

Visual performance of four types of diffractive multifocal intraocular lenses and a review of articles

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Abstract

• **AIM:** To compare the clinical outcomes of a variety of multifocal intraocular lenses (MIOLs) in patients diagnosed with presbyopia or cataracts.

• **METHODS:** This clinical trial study included 141 patients (282 eyes) with different MIOLs implantation. The Symphony (60 eyes), the ReSTOR (100 eyes), the AT LISAtri (60 eyes), and the PanOptix (62 eyes) intraocular lenses were evaluated in this prospective interventional study. The near, intermediate, and distant visual acuities, contrast sensitivity, and defocus curve were measured as valid criteria. To statistically analyze the results, we used the Statistical Package for Social Science software, the non-parametric Wilcoxon signed-rank *t*, the one-way analysis of variance and the Tukey's post-hoc test in our analysis. Moreover, we conducted a detailed literature search on the PubMed database in English about MIOLs, in total 59 studies were included in this review article.

• **RESULTS:** The four approaches did not show any significant difference in the best-corrected distance visual acuity ($P > 0.05$). The defocus curves at the contrast of 100% showed that trifocal IOLs had better intermediate performance than the bifocal IOL ($P < 0.05$). There were no statistically significant differences between AT LISAtri

and PanOptix lenses for visual acuity at all distances. The eyes with PanOptix, Symphony, and AT LISAtri IOL showed better contrast sensitivity than those ReSTOR at spatial frequencies of 1, 3, and 6 cpd in photopic and mesopic conditions ($P < 0.001$).

• **CONCLUSION:** All four groups of the multifocal lenses were satisfying in terms of distance and near vision. Also, the group of trifocal lenses led to satisfactory outcomes in intermediate vision, without degradation in quality of vision.

• **KEYWORDS:** multifocal lens; visual acuity; cataract; presbyopia

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INTRODUCTION

Multifocal intraocular lenses (MIOLs) have been reported as a substitute for improving near vision and quality of life for many patients^[1]. A large portion of the intraocular lenses (IOLs) that are industrially accessible has two principal foci comparing to near and far vision. Notwithstanding, subjects with these IOLs encounter poor vision at intermediate vision because of its trademark V-design, containing two crests relating to near and far vision and a hole in the middle of it for intermediate vision^[2-5]. Today, intermediate vision plays a significant role, such as working with computers. Trifocal IOLs have designed by join two diffractive profiles to enhance the intermediate vision. The *in vitro* and also *in vivo* researches have demonstrated the ability of these IOLs for the restoration of far, intermediate, and near visual capacity^[5-7], reduction of spectacle dependency^[8-12], and patient satisfaction^[6]. The trifocal IOLs illustrated excellent optical quality at the intermediate distance rather than bifocal IOLs^[4-5,13-14]. However, photopic phenomena such as halo and glare and loss of contrast sensitivity may occur unintentionally. Furthermore, the most sensitive division of the eye that includes the dominant of the optical principle of

the eye is green light while the life is polychromatic. Besides the conceivable compensation, both refraction and diffraction make longitudinal chromatic aberration (LCA)^[15]. In order to correct chromatic aberration, multifocal IOLs with an extended range of vision and the propriety of achromatic technology were designed^[15]. Regarding these detections, the authors realized that a comparison of the visual outcome by trifocal (with three different types of performance) and bifocal IOLs were needed.

To date, there is no simultaneous comparison of visual performance after implantation of a quadrifocal IOL with trifocal function (AcrySof IQ PanOptix, Alcon Laboratories Inc., USA), a trifocal IOLs (AT LISATri 839MP Carl Zeiss Meditec AG, Jena, Germany), extended depth of focus (EDOF) IOL (TECNIS Symphony; Abbott Medical Optics, Inc., Abbott Park, IL, USA) and a bifocal IOL (ReSTOR, Alcon Laboratories Inc., USA).

The current prospective clinical trial study investigates far, intermediate, and near visual acuities (VA) of a quadrifocal IOL with trifocal function (AcrySof IQ PanOptix, Alcon Laboratories Inc., USA), a trifocal IOLs (AT LISATri 839MP Carl Zeiss Meditec AG, Jena, Germany), EDOF IOL (TECNIS Symphony; Abbott Medical Optics, Inc., Abbott Park, IL, USA) and a bifocal IOL (ReSTOR, Alcon Laboratories, Inc, USA). Furthermore, the difference affectability of various multifocal IOLs implantation on the contrast sensitivity function (CSF) under photopic and mesopic conditions and defocus curves in presbyopic patients or cataract after implantation of the four intended IOLs were assessed.

SUBJECTS AND METHODS

Ethical Approval All procedures performed in studies involving human participants followed the ethical standards of the Institutional Review Board of the Shahid Beheshti University of Medical Sciences, Tehran, Iran, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

In this prospective clinical trial study (No.NCT03454334), 141 patients (282 eyes) with different IOLs included AMO Symphony in 60 eyes, AcrySof ReSTOR (Alcon) in 100 eyes, Zeiss AT LISATri in 60 eyes, PanOptix (Alcon) in 62 eyes and were at least 40y of age and had bilateral cataracts or presbyopia. Enrollment criteria included uncomplicated bilateral IOL implantation and good ocular health with no pathology that could compromise best VA (outside of residual refractive error). Cases meeting these criteria had a best corrected distance visual acuity (BDVA) less than 20/40, glare VA test worse than 20/40 preoperatively. Individuals also had a potential need for VA of 20/30 or better after surgery, and were completely willing to conform to the

investigation requirements. Excluded from entry were subjects with irregular astigmatism or regular astigmatism; ≥ 1.25 D with the rule (WTR), and ≥ 0.75 D against the rule (ATR) to consider; probable increment of ATR astigmatism with age and posterior corneal astigmatism^[16], large mesopic pupil^[17] using the millimeter scale with the Colvard pupillometer in different light conditions and angle kappa and alpha^[18-19] by the iTrace aberrometer (Tracey Technologies), corneal transplant surgery or previous glaucoma-filtering, a history of retinal detachments. Also excluded were patients with other clinically non-cataract ocular abnormality (e.g., microphthalmos, chronic drug-induced miosis, any pathology in the cornea to the retina, ocular surface problems and amblyopia). IOL implantation accomplished by one surgeon (Doroodgar F) at a single site. Surgery had to consist of bilateral implantation of either the AMO Symphony, AcrySof ReSTOR (Alcon), Zeiss AT LISATri, PanOptix (Alcon; Table 1). Trifocal implantation was accomplished based on the patient's interest in a higher degree of spectacle freedom at near, intermediate, and far distances after cataract surgery. The axial length and anterior segment size were assessed with a swept-source optical coherence tomography-based biometer (IOLMaster 700, Carl Zeiss Meditec AG). The A-constant was 119.1 for the AcrySof IQ PanOptix IOL, 118.6 for the AT LISATri 839MP IOL, and 119.3 for the Symphony IOL. The target refraction was emmetropia in all groups, except the Symphony group that ordered to be -0.5 in the non-dominant eye.

Patient Follow-up and Study Outcomes All patients underwent full ophthalmologic examinations two weeks after surgery to confirm the healing process and another after second eye surgery. The binocular and monocular uncorrected distance visual acuity (UDVA), uncorrected intermediate visual acuity (UIVA; 60 cm), and corrected intermediate visual acuity (CIVA; 60 cm, 40 cm), uncorrected near visual acuity (UNVA), corrected near visual acuity (CNVA; 40 cm) were measured with Early Treatment of Diabetic Retinopathy Study (ETDRS) charts. The Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) was used to assess posterior cornea.

Postsurgical evaluations were directed at a regular follow-up program (baseline and at 6mo and 1, 2y for the PanOptix group and 6mo, 1 and 4y for another group (AT LISATri, Symphony, ReSTOR) between November 2013 and July 2019.

The postsurgical convention also contained measuring of VA in far, intermediate and near distances, contrast sensitivity test was accomplished under photopic (85 cd/m²) and mesopic (3 cd/m²) conditions using the CVS1000 contrast sensitivity test (VectorVision, Greenville, SC) for each group separately.

Binocular distance corrected defocus curves were measured in each subject with the Test Chart 2000, positioned at 6 m, to

Table 1 Optical features of the bifocal (ReSTORE), trifocals (PanOptix, AT LISA tri 839MP), and EDOF (Symphony) IOLs

IOL characteristics	AcrySof IQ PanOptix	ReSTORE	AT LISA tri 839MP	TECNIS Symphony
Optical design	Diffractive-refractive hybrid	Diffractive	Diffractive	Diffractive
Optic type	Non-apodized	Apodized	Non-apodized	Non-apodized
Addition (near/intermediate)	+3.25 D/+2.17 D	+3.00 D	+3.33 D/+1.66 D	-/+1.75 D
IOL size, mm	13.0	13.0	11.0	13.0
Optic size, mm	6.0	6.0	6.0	6.0
Diffractive zone, mm	4.5	6.0	6.0	~4.9
Optic material	Hydrophobic acrylate/methacrylate copolymer	Hydrophilic acrylate	25% hydrophilic acrylate with hydrophobic surface properties	Hydrophobic acrylate
Spherical aberration, μm	-0.10	-0.1	-0.18	-0.27
Refractive index	1.55	1.4	1.46	1.47
Range	+6.0 to +34.0 D	+10.0 to +35.0 D	0 to +32.0 D	+5.0 to +34.0 D
Pupil dependence	Less dependent diffractive zone (4.5 mm) and lower energy utilization (up to 88%). The IOL incorporates 3 focal points at 40, 60, and 120 cm plus a distance focus from the base curve.	Dependent	Independent diffractive zone (6.0 mm) energy utilization (85%-86%)	Independent diffractive zone (6.0 mm) energy utilization (85%-56%)

D: Diopter; IOL: Intraocular lens.

measure the VA with each defocus lens. These were sequenced in a random order over the range of +2.0 to -3.00 D in 0.50 D steps with the letters on the Test Chart 2000 randomized between measures. An Oculus Universal Trial Frame (Keeler Ltd., Windsor, UK), adjusted to ensure a 12-mm back vertex distance, was used to house the manifest refraction and each additional defocus lens. For each measurement of VA, subjects were prompted once with the phrase, “can you read any more letters on the line below”? According to the methodology described by Gupta and colleagues^[20]. Each subject also subjectively rated his or her intermediate and near vision on a scale of 0 (completely unsatisfied) to 5 (completely satisfied).

Intraocular Lens Power Calculation The IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) biometry outcomes were optimized, and the SRK-T between 21 and 26, the Haggis above, the Hoffer Q formula below and the Barret universal two formulas^[17,21] calculated the IOL power for all patients. Target refraction was emmetropia for PanOptix, AT LISATri, and ReSTOR while in the Symphony IOLs group, micro monovision was considered; target refraction for dominant eye was emmetropia and for the fellow eye was low myopia of -0.75 D.

Surgical Technique Surgery was accomplished by one surgeon (Doroodgar F) using a standardized procedure. Cataracts were extracted by phacoemulsification through a 2.2 mm clear corneal incision. Multifocal IOLs were implanted in the capsular bag with utilizing the injector produced for the every particular IOL^[18-19,22-23]. The time between two surgical procedures was about 14d based on the patient’s condition and other factors. Postoperatively, ciprofloxacin eye drops (Ciplex; Sina Darou, Tehran, Iran) were prescribed of times per day for ten days. Betamethasone eye drops (Betasonate, 0.1% betamethasone disodium phosphate; Sina Darou, Tehran,

Iran) were given every 6h for two weeks then tapered, and artificial tears (ArtelacTM, Hypromellose; Bausch and Lomb, Montpellier, France) were administered every six hours for two weeks.

Statistical Analysis To statistically analyze the results, we used the SPSS software (SPSS Statistics for Windows, V.23.0, 2013; IBM). The non-parametric Wilcoxon signed-rank test was applied to determine the significant differences between the objective results before and after the implantation of the trifocal lenses, such as contrast sensitivity and the logMAR VA. Given that these factors had a normal distribution, we report the mean and SD for them. Also, we used the one-way analysis of variance (ANOVA) to determine any statistically significant differences between the means of the effectiveness of four studied independent groups. We applied Tukey’s post-hoc test to make pairwise comparisons of means and considered 5% level to find the statistically significant differences in our analysis.

RESULTS

There were 141 enrolled patients. This study consisted of 30 patients (60 eyes) for the Zeiss AT LISATri IOL also ReSTOR ($n=100$), PanOptix ($n=62$), Symphony ($n=60$) with range age 40 to 70y in the four groups that underwent cataract surgery. Table 2 shows the preoperative demographics of each group of 80 women and 61 men in the study. There were no discontinuations throughout the study. The cases in the four groups had similar demographic features.

In the trifocal group (AT LISA tri 839 MP, PanOptix and Symphony), the mean binocular UNVA; 40 cm and UIVA; 60 cm were significantly better than in the bifocal group (ReSTOR) respectively (UNVA: 0.037 ± 0.07 , 0.033 ± 0.05 , 0.017 ± 0.04 vs 0.086 ± 0.07 ; $P<0.001$ and UIVA: 0.037 ± 0.07 , 0.040 ± 0.06 , 0.052 ± 0.07 vs 0.105 ± 0.07 ; $P<0.001$).

Table 2 Descriptive measures for the number of implanted IOL in each group, age, pupil size, spherical equivalent, astigmatism, and visual acuities preoperatively mean±SD

Measurement	AT LISA (n=60)	PanOptix (n=62)	ReSTOR (n=100)	Symfony (n=60)
Age, y	51.73±6.08	53.62±6.97	51.46±6.12	52.7±6.48
Mesopic pupil size	4.02±0.35	4.30±0.35	4.51±0.37	4.28±0.35
Photopic pupil size	3.48±0.33	3.48±0.33	3.43±0.36	3.45±0.35
Spher	0.91±2.75	+0.72±2.94	+0.81±2.96	+0.95±2.82
Astigmatism	-0.73±0.39	-0.80±0.32	-0.69±0.42	-0.70±0.41
UCVA (logMAR)	0.50±0.17	0.51±0.19	0.58±0.15	0.61±0.10
BCVA (logMAR)	0.30±0.17	0.29±0.15	0.30±0.17	0.34±0.16

UCVA: Uncorrected visual acuity, BCVA: Best corrected visual acuity.

Table 3 Postoperative UCVA and BCVA logMAR

VA	AT LISA (n=60)	PanOptix (n=62)	ReSTOR (n=100)	Symfony (n=60)	P
UCVA					
Bilateral near vision					
6mo	0.025 (0.05)	0.020 (0.04)	0.089 (0.07) ^a	0.017 (0.04)	<0.001
1y	0.022 (0.05)	0.027 (0.04)	0.087 (0.07) ^a	0.12 (0.03)	<0.001
2 or 4y	0.037 (0.07)	0.033 (0.05)	0.086 (0.07) ^a	0.017 (0.04)	<0.001
Bilateral intermediate vision					
6mo	0.020 (0.05)	0.020 (0.04)	0.17 (0.07) ^a	0.045 (0.07)	<0.001
1y	0.015 (0.05)	0.027 (0.04)	0.096 (0.07) ^a	0.05 (0.13)	<0.001
2 or 4y	0.037 (0.07)	0.040 (0.06)	0.105 (0.07) ^a	0.052 (0.07)	<0.001
Far vision					
6mo	0.032 (0.06)	0.020 (0.04)	0.040 (0.06)	0.092 (0.08) ^a	<0.001
1y	0.035 (0.06)	0.047 (0.06)	0.036 (0.06)	0.062 (0.08) ^a	0.06
2 or 4y	0.032 (0.06)	0.020 (0.04)	0.033 (0.06)	0.090 (0.08) ^a	<0.001
BCVA					
Bilateral near vision					
6mo	0.025 (0.05)	0.019 (0.04)	0.059 (0.07) ^a	0.025 (0.05)	<0.001
1y	0.021 (0.05)	0.025 (0.04)	0.057 (0.07) ^a	0.022 (0.05)	<0.001
2 or 4y	0.037 (0.07)	0.038 (0.6)	0.055 (0.07) ^a	0.015 (0.05)	<0.001
Bilateral intermediate vision					
6mo	0.058 (0.14)	0.019 (0.04)	0.077 (0.07) ^a	0.058 (0.14)	<0.001
1y	0.040 (0.06)	0.025 (0.04)	0.088 (0.07) ^a	0.040 (0.06)	<0.001
2 or 4y	0.037 (0.07)	0.031 (0.05)	0.097 (0.07) ^a	0.027 (0.06)	<0.001
Far vision					
6mo	0.025 (0.05)	0.019 (0.04)	0.023 (0.04)	0.025 (0.05)	0.96
1y	0.022 (0.05)	0.025 (0.04)	0.036 (0.06)	0.022 (0.05)	0.28
2 or 4y	0.037 (0.07)	0.038 (0.04)	0.023 (0.04)	0.027 (0.06)	0.38

UCVA: Uncorrected visual acuity; BCVA: Best corrected visual acuity; SD: Standard deviation. ^aStatistically significant.

The considerable improvement was observed postoperatively in logMAR UDVA, CDVA, UNVA (40 cm), UIVA (60 cm) in four groups at 0.05 significance level (Table 3). Likewise, as expected, a significant decrease in the refractive error was observed postoperatively ($P=0.02$; Figure 1). According to Table 3, ReSTOR lens has less vision than the other groups at near and intermediate distances.

Contrast Sensitivity Figures 2 and 3 demonstrate the mean postoperative contrast sensitivity in the logarithmic scale under binocular mesopic and photopic conditions. There was

no significant difference in the values obtained between AT LISAtri and PanOptix at spatial frequencies of 1 cpd and 3, 6, 12, 18 cpd. Eyes with the PanOptix, Symfony, and AT LISAtri IOL illustrated preferred contrast sensitivity than ReSTOR at spatial frequencies of 1, 3, 6 cpd photopic and mesopic conditions ($P<0.001$). The curves achieved with monocular vision were equivalent to binocular vision.

Defocus Curves Figure 4 demonstrates the defocus curves under 100% of contrast. No statistically significant differences were observed between four groups in -2.00 D defocus ($P=0.167$).

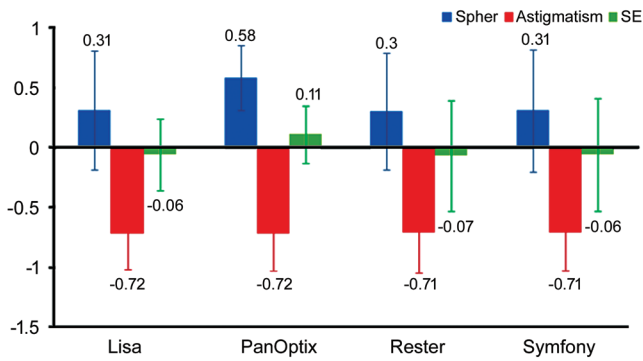


Figure 1 Post-operative refraction.

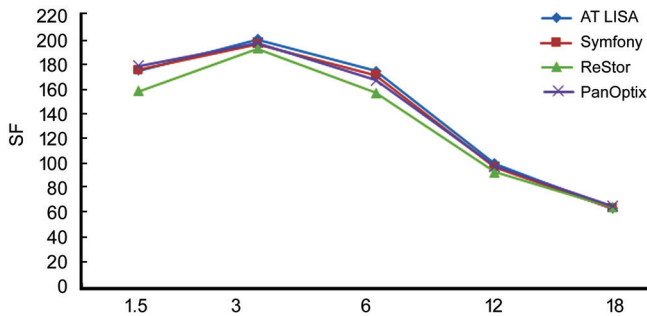


Figure 2 Binocular photopic contrast sensitivity for four IOL types.

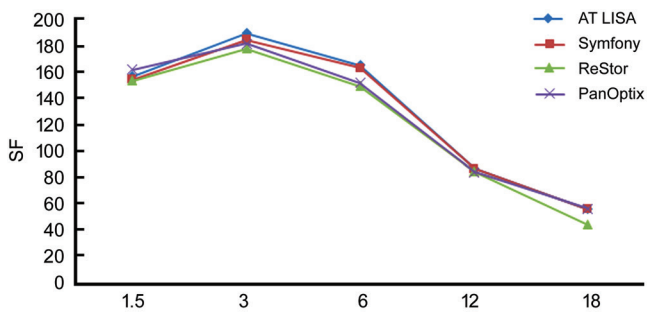


Figure 3 Binocular mesopic contrast sensitivity for four IOL types.

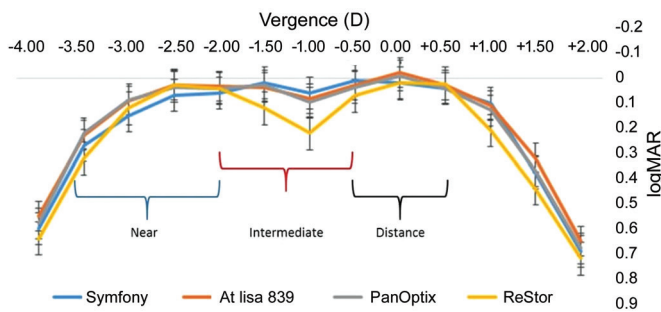


Figure 4 Mean monocular 100% contrast logarithm of the minimum angle of resolution visual acuity (logMAR) with correction for distance as a function of lens defocus in the four groups.

There was no significant difference for three groups trifocal IOLs in defocus of -1.00 D ($P=0.07$), all of which would do well to results than the bifocal group (AcrySof ReStOR; $P=0.04$). At this level of defocus, VA results were comparable between the other two groups of trifocal IOLs ($P=0.09$), the two of which had essentially preferred VA over the symphony group with 0.0 D defocus ($P<0.001$ and $P=0.008$ for AT LISA and Pan Optix, respectively). In any case, there were

no contrasts between the three groups with -2.00 D defocus ($P=0.1$). At defocus level -2 and from -2.5 D to -4.0 D the PanOptix and AT LISA group showed better acuity than the Symphony group. With -2.00 D defocus, the AcrySof IQ PanOptix group and AT LISAtri 839MP group acquired practically identical outcomes.

Spectacle Independence All subjects were spectacle independent in four groups.

DISCUSSION

The current clinical trial study provides a comparative analysis of the clinical performance of the PanOptix IOL, the AT LISAtri 839MP IOL, the TECNIS Symphony IOL, and ReStOR IOL. The clinical results demonstrated satisfactory outcomes for four groups. However, the group of ReStOR achieved less intermediate vision in comparison to the trifocal IOLs.

We conducted a detailed literature search on the PubMed database in the English language, without date limitation. Search terms included “Multifocal IOL”, “cataract surgery”, “Monofocal IOL”, “Angle κ and α ”, “IOL formulas in Multifocal IOL implantation”, “Pupil size” and commercially available trifocal IOLs such as “FineVision Micro F (PhysIOL, Liege, Belgium)”, “the AT LISAtri 839MP (Carl Zeiss Meditec AG, Jena, Germany)”, “the AcrySof IQ PanOptix, Alcon Laboratories, Inc.”, “the EDof IOL, TECNIS Symphony (Abbott Medical Optics, Santa Ana, CA)”, and “Aspheric IOLs”. In cases of non-English articles, abstract information was used whenever possible. The review of related articles including six randomized clinical trials and two cohort studies illustrated that the trifocal IOLs analyzed remarkably prefer to give intermediate VA than bifocal IOLs without dealing distance or near visual acuity (Table 4)^[1,3,7,9,24-55].

The findings of a prospective randomized multicenter study of Alió *et al*^[1,9,36] studies of Cochener *et al*^[7-8,34-35], and review of the previous studies (Table 4) suggested incorporation of a third focus does not harm reading performance when compared with the performance of bifocal IOLs. In agreement, the authors found no differences between the IOLs, even when the measurements were performed. The findings of defocus vergences in the current study are comparable with the previous studies that described the defocus curve between different trifocal IOLs (Table 4)^[31,35,45,49].

The PanOptix IOL provided better VA results at the distance range from 50 to 60 cm than Symphony, although acuity was slightly worse at 80 cm, Kohnen *et al*^[32] also reported a statistically significantly better VA, 1 line better VA, at defocus level -1.5 D, and from -2.5 D to -4.0 D of PanOptix than the Symphony IOL^[32].

Sudhir *et al*^[49] illustrated the better optical quality of Trifocals (Symphony and PanOptix) at a distance and near vision rather than bifocal lenses. Furthermore, they showed comparable

Table 4 Summary of outcomes included in the review

Study author	Others	Bifocal		Trifocal			Bifocals better	Trifocals better
		ReSTOR	Lentis Mplus	TECNIS	AT LISA	LISA 839		
Cochener <i>et al</i> (2012) ^[7]	Accommodative	a	a					
Alfonso <i>et al</i> (2012) ^[3]		a	a					
Alió <i>et al</i> (2011) ^[1]		a	a					
Alió <i>et al</i> (2013) ^[9]		a	a	a				
van der Linden <i>et al</i> (2012) ^[85]		a	a					
Marques <i>et al</i> (2015) ^[42]								
Dominguez-Vicent <i>et al</i> (2016) ^[43]								
Jonker <i>et al</i> (2015) ^[30]		a						
Gundersen <i>et al</i> (2016) ^[41]		a						
Cochener <i>et al</i> (2016) ^[34]				a				
Bilbao-Calaiburg <i>et al</i> (2016) ^[44]		a						
Plaza-Puche <i>et al</i> (2016) ^[38]		a	a					
Mojzis <i>et al</i> (2014) ^[39]								
Lubiński <i>et al</i> (2020) ^[31]								
Monaco <i>et al</i> (2017) ^[40]								
Mencucci <i>et al</i> (2018) ^[45]								
Cochener <i>et al</i> (2018) ^[35]								
Esteve-Jaboda <i>et al</i> (2015) ^[46]								
Ruiz-Mesa <i>et al</i> (2018) ^[48]								
Ruiz-Mesa <i>et al</i> (2017) ^[47]								
Sudhir <i>et al</i> (2019) ^[49]								
de Medeiros <i>et al</i> (2017) ^[33]								
Pedrotti <i>et al</i> (2016) ^[50]								
Chang <i>et al</i> (2016) ^[51]								
Eppig <i>et al</i> (2015) ^[52]	Accommodative M							
Crmej <i>et al</i> (2014) ^[53]	Accommodative M							
Kretz <i>et al</i> (2015) ^[54]								
Kohnen <i>et al</i> (2017) ^[52]								

SI: Spectacle independence; UCNVA: Uncorrected near visual acuity; UCIVA: Uncorrected intermediate visual acuity; †: Higher; VP: Visual performance; DC: Defocus curve in 100%; CS: Contrast sensitivity; I: Intermediate; F: Far; N: Near; SF: Spatial frequency; SA: Spherical aberrations; IOHOA: Internal and ocular higher-order aberration; Sc: Statistically significant differences; Id: Insignificant differences; L: Zeiss AT LISA Tri; P: AcrySof IQ PanOptix (Alcon Laboratories, Inc); R: ReSTOR multifocal IOLs (Alcon Laboratories, Inc., Fort Worth, TX) with +2.50 and +3.00 diopters, EDOF IOLs; S: TECNIS Symfony (Abbott Medical Optics, Inc., Abbott Park, IL); MW: Mini well (SIFI, Catania, Italy); LMP: Oculentis GmbH-Lentis Mplus LS-312; F: FineVision Micro F (PhysIOL SA, Liège, Belgium). †Implanted lens.

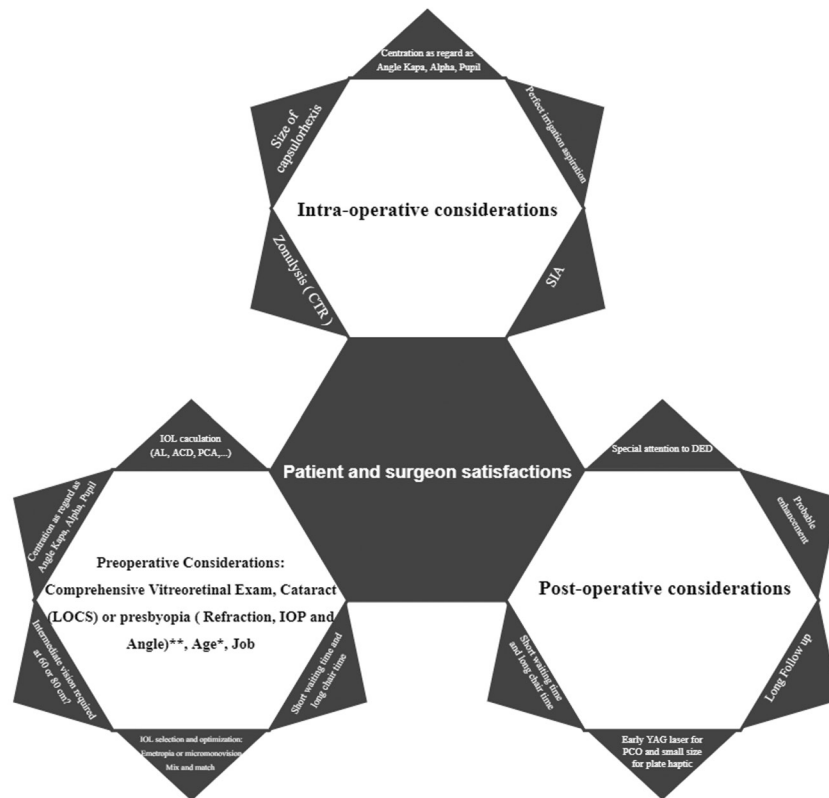


Figure 5 Factors requirement for best outcomes in MIOL implantation.

modulation transfer function (MTFs) at -1.50 D and -3.00 D for Symphony and PanOptix but better performance through Symphony at the intermediate range (highest MTF at -2.00 D and -2.50 D)^[49]. Ruiz-Mesa *et al*^[48] reported a significantly better near and better reading distance (the range of 37 to 39 cm for both IOL) with PanOptix than Symphony, the distance corrected intermediate vision between PanOptix (60 cm) and Symphony (80 cm) was similar. The contrast sensitivity under photopic and mesopic conditions and the high order aberrations were identical between two groups at all spatial frequencies^[47-48]. Mencucci *et al*^[45] PanOptix provided better VA at 60 cm than the Symphony and at; similarly, 80 cm, Symphony was significantly better than the PanOptix and AT LISA. The near vision was relatively better with PanOptix than AT LISA; both IOLs showed significantly better near vision than Symphony^[45].

Our findings are similar, whereas Trifocals (AT LISA, Symphony, and PanOptix) had not priority rather bifocal lenses (ReSTOR) at a distance. Furthermore, the AT LISA and PanOptix lenses had no preference in near vision. Fortunately, all subjects in the current study are spectacle independent, except ReSTOR group that somehow complain about blurred vision when working with computers. Previous studies reported 100% and 90% spectacle independence for AT LISA and Symphony respectively to see small letters thus needing prescription about 1.0 D add^[31]. The target refraction -0.5 to -0.75 D in the non-dominant eye in the Symphony group

and emmetropia for the other three lenses in our study might have supported near vision tasks in the Symphony group. This fantastic development (particularly in hyperopic patients with individual adaptability and flexibility) can be troublesome for myopic patients who have to drive a long time. The patient should not be losing any visual capacity. Thereby age, intraocular pressure (IOP), and angle (Figure 5) are important preoperative factors^[25,56-59]. Post-operative residual astigmatism ought to be under 1.00 diopter. The difference in surgically induced astigmatism is negligible in eyes with a corneal incision below 2.2 mm, and in surgical incisions <3.5 mm, astigmatism decreased with the longer follow-up. According to the previous studies, combining two subgroups (clear corneal incision 1.8 mm and 2.2 mm) did not significantly affect postoperative visual outcome^[29-30].

It should be noted that every MIOL has its advantages and de-escalations, which along with the patient's personality and necessity expectation and clinical conditions, are essential factors to consider while selecting an IOL for the best result. An excellent near vision for reading is necessary for daily activities. Writing and reading is a complicated procedure that involves rather than just distinction optotypes. Furthermore, to achieve optimal postoperative outcomes, the decision about post-operative emmetropia or micro monovision and mix and match IOLs are some optional management^[44].

Although all the patients were satisfied with near vision as well in the ReSTOR group, we observed some back falling off the

ReSTOR group in near vision. It was not established whether it is due to patient cooperation or other confounding factors for better near VA by preoperative planning micro monovision. Even though the defocus curves illustrate thoughtful information, however, regarding evaluation at 100% contrast can lead to overestimation and decline in low contrast^[29,34].

By applying of the swept-source optical coherence tomography technology as the IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) and OA-2000 (Tomey, Nagoya, Japan), advanced tomography and formula such as Barret universal two and ray trace technology, we tried to overcome the carelessness to some extent^[21]. However, one of the limitations of studies was lack of complete measurement of higher-order aberrations before and after IOL implantation. Furthermore, because of the small number of the patients who received the other MIOLs, all the different kinds of MIOLs were not included in one prospective study. The authors suggest an attractive idea to customized lens for each patient based on bag volume, aberrometry, and necessity expectations for additional comparisons of the visual performance.

In conclusion, if all the criteria, as discussed above, are met, the results of the current study indicate good visual outcomes following implantation of these four group MIOLs. The visual outcome at a distance and near was comparable between four groups, although the trifocal lenses performed better at intermediate vision.

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