermediate VA at 80 cm and at 60 cm compared to group B. Group A had significantly better uncorrected near visual acuity than groups B and C (p=0.032). Mesopic contrast sensitivity testing showed group C had higher contrast sensitivities without glare in at the spatial frequency of 6 CPD (p=0.038) and with glare at 3 CPD (p=0.039) and at 12 CPD (p=0.009). MTF average height analysis showed that the group A had significantly superior resolution in far targets compared to groups B and C (p=0.001). At near targets, groups A and C had better resolutions compared to group B (p=0.017). There was no significant difference in patient satisfaction for far, intermediate and near VA among the groups.

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Conclusion: Eyes implanted with any of the 3 trifocal IOL designs achieved excellent uncorrected and best-corrected distance, intermediate and near vision. FineVision and PanOptix provided significantly better intermediate vision than LISA tri at both 80 cm and 60 cm testing distance. FineVision had better near visual outcomes than PanOptix and LISA tri. Patient satisfaction was high in all 3 trifocal IOLS.

Keywords: trifocal intraocular lenses, AT LISA tri 839MP, AcrySof IQ Panoptix, FineVision Micro F, modulated transfer functions (MTF)–average height, Strehl ratio, visual Strehl optical transfer function (VSOTF)

Innovations in intraocular lens (IOL) technology have led to improved visual outcomes after cataract surgery and consequently, raised the bar for patient satisfaction.[1] There is a higher expectation for spectacle independence and if unmet, may result in patient dissatisfaction.[1,2] Traditionally, monofocal IOLs targeted for emmetropia provide the best possible distance vision for a patient. However, patients remain presbyopic postoperatively, requiring the use of eyeglasses for intermediate and near vision tasks. The development of multifocal IOLs has greatly increased the probability of spectacle independence and patient satisfaction.[3-5]

The concept of multifocal IOL technology is to split light as it passes through the lens to multiple focal points.[6] Bifocal IOLs provide good distance and near vision. However, decreased contrast vision, presence of photic phenomena such as glare, starburst and haloes, and incomplete range of vision particularly for intermediate distance limited their acceptability. Trifocal technology focuses on improving visual outcomes by providing intermediate correction while preserving satisfactory correction for far and near vision. However, the success of trifocal IOLs does not only depend on improved visual outcomes. Photic symptoms and patient-reported outcomes are likewise important because these factors affect quality of life after cataract surgery.[7]

There are 3 popular trifocal IOLs available in the market today. These are FineVision Micro F (Physiol, Belgium), AT LISA tri 839MP IOL (Carl Zeiss Meditec, Jena, Germany), and AcrySof IQ PanOptix IOL (Alcon, Texas, USA). These IOLs use non-sequential diffractive orders to create 3 focal points for distance, intermediate, and near.[8] The PanOptix and LISA tri IOLs are single-piece, hydrophobic lenses, while the FineVision Micro F is a single-piece, hydrophilic lens.[9-11]

The trifocality of the FineVision IOL is created by 26 apodized diffractive rings across the entire 6.15 mm optic diameter while combining 2 diffractive profiles: one for distance and near with an add power of +3.50D and the other for distance and intermediate using an add power of +1.75D.[11] Three foci of light are created and distributed at approximately 42, 15 and 29% for distance intermediate, and near, respectively through a 3 mm pupil. This distribution of light energy for distance however, may vary and increase with larger pupil sizes because of its apodized design.[12]

The LISA tri IOL is made with a series of equally-spaced, concentric, diffractive rings. Its design combines a central 4.34 mm trifocal area with bifocal diffractive surfaces between 4.3 and 6 mm of diameter, generating 3 foci of light. It has a +3.33D add power for near and a +1.66D add power for intermediate vision. Light distribution is 50% distance, 20% intermediate, and 30% near.[12-14]

PanOptix has a quadrifocal design which produces a distance focal point, 2 intermediate focal points distributed at 120 cm and 60 cm, and a near focal point at 40 cm. To amplify IOL performance, it uses the ENLIGHTEN™ optical technology. This redirects the 120 cm intermediate focal point to distance, thereby converting PanOptix to an IOL that is functionally trifocal (distance, intermediate 60 cm, and near 40 cm).[10,15] Its 15 diffractive rings are limited to the central 4.5 mm region of its 6.0 mm total optic diameter. The near add power is +3.25D and the intermediate add power is +2.17D.[11] Light is distributed at 50% distance and 25% each for intermediate and near.[10,16]

An optical performance bench test using modulation transfer function (MTF) curves in a model eye comparing these 3 IOLs was published recently by Carson and colleagues.[8] It showed that PanOptix is expected to provide better intermediate vision at 60 cm. This distance might be more preferable for real-life tasks such as computer work over the 80 cm intermediate distance offered by the other 2 trifocal IOLs. Various post-operative comparisons of 2 out of the 3 trifocal IOLs have been reported in the literature.[11,12,17-20] However, to our knowledge, there is no single, published study comparing the visual, refractive, and patient-reported outcomes of these 3 trifocal IOLs.

The objective of this study was to compare the visual, refractive, and patient-reported outcomes of eyes that underwent phacoemulsification with implantation of one of these 3 commercially available diffractive trifocal IOLs. Results from this study can help cataract surgeons in IOL selection and counselling of patients who are about to undergo cataract surgery.

METHODS

This is a cross-sectional, comparative, non-interventional study. Approval of a local technical and ethics review committee was sought prior to recruitment. Patient subjects signed an informed consent prior to enrollment to the study.

Subjects recruited for the study had 1 post-operative visit at least 1 month after uncomplicated cataract surgery performed by a single surgeon at a single site.

Inclusion criteria included uncomplicated phacoemulsification with implantation of one of 3 IOLs [FineVision MicroF (Physiol, Belgium), LISA tri 839MP IOL (Carl Zeiss Meditec, Jena, Germany), or AcrySof IQ PanOptix IOL (Alcon, Texas, USA)] in at least one eye. Exclusion criteria were presence of any of the following conditions: pre-operative corneal astigmatism of more than 1 diopter (D), corneal pathology that may affect manifest refraction, posterior capsular opacity, ocular inflammation or corneal edema, ocular trauma, corneal transplant, retinal disease, degenerative eye disorders, color vision deficiencies, and glaucoma. Patients with previous history of refractive surgery and ophthalmic surgeries other than cataract surgery or lens exchange were excluded.

Data collected were demographic data (eye, age, gender, and interval between cataract surgery and study visit) and pre-operative clinical profile which included uncorrected and corrected, distance, intermediate, and near visual acuity (VA), manifest refraction expressed as mean refractive spherical equivalent (MRSE), and biometric data [axial length (AL), cylinder (CYL), mean keratometry (K), anterior chamber depth (ACD), IOL power, and target spherical equivalent (SE)].

During the singular study visit, VA, refraction, contrast sensitivity testing, and manual defocus curves were taken. VA was measured using standardized ETDRS charts at 6 meters, 80 cm, 60 cm and 40 cm. Mesopic contrast sensitivity was taken using the CSV-1000 HGT (Vector Vision, Dayton, OH, USA) chart, with and without glare. MTF average height, Strehl ratio, and through focus-visual Strehl optical transfer function (VSOTF) values were obtained using the iTrace aberrometer (Tracey Technologies, Houston, TX, USA). Measurements were done using far and near targets, with and without correction.

Patients with binocularly-implanted trifocal IOLs were asked to answer a self-administered questionnaire, the modified TyPE Spec questionnaire validated by Javitt et al.[21] Responses for satisfaction in distance, intermediate and near vision were recorded. A subset analysis of their binocular VA [uncorrected and best-corrected VA at distance, intermediate (80 cm and 60 cm), and near at 40 cm], glarometer scores (halo and starburst), and defocus curves were also performed.

Primary outcome measures were post-operative uncorrected and best-corrected VA at distance, intermediate (80 cm and 60 cm), and near (40 cm). Secondary outcome measures included manifest refraction (Sph, Cyl, MRSE), defocus curves, contrast sensitivity, glarometer (halo and starburst), aberrometry data [Strehl ratio, MTF average height, and VSOTF], and patient-reported outcomes on satisfaction and photic symptoms.

The de-identified data sets were recorded in a password-protected Excel spreadsheet (Microsoft Corp., USA). Analysis of Variance (ANOVA) was employed to compare data sets among the 3 groups using Statistical Package for the Social Sciences (SPSS) Statistics 20.0 (SPSS Inc, USA). Statistical significance was set at p-values less than 0.05.

RESULTS

A total of 57 eyes were included in the study and classified into 3 groups: 21 eyes in the FineVision group (group A), 21 eyes in the Lisa Tri group (group B), and 15 eyes in the PanOptix group (group C). Mean age of subjects were 64.7 years for group A, 68.3 years for group B and 70.1 years for group C (P=0.070). The pre-operative mean refractive spherical equivalents (MRSE) were -0.74 ± 2.93, -1.63 ± 3.54 , and -0.67 ±

2.57 D for groups A, B, and C, respectively (P=0.210). The preoperative mean axial lengths measured were 24.31 ± 1.13, 23.93± 0.91 and 24.17 ± 0.91 mm for groups A, B, and C, respectively (P=0.500). The mean interval from the date of cataract surgery to the one-time study visit was 23.3 ± 17.7 months for group A, 29.0 ± 18.0 months for group B, and 4.5 ± 3.8 months for group C (P<0.001) (Table 1).

Table 1. Subject demographics and pre-operative clinical profile

	FineVision (Group A)	LISA tri (Group B)	PanOptix (Group C)	All	P-value
N (eyes)	21	21	15	57	
A. Demographics					
Mean age ± SD (years)	64.7 ± 3.3	68.3 ± 9.5	70.1 ± 6.0	67.4 ± 7.1	0.070
Female (%)	16 (35.6%)	17 (37.8%)	12 (26.7%)	42 (76%)	N/A
Mean interval between cataract surgery and study visit ± SD (months)	23.3 ± 17.7	29.0 ± 18.0	4.5 ± 3.8	21.5 ± 18.1	<0.001
B. Pre-Operative Refraction and Visual Acuity					
Mean MRSE ± SD (D)	-0.74 ± 2.93	-1.63 ± 3.54	-0.67 ± 2.57	-0.79 ± 3.13	0.210
Mean UDVA ± SD (logMAR) Snellen equivalent	0.6 ± 0.4 20/80	0.7 ± 0.5 20/100	0.6 ± 0.4 20/80	0.6 ± 0.4 20/80	0.740
Mean UIVA ± SD (logMAR) Snellen equivalent	0.4 ± 0.1 20/50	0.4 ± 0.2 20/50	0.3 ± 0.1 20/40	0.4 ± 0.1 20/50	0.590
Mean UNVA ± SD (logMAR) Jaeger equivalent	0.4 ± 0.3 J6	0.6 ± 0.2 J9	0.5 ± 0.3 J7	0.5 ± 0.3 J7	0.270
Mean BCDVA ± SD (logMAR) Snellen equivalent	0.1 ± 0.2 20/25	0.2 ± 0.2 20/30	0.4 ± 0.5 20/50	0.2 ± 0.3 20/30	0.050
Mean DCIVA ± SD (logMAR) Snellen equivalent	0.3 ± 0.2 20/40	0.3 ± 0.2 20/40	0.3 ± 0.1 20/40	0.3 ± 0.3 20/40	0.340
Mean DCNVA ± SD (logMAR) Jaeger equivalent	0.4 ± 0.2 J6	0.5 ± 0.2 J7	0.5 ± 0.1 J7	0.5 ± 0.2 J7	0.220
Mean BCNVA with Adds ± SD (logMAR) Jaeger equivalent	0.1 ± 0.1 J2	0.1 ± 0.2 J2	0.2 ± 0.3 J3	0.1 ± 0.2 J2	0.050
C. Biometric Data					
Mean AL ± SD (mm)	24.31 ± 1.13	23.93 ± 0.91	24.17 ± 0.91	24.12 ± 0.98	0.500
Mean CYL ± SD (D)	-0.58 ± 0.34	-0.61 ± 0.17	-0.47 ± 0.17	-0.56 ± 0.25	0.310
Mean K ± SD (D)	43.20 ± 0.84	44.19 ± 1.19	44.56 ± 0.70	44.10 ± 1.12	0.350
Mean ACD ± SD (mm)	3.47 ± 0.42	2.91 ± 0.33	3.43 ± 0.40	3.19 ± 0.43	0.006
Mean IOL power ± SD (D)	18.5 ± 2.7	18.6 ± 3.2	18.5 ± 3.5	18.5 ± 3.0	0.990
Mean Target SE ± SD (D)	-0.07 ± 0.20	-0.11 ± 0.16	-0.03 ± 0.17	-0.08 ± 0.18	0.450

Abbreviations: SD, standard deviation. LogMAR, logarithm of minimum angle of resolution. MRSE, mean refractive spherical equivalent. D, diopter. UDVA, uncorrected distance visual acuity. UIVA, uncorrected intermediate visual acuity. UNVA, uncorrected near visual acuity. BCDVA, best-corrected distance visual acuity. DCIVA, distance corrected intermediate visual acuity. DCNVA, distance corrected near visual acuity. BCNVA, best-corrected near visual acuity. AL, axial length. CYL, cylinder. K, keratometry. ACD, anterior chamber depth. IOL, intraocular lens. SE, spherical equivalent.

The post-operative MRSE were -0.01 ± 0.32 D for group A, -0.07 ± 0.45D for group B and 0.05 ± 0.40D for group C (P=0.083). The mean post-operative cylinders were -0.43 ± 0.28, -0.95 ± 0.51D and -0.79 ± 0.38, for groups A, B, and C respectively (P=<0.001) (Table 2).

Monocular uncorrected distance VA (UDVA) was similar among the 3 groups (p=0.431). Eyes in groups A and C had better mean uncorrected intermediate VA (UIVA) compared to group B at testing distance of 80 cm (LogMAR 0.12 and 0.09 vs 0.19, p=0.005) and 60 cm (LogMAR 0.00 and 0.00 vs 0.07, p=0.026). Mean uncorrected near VA (UNVA) at 40 cm was statistically better in group A compared to group B and C (LogMAR 0.04 vs 0.11 and 0.06, p=0.032). Mean binocular UDVA was better in the group A compared to groups B and C (LogMAR 0.02 vs 0.07 and 0.11, p=0.15). Mean binocular UIVA at 60 cm was significantly better in the group A and C compared to group B (LogMAR -0.04 and -0.02 vs 0.05, p=0.030). Mean binocular UIVA at 80 cm and UNVA at 40 cm showed no statistical differences among the groups (Table 3).

Table 2. Post-operative manifest refraction

	FineVision (Group A)	LISA tri (Group B)	PanOptix (Group C)	All	P-value
N (eyes)	21	21	15	57	
Mean SPH ± SD (D)	0.20 ± 0.29	0.40 ± 0.47	0.44 ± 0.48	0.34 ± 0.42	0.173
Mean CYL ± SD (D)	-0.43 ± 0.28	-0.95 ± 0.51	-0.79 ± 0.38	-0.71 ± 0.46	<0.001
Mean MRSE ± SD (D)	-0.01 ± 0.32	-0.07 ± 0.45	0.05 ± 0.40	-0.02 ± 0.39	0.083
Abbreviations: SPH, sphere. CYL, cylinder. MRSE, manifest refraction in spherical equivalent. D, diopter. SD, standard deviation.					

Table 3. Post-operative uncorrected visual acuity (LogMAR)

	FineVision (Group A)	LISA tri (Group B)	PanOptix (Group C)	P-value
A. Monocular				
N (eyes)	21	21	15	
Mean UDVA ± SD (logMAR) Snellen Equivalent	0.07 ± 0.07 20/25	0.10 ± 0.11 20/25	0.08 ± 0.09 20/25	0.431
Mean UIVA at 80 cm ± SD (logMAR) Snellen Equivalent	0.12 ± 0.09 20/25	0.19 ± 0.10 20/30	0.09 ± 0.08 20/25	0.005
Mean UIVA at 60 cm ± SD (logMAR) Snellen Equivalent	0.00 ± 0.09 20/20	0.07 ± 0.09 20/25	0.00 ± 0.07 20/20	0.026
Mean UNVA at 40 cm ± SD (logMAR) Jaeger Equivalent	0.04 ± 0.07 J1	0.11 ± 0.09 J2	0.06 ± 0.09 J2	0.032
B. Binocular				
N (patients)	10	9	6	
Mean UDVA ± SD (logMAR) Snellen Equivalent	0.02 ± 0.04 20/20	0.07 ± 0.07 20/25	0.11 ± 0.03 20/25	0.015
Mean UIVA at 80 cm ± SD (logMAR) Snellen Equivalent	0.09 ± 0.10 20/25	0.16 ± 0.12 20/30	0.09 ± 0.06 20/25	0.353
Mean UIVA at 60 cm ± SD (logMAR) Snellen Equivalent	-0.04 ± 0.08 20/20	0.05 ± 0.07 20/25	-0.02 ± 0.04 20/20	0.030
Mean UNVA at 40 cm ± SD (logMAR) Jaeger equivalent	0.02 ± 0.04 J1	0.09 ± 0.10 J2	0.04 ± 0.05 J1	0.159
Abbreviations: LogMAR, logarithm of minimum angle of resolution. SD, standard deviation. UDVA, uncorrected distance visual acuity. UIVA, uncorrected intermediate visual acuity. UNVA, uncorrected near visual acuity				

There was no significant difference among the 3 groups in terms of monocular best-corrected distance visual acuity (BCDVA, p=0.809) and distance corrected near visual acuity at 40 cm (DCNVA, p=0.061). Distance corrected intermediate visual acuity (DCIVA) was significantly better in groups A and C compared to group B at 80 cm (LogMAR 0.12 and 0.06 vs 0.17, p=0.003) and 60 cm (LogMAR -0.01 and -0.02 vs 0.05, p=0.040). Binocular BCDVA, DCIVA, and DCNVA were similar between groups (Table 4).

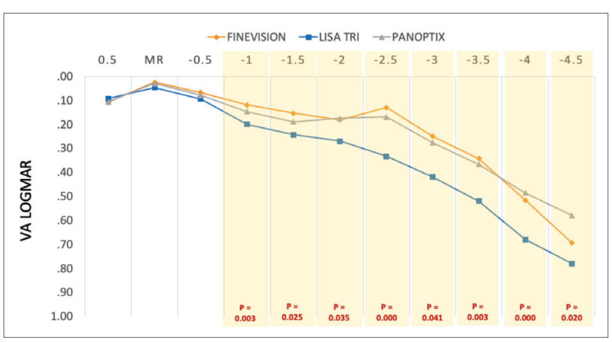
Monocular defocus curves showed groups A and C significantly outperformed group B from -1.0 to -4.5D defocus, with eyes implanted with FineVision IOL (group A) having the best performance (Figure 1A). Binocular defocus tests showed a similar trend wherein groups A and C had significantly better outcomes compared to group B. FineVision was better than PanOptix from -1.0 to -4.5D, except for -2.00 and -2.5D vergences where PanOptix was better (Figure 1B).

Table 4. Post-operative best-corrected visual acuity (LogMAR)

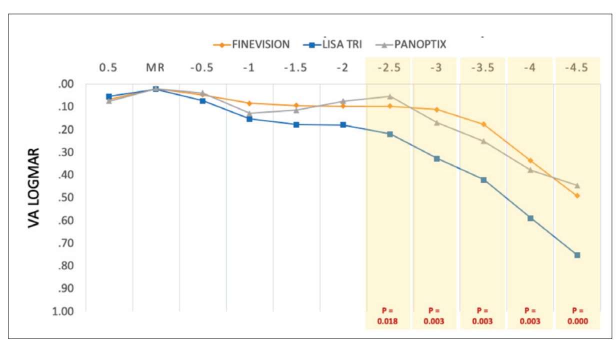
	FineVision (Group A)	LISA tri (Group B)	PanOptix (Group C)	P-value
A. Monocular				
N (eyes)	21	21	15	
Mean BCDVA ± SD (logMAR) Snellen equivalent	0.02 ± 0.05 20/20	0.03 ± 0.05 20/20	0.03 ± 0.05 20/20	0.809
Mean DCIVA at 80 cm ± SD (logMAR) Snellen equivalent	0.12 ± 0.09 20/25	0.17 ± 0.09 20/30	0.06 ± 0.06 20/25	0.003
Mean DCIVA at 60 cm ± SD (logMAR) Snellen equivalent	-0.01 ± 0.09 20/20	0.05 ± 0.07 20/25	-0.02 ± 0.08 20/20	0.040
Mean DCNVA at 40 cm ± SD (logMAR) Jaeger equivalent	0.04 ± 0.06 J1	0.09 ± 0.09 J2	0.05 ± 0.08 J2	0.061
B. Binocular				
N (patients)	10	9	6	
Mean BCDVA ± SD (logMAR) Snellen equivalent	0.02 ± 0.04 20/20	0.02 ± 0.04 20/20	0.02 ± 0.04 20/20	0.993
Mean DCIVA at 80 cm ± SD (logMAR) Snellen equivalent	0.08 ± 0.09 20/25	0.12 ± 0.11 20/25	0.06 ± 0.05 20/25	0.422
Mean DCIVA at 60 cm ± SD (logMAR) Snellen equivalent	-0.04 ± 0.08 20/20	0.02 ± 0.04 20/20	-0.06 ± 0.05 20/16	0.064
Mean DCNVA at 40 cm ± SD (logMAR) Jaeger equivalent	0.03 ± 0.04 J1	0.08 ± 0.10 J2	0.02 ± 0.04 J1	0.319

Abbreviations: LogMAR, logarithm of minimum angle of resolution. SD, standard deviation. BCDVA, best-corrected distance visual acuity. DCIVA, distance corrected intermediate visual acuity. DCNVA, distance corrected near visual acuity.

A. Monocular defocus curves



B. Binocular defocus curves

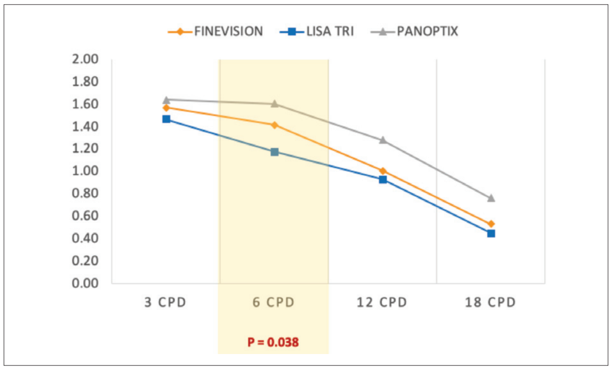


Abbreviations: VA, visual acuity. LOGMAR, logarithm of minimum angle of resolution.

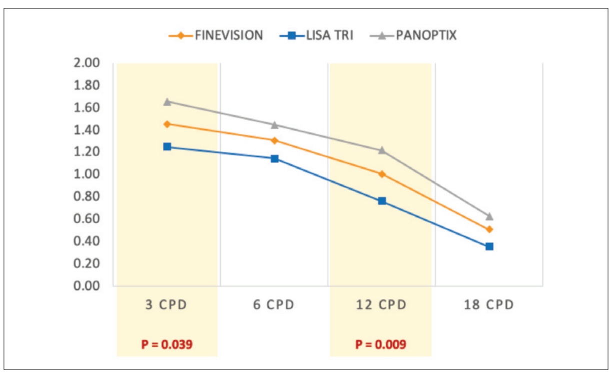
Figure 1. Monocular (A) and binocular (B) defocus curves

Mesopic contrast sensitivity without glare was best in group C, followed by group A then B. Group B was significantly worse at 6 CPD (p=0.038) (Figure 2A). Mesopic contrast sensitivity with glare followed the same trend with PanOptix (group C) best, followed by FineVision (group A), then LISA tri (group B). LISA tri was significantly worse at 3 CPD (p=0.039) and 12 CPD (p=0.009) (Figure 2B).

A. Mesopic contrast sensitivity without glare



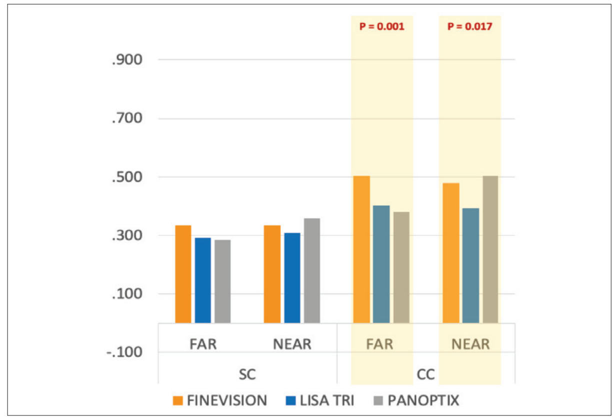
B. Mesopic contrast sensitivity with glare



Abbreviation: CPD, cycles per degree.

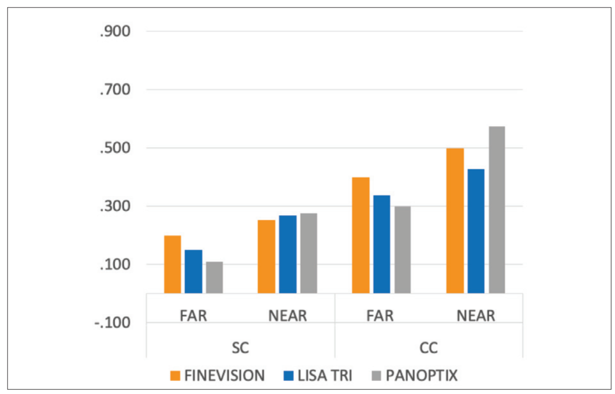
Figure 2. Mesopic contrast sensitivity without glare (A) and with glare (B)

Modulated transfer function (MTF) analysis showed that there were no significant differences between average height values when viewing far and near targets without the Tracey refraction correction (Figure 3). However, with the correction based on Tracey refraction, MTF average height values showed that group A had statistically significant superior resolutions in far targets compared to groups B and C (p=0.001). While at near targets, groups A and C had better resolutions compared to group B (p=0.017). Although not statistically significant, the same trend was noted in the analysis of Strehl ratio point spread function (PSF) (Figure 4) and VSOTF values (Figure 5) wherein group A had superior values in far targets while groups C and A were better than group B in near targets.



Abbreviations: SC, without Tracey correction, CC, with Tracey correction

Figure 3. Modulation transfer function (average height)



Abbreviations: SC, without Tracey correction, CC, with Tracey correction

Figure 4. Strehl ratio (point spread function)

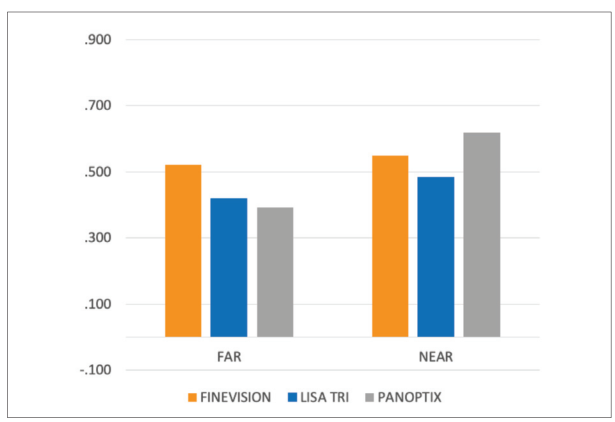
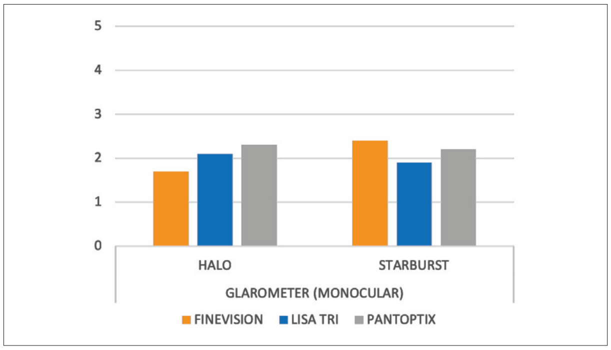


Figure 5. Visual Strehl optical transfer function (VSOTF)

Monocular (Figure 6A) and binocular (Figure 6B) glarometer testing for haloes and starbursts yielded no significant difference among the 3 groups. Patient satisfaction was high for distance, intermediate, and near vision in all 3 groups. All scores were at least 9 out of 10 except for the near vision of group B which scored below 9 (Figure 7).

A. Monocular glarometer scores



B. Binocular glarometer scores

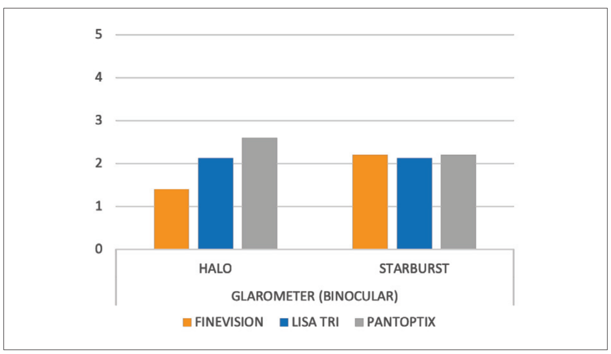


Figure 6. Monocular (A) and binocular (B) glarometer scores

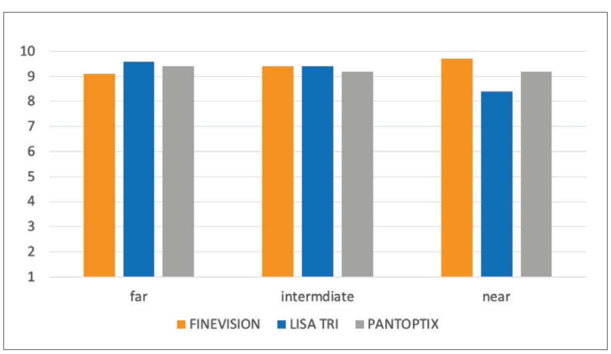


Figure 7. Visual satisfaction scores (far, intermediate and near vision)

Subjective reports from patients with binocular implants showed that at least 10% of the patients in group A needed spectacle assistance for driving at night and reading leaflets and medicine information. A proportion of patients in group B required more spectacle assistance; at least 22.2% for reading leaflets and newspapers, while 11.1% for reading books, menus and looking at pictures. Group C patients were completely independent from spectacles for all tasks mentioned in the questionnaire. At least 40% of patients per group experienced glare and haloes at night. However, only 20% of groups A and C patients experienced haloes during daytime compared to 45% of group B patients (Table 5).

Table 5. Questionnaire answers on spectacle dependence and photic symptoms

	FineVision (Group A)	LISA tri (Group B)	PanOptix (Group C)
N (patients)	10	9	6
A. Spectacle Dependence, n (%)			
Computer	0 (0%)	0 (0%)	0 (0%)
Leaflet	1 (10%)	2 (22%)	0 (0%)
Pictures	0 (0%)	1 (11%)	0 (0%)
Driving at night	1 (10%)	0 (0%)	0 (0%)
Newspaper	0 (0%)	2 (22%)	0 (0%)
Books	0 (0%)	1 (11%)	0 (0%)
Medicine info	1 (10%)	0 (0%)	0 (0%)
Watching television	0 (0%)	0 (0%)	0 (0%)
Watch	0 (0%)	0 (0%)	0 (0%)
Menu	0 (0%)	1 (11%)	0 (0%)
B. Presence of Photic Symptoms			
Glare	5 (50%)	4 (45%)	2 (40%)
Haloes in day-time	2 (20%)	4 (45%)	1 (20%)
Haloes in night-time	4 (40%)	5 (55%)	2 (40%)

DISCUSSION

Multifocal IOLs have evolved from bifocal to trifocal technology. Adding good intermediate vision without sacrificing good distance and near vision increased patient satisfaction post-operatively.[6] Trifocal IOLs were first introduced in 2012, beginning with FineVision and LISA tri, while PanOptix became commercially available in the Philippines only in early 2018. Glare and haloes are commonly reported with multifocal IOLs.[7] However, with trifocal lens designs, there is high patient satisfaction despite these photic phenomena.[8,9]

We believe it is critical to be as close to emmetropia as possible to optimize the performance of multifocal IOLs. We customized our A-constants and used 119.0 for FineVision, 118.5 for LISA tri, and 119.3 for PanOptix. Our refractive outcomes were on target for emmetropia in all 3 groups with post-operative mean MRSE of less than ± 0.1D. This led to good overall uncorrected distance, intermediate, and near vision in all 3 groups. This outcome is better compared to the trifocal lens studies of Marques et al., Kretz et al., and Ganesh et al. where majority of their subjects had post-operative MRSE within ± 0.50D.[12-14] The majority of the subjects from the same studies had residual post-operative cylinders within ± 0.75D which was better than the results of the LISA tri group in our study.

To sufficiently compare the visual outcomes of these 3 trifocal lenses, we need to highlight the design features of each IOL to better understand their subtle differences in clinical performance.

First, the add powers for intermediate vision of FineVision, LISA tri, PanOptix IOLs are +1.75, +1.66, and +2.17D, respectively. Therefore, the intended viewing distance for intermediate vision is at 80 cm for FineVision and LISA tri, whereas it is closer at 60 cm for the PanOptix. The difference in intermediate add powers of these lenses is the reason we collected 2 separate intermediate visual acuities at distances of 60 and 80 cm to confirm if the clinical performance met the intended designs. Incorporating a stronger intermediate add in PanOptix was intended to make the intermediate vision better and closer at 60 cm and to set it apart from its competitors.[8] In our study, we found that PanOptix was indeed better in intermediate vision at 60 cm compared to LISA tri. But FineVision performed surprisingly as good as the PanOptix at the same distance, both monocularly and binocularly. This finding is different from a published study that showed PanOptix to be more superior than FineVision at 60 cm.[11] Similar to our study, Marques et al. reported that eyes implanted with FineVision did slightly better than eyes implanted with LISA tri in monocular DCIVA at 80 cm and DCNVA at 40 cm.[12]

Although all our subjects had pre-operative corneal astigmatism of less than 1D, the residual post-operative manifest cylinder in eyes implanted with LISA tri IOL may have affected its performance. Hayashi et al. reported the effect of residual astigmatism greater than 1D on visual outcomes of eyes implanted with diffractive multifocal IOLs. They found that patients with these IOLs had low tolerance to small degrees of astigmatism. Astigmatism of ±1D or more compromised all visual acuities of their subjects at different intermediate distances.[22] A review of post-operative keratometry readings was done to verify these findings in the LISA tri group. An average of -0.58D corneal astigmatism was noted. This value is close to the pre-operative value of -0.61D. This proves that the residual manifest astigmatism was not surgically-induced. Other reasons for the high residual cylinder for the LISA tri group should then be considered.

Second, the near add powers in FineVision, LISA tri, and PanOptix are +3.50, +3.33 and +3.25D, respectively, with FineVision having the strongest reading add. The optimum distance for near vision of FineVision and LISA tri IOLs is 40 cm, while it is 42 cm for the PanOptix. In our study, FineVision and PanOptix were consistently better at reading distance of 40 cm (corrected and uncorrected) compared to LISA tri, even though by design, LISA tri should be better than PanOptix. These findings are in agreement with the results of the study by Gunderson which showed that FineVision and PanOptix had comparable corrected and uncorrected near vision at 40 cm.[11]

Third, FineVision has an apodized lens design; whereas, LISA tri and PanOptix are non-apodized. Apodization means that as the pupil aperture increases in size, more light energy is directed towards distance vision; conversely, when the pupil size is small, more light energy is directed at near vision. This is achieved by gradually reducing diffractive step heights from center to periphery.[23,24] This pupil size dependence follows the physiologic pattern of accommodation wherein our pupils get smaller when reading and larger when looking at distant objects. Maximizing light transfer in apodized lenses also decreases photic symptoms. This is seen in the studies of Vega et al. and Portney where light energy efficiency was well preserved through different pupil sizes in apodized over non-apodized bifocal lenses.[25,26] In contrast, light distribution is independent of pupil sizes in non-apodized lenses. Light energy is therefore constant when looking at far or near objects.

Mean uncorrected distance visual acuities monocularly and binocularly in all 3 groups were equivalent to 20/25 on the Snellen chart. Residual post-operative astigmatism may have decreased far vision in the LISA tri group but not significantly (p=0.431). This highlights the importance of good refractive outcomes. The UDVA results confirm the ability of all 3 IOLs to restore excellent distance visual function similar to other studies comparing FineVision and PanOptix[11], FineVision and LISA tri[12], LISA tri and PanOptix[18], wherein authors found no significant difference in uncorrected and best-corrected distance vision.

Meanwhile, the defocus curve gives us an indication on visual performance as the eye's focus transitions from distance to near vision. Our monocular defocus curve results show that FineVision displayed the best performance across the vergences of -1.0 to -4.5D, indicating good transition of vision across intermediate to near vision. Binocular defocus curves showed improvement in visual acuities for all 3 lenses, especially PanOptix which displayed superiority at -2.0D and -2.5D vergences. This is consistent with its higher intermediate add of 2.17D. Gunderson and Potvin also showed PanOptix was superior to FineVision in binocular vergences of -1.50D and -2.00D, even though their results did not reach statistical significance.[11] On the other hand, the study by Plaza-Puche and Alio demonstrated that LISA tri had statistically better visual acuities for vergences of -1.50D than FineVision which is contrary to the results of our study.[27]

Contrast sensitivities without glare was better at 6 CPD for the PanOptix group as well as with glare at 3 and 12 CPD. The trend revealed contrast sensitivity was best with PanOptix, followed by FineVision then LISA tri. However, when compared to the population norm, contrast sensitivities with and without glare for all 3 IOLs were all less than the normal range for their age group through spatial frequencies of 3, 6, 12 and 18 CPD. In a study by Ravalico et al., contrast sensitivities using Pelli-Robson and Vistech 6500 charts between diffractive multifocal and monofocal IOLs showed significant reduction in contrast sensitivities in the multifocal group though high visual acuities were attained post-operatively.[28] Decreased contrast sensitivities were also reported in eyes implanted with multifocal IOLs compared to eyes with monofocal IOLs.[29,30] Low contrast sensitivities with these lenses can be attributed to the decrease in light energy and increase in higher order aberrations with multifocality.[31]

MTF and PSF are accepted measures of image quality resolutions. They are expressed in average height and Strehl ratio values, with values closer to 1.0 indicating better quality of vision. These are also established to be predictive of not only VA but also contrast acuity.[32,33] In a study by Son et al. comparing aberrations among monofocal, diffractive bifocal, and diffractive trifocal IOLs, decreasing MTF values was observed with increasing lens focality.[34] On the other hand, VSOTF is a newer measurement of depth of focus. It is considered one of the best descriptors of visual performance that can be directly measured using wave-front guided aberrometers and has been proven to strongly correlate with the subjective visual acuity.[35-37]

The aberrometry results in our study showed a significantly higher far-focus MTF average height with Tracey refraction for FineVision compared to LISA tri and PanOptix (p=0.001). This trend was also noted in the analysis of Strehl ratio and VSOTF values though statistical significance was not met (p=0.440 and 0.121, respectively). Similarly, Dominguez-Vicent and colleagues reported higher MTF values at distance for Finevision compared to LISA tri.[38] Another study compared MTF values of FineVision and LISA tri through different pupil sizes. The investigators reported that MTF values in FineVision was directly proportional to pupil size. The apodized lens design of FineVision intensifies light energy for distance as the pupil physiologically enlarges when looking at far targets.[39] This may explain why FineVision was consistently superior to LISA tri and PanOptix in far-focus MTF average height, Strehl ratio, and VSOTF values.

Patient-reported outcomes are important measures in the success of treatment. Dysphotopsia is expected in multifocal IOLs. Patients implanted with multifocal IOLs have a 3.5 times more likely chance of experiencing photic symptoms than those implanted with monofocal IOLs.[3] In our study, photic symptom scores using a glarometer showed no significant difference between groups, both monocularly and binocularly. Questionnaire answers revealed that at least 40% of patients experienced glare and haloes during night-time in all subgroups. There is no way to predict who will experience dysphotopsia after multifocal implantation.[3,40] But targeting emmetropia improves satisfaction despite photic phenomena. Patients are generally more intolerant to ametropia than to glares and haloes.[7]

Although our study findings showed that more subjects in the LISA tri group reported the need of spectacles for certain tasks, this did not affect the patient satisfaction ratings. Patient satisfaction was high for distance, intermediate and near vision in all 3 groups. This is in agreement with other studies that also showed high visual satisfaction for FineVision[11,41], LISA tri[18,42,43] and PanOptix[13,15,18].

Our study has its limitations. The fairly-recent launch and availability of PanOptix contributed to the shorter follow-up duration and smaller sample size in that group. We recommend a randomized, controlled study design to compare the visual performance of each lens.

CONCLUSION

Our study highlights the importance of refractive targeting. Achieving a near-emmetropic refraction for trifocal IOLs brings out the best performance of each lens despite their individual variances in lens design.

In summary, eyes implanted with one of three diffractive, trifocal IOLs achieved excellent uncorrected and best-corrected VA for distance, intermediate and near. FineVision and PanOptix provided significantly better intermediate vision than LISA tri at both 80 cm and 60 cm testing distance. FineVision had better near visual outcomes than PanOptix and LISA tri. Despite these differences, patient satisfaction was high for all 3 trifocal IOLS.

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APPENDIX

Modiþed type questionnaire

Patient's Name: ______________________ Date today: ______________

Type of Intraocular Lens Used:
Date of Surgery on Each Eye: Right: ____________ Left: ____________
Interval from Surgery Date: Right: ____________ Left: ____________

MODIFIED TYPE QUESTIONNAIRE

How do you assess your vision without glasses after surgery on a scale of 0 to 10, where 0 means very dissatisþed, 5 means neutral and 10 means very satisþed (for both eyes)?

QUESTIONNAIRE	SCORE
1) How satisfied are you with your current FAR vision?	0 1 2 3 4 5 6 7 8 9 10
2) How satisfied are you with your current INTERMEDIATE vision?	0 1 2 3 4 5 6 7 8 9 10
3) How satisfied are you with your current NEAR vision?	0 1 2 3 4 5 6 7 8 9 10
4) Would you undergo the same procedure again	0 1 2 3 4 5 6 7 8 9 10
5) Would you undergo this procedure again on to overcome your dependency from glasses regardless of the presence of cataract?	0 1 2 3 4 5 6 7 8 9 10
6) Would you recommend the procedure to a close friend or family member?	0 1 2 3 4 5 6 7 8 9 10

INDEPENDENCE FROM GLASSES	
7) Do you wear glasses for: (Please encircle your answer)	Computer Newspaper Watch Leaflet Books Menu Pictures Medicine information Driving at night Watching Television

GLARE	
8) Do you find it difficult to read road signs due to strong lights or car headlights?	YES NO If YES: No difficulty Moderate Severe

HALOS	
9) Do you see rings around lights during the day?	YES NO If YES: Experiencing Halos No difficulty (Mild) Adapting to halos (Moderate) No change (Severe)
10) Do you see rings around lights at night:	YES NO If YES: Experiencing Halos No difficulty (Mild) Adapting to halos (Moderate) No change (Severe)

Source: Jevitt JC, Jacobson G, Schittman RM. Validity and reliability of the Cataract TyPE Spec: an instrument for measuring outcomes of cataract extraction. Am J Ophthalmol. 2003,136(2):285:90