Reading Speed and Visual Acuity in Photopic and Mesopic Conditions After Bilateral Implantation of Diffractive Multifocal Intraocular Lenses

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• PURPOSE: To assess functional visual performance – particularly reading speed - under photopic and mesopic conditions in patients bilaterally implanted with either the AT LISA Tri 839MP or Tecnis Synergy DFR00V diffractive multifocal intraocular lenses (IOL).
• DESIGN: Prospective randomized controlled trial.
• METHODS: This trial included 60 patients that underwent bilateral cataract surgery with implantation of either the AT LISA Tri or Synergy IOLs. At 3 months postoperatively, distance-corrected visual acuity (VA) and distance-corrected reading speed were measured under photopic (85 cd/m²) and mesopic (3 cd/m²) conditions. Photopic defocus curves were also analyzed and compared.
• RESULTS: Mesopic VA was significantly worse than photopic VA by ~1 ETDRS line, without inter-IOL differences. Photopic reading speeds were 143.4 ± 40.0 and 136.4 ± 27.0 wpm for the AT LISA Tri and Synergy, respectively. Mesopic reading speeds declining significantly to 38.2 ± 34.2 and 22.4 ± 29.7 wpm under mesopic conditions, respectively. Mesopic reading speed was significantly lower than in photopic conditions for both groups.
• CONCLUSIONS: Standard VA testing may underestimate functional limitations of multifocal IOLs under mesopic conditions. The substantial loss of reading speed suggests that mesopic near vision is impaired. Low luminance reading speed is a practical, patient-relevant endpoint and should be considered in IOL evaluations. (Am J Ophthalmol 2026;281: 516–525.

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INTRODUCTION

Modern cataract surgery has evolved into a refractive procedure, allowing for effective presbyopia correction through multifocal intraocular lens (IOL) implantation or pseudophakic monovision using monofocal or enhanced depth of field (EDOF) IOLs. Both approaches provide viable solutions to improve post-cataract surgery vision, each with distinct advantages and considerations.[1]

Historically, diffractive multifocal IOLs have demonstrated superior intermediate and near visual acuity, thereby increasing the likelihood of spectacle independence compared to other IOL types. These lenses offer the largest depth of field among current IOL designs. However, patient satisfaction is closely tied to postoperative visual quality (particularly regarding visual disturbances such as halos and glare), impact of varying light conditions on visual acuity, and the functional level of spectacle independence.[2]

The crystalline lens of the human eye exhibits high light transmittance and functions as a monofocal optical element capable of dynamically adjusting its shape to accommodate different focal distances. In an optimal configuration, the crystalline lens directs all available light to a single focal point, ensuring maximum image clarity at the accommodated distance. In contrast, diffractive multifocal IOLs manipulate incoming light by dividing it into several diffraction orders based on the geometry of the lens surface. Splitting the light allows for several focal points and therefore vision at different distances, but comes at the cost of reduced light efficiency and potential contrast loss.

Multifocal IOLs vary in their diffractive optics, influencing diffraction efficiency and the distribution of light across

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multiple focal points.[3] The efficiency at each order determines the proportion of light allocated to specific distances and is influenced by parameters such as step height, groove spacing, number of diffractive zones, and wavelength considerations.[3] The interaction between these factors plays a crucial role in optimizing vision at different distances. Most clinical studies assess postoperative outcomes using standardized visual acuity testing, contrast sensitivity measurements, and patient-reported questionnaire data. However, these methods may not fully capture functional differences between IOL designs, particularly under varying lighting conditions.

In this study, we compared 2 modern multifocal IOL designs under both photopic and mesopic conditions, with a focus on reading speed as a functional metric of near vision and the extent of visual function loss from photopic to mesopic conditions. While standard ETDRS visual acuity testing remains the benchmark for clinical evaluations, it does not fully capture real-world visual tasks such as reading under low-light conditions. By directly comparing photopic and mesopic reading speeds, we aimed to reveal functional differences between IOL designs that might not be apparent through acuity metrics alone.

METHODS

This was a prospective, single-center, patient- and assessor-masked, double-arm randomized controlled trial. The study was conducted at the Institute for Refractive and Ophthalmic Surgery (IROC), Zurich, Switzerland, between January 2023 and April 2024. The study was conducted in accordance with the International Conference on Harmonization Good Clinical Practice (ICH-GCP) guidelines and the tenets of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Commission of the Canton of Zurich (EK-2010-0271), and all participants provided written informed consent before enrollment. This study is registered at ClinicalTrials.gov under the identifier (NCT06978556).

Consecutive adults scheduled for bilateral cataract surgery at the Institute for Refractive and Ophthalmic Surgery (IROC), Zürich, between January 2023 and April 2024, were screened and enrolled after written informed consent. Inclusion criteria were bilateral cataract, desire for presbyopia correction with multifocal IOLs, and an expected postoperative CDVA $\geq$ 0.2 logMAR. Exclusion criteria were retinal or corneal disease compromising optical quality, history of uveitis, glaucoma, or previous refractive corneal surgery.

Participants were randomized 1:1 to receive bilateral AT LISA Tri 839MP or Tecnis Synergy DFR00V implantation. Each eye received either the stigmatic AT LISA Tri 839MP or the Tecnis Synergy DFR00V if preoperative corneal astigmatism was $<$ 0.8 D, and either the astigmatic AT LISA Tri Toric 949 M or Tecnis Synergy Toric II if preoperative corneal astigmatism was $\geq$ 0.8 D. The postoperative target spherical equivalent was emmetropia for all eyes. Patients and assessors/examiners were not informed of the IOL brand/model until after the 3-month follow-up; the surgeon was not masked. Outcome assessors were not involved in surgery and accessed only de-identified study IDs during testing.

• **MULTIFOCAL INTRAOCULAR LENSES:** This study investigated 2 modern multifocal IOLs: The AT LISA Tri 839MP (Carl Zeiss Meditec) and the Tecnis Synergy DFR00V (Johnson & Johnson). All information regarding these lenses is based on manufacturer data, as independent studies verifying their optical properties are not available.

The AT LISA Tri 839MP is a 1-piece hydrophilic acrylic trifocal IOL with a diffractive optic design that redistributes incoming light across different focal points. According to the manufacturer, approximately 50% of light is allocated to distance vision, 30% to near vision, and 20% to intermediate vision. Within the central 4.3 mm zone, the lens functions as a trifocal IOL, while the area between 4.3 mm and 6 mm incorporates a bifocal design. It features a near addition of + 3.33 D within the trifocal zone and an intermediate addition of + 1.66 D in the bifocal periphery. The IOL is designed with aspheric optics to reduce spherical aberration.

The Tecnis Synergy DFR00V is a 1-piece hydrophobic acrylic IOL with a diffractive optic design. It integrates aspheric or toric-aspheric optics on the anterior surface, which is intended to neutralize corneal spherical aberration. Its posterior surface incorporates a diffractive structure. The exact addition powers of this IOL are not explicitly stated by the manufacturer. The achromatic diffractive technology used in this IOL is claimed to minimize chromatic aberrations, potentially enhancing contrast sensitivity even under low-light conditions. Additionally, it includes UVAM, UV, and violet light-filtering chromophores to protect against high-energy visible (HEV) light.

• **CLINICAL EXAMINATIONS - PREOPERATIVE MEASUREMENTS:** Optical biometry was performed with the IOLMaster 700 (Carl Zeiss Meditec AG, Germany). Corneal optical quality and astigmatism were assessed using both the IOLMaster 700 and 3 consecutive measurements with a hybrid anterior segment optical coherence tomography (AS-OCT) device (MS-39, CSO, Italy). The IOL power was calculated using the median of the predicted postoperative spherical equivalent from 3 different formulas: EVO 2.0, K6, and Kane. For the postoperative predicted astigmatism, vector averages of the EVO 2.0 and Kane formulas were used. Additionally, OCT of the macula and optic disc was performed to exclude any relevant ocular comorbidities that could impact postoperative outcomes.

• **CLINICAL EXAMINATIONS - POSTOPERATIVE MEASUREMENTS:** Patients were examined 3 months postoperatively, with standardized assessments of visual acuity, reading speed, and patient-reported outcomes. Manifest refraction was measured using the ETDRS chart at 4 m. Visual acuity measurements were performed at 4 meters (distance vision), 0.80 meters (intermediate vision), and 0.40 meters (near vision) using ETDRS optotypes. Distance correction was applied for the distance corrected intermediate (DCIVA) and near (DCNVA) testing. All measurements were obtained using the Good-Lite ETDRS viewer ESV-3000 under controlled photopic (85 cd/m²) and mesopic (3 cd/m²) conditions, with an adaptation time of 5 minutes from photopic to mesopic conditions.

Distance-corrected reading speed was assessed at 0.40 meters using the International Reading Speed Texts (IReST) test and was reported in words per minute (wpm).[4] IReST employs a fixed, standardized print size at the set distance; we did not vary print size and did not estimate critical print size. The calculation formula used was:

$$\frac{\textit{read words} - \textit{wrong words}}{\frac{\textit{seconds needed to read}}{60}}$$

In addition to these standardized measurements, patients were asked to report their preferred reading distance, providing insight into their functional near vision in real-world settings.

The primary outcomes of the study included CDVA, DCIVA, and DCNVA under both photopic and mesopic conditions, as well as distance corrected reading speed in photopic and mesopic conditions. Secondary outcomes included loss of CDVA, DCIVA, and DCNVA from photopic to mesopic conditions, as well as the reduction in distance corrected reading speed between lighting conditions. Additionally, defocus curves of both IOLs were assessed under photopic conditions, along with uncorrected distance, intermediate, and near visual acuity. The rate of patients seeking unilateral or bilateral postoperative LVC was also recorded. LVC enhancement decisions were made at the 3-month follow-up visit based on patient satisfaction with uncorrected visual acuity, presence of photic phenomena, and their satisfaction in both regards with distance correction in place.

• **STATISTICAL ANALYSIS:** Data were analyzed using Microsoft Excel (vs.16.12, Microsoft Corp) and SPSS (vs.24.0, IBM Corp, USA). Descriptive statistics are presented in tables. The Shapiro-Wilk test was used to assess normality for continuous variables. Comparisons of visual acuity, refractive accuracy, and reading speed at various defocus steps and distances under photopic and mesopic conditions were conducted using paired t-tests for paired samples and unpaired t-tests for independent samples when normality was confirmed. If normality was not met, the nonparametric Wilcoxon signed-rank test or Mann-Whitney U test was applied. For multiple comparisons, a Benjamini-Hochberg post-hoc correction was used when necessary. In cases involving continuous percentages, a Z-test for 2 proportions was performed to assess statistical significance. P-values $<$ .05 were considered statistically significant.

Based on previous studies, we calculated the required sample size to detect a clinically relevant difference of 0.1 logMAR in visual acuity (VA) between groups. Prior research has reported a SD of 0.12 logMAR for VA measurements.[5,6] Assuming a significance level (α) of 0.05 and a statistical power (1–ß) of 0.80, a sample size calculation indicated that 23 patients per group would be sufficient to detect the anticipated difference. To account for an estimated dropout rate of 20% and an additional 10% uncertainty, we aimed to include 30 patients per group. This resulted in a total recruitment target of 60 patients (120 eyes). In addition, because distance-corrected reading speed was a primary endpoint, we provided a clinically anchored sensitivity analysis. Using the pooled mesopic SD from our cohort (≈32 wpm) and a 2-sided α=0.05, detecting a 25-wpm between-group difference (≈10%–15% of typical photopic reading speed in older adults) would require $n = 26$ per group for 80% power. With $n = 30$ per group, the realized power was ≈ 86% for Δ=25 wpm and ≈ 68% for Δ=20 wpm, and the minimal detectable difference at 80% power was ≈ 23 wpm. These thresholds are reported to contextualize our negative between-IOL findings in reading speed.

RESULTS

• **DEMOGRAPHIC DATA:** A total of 60 patients were enrolled in the study and completed the 3-month follow up visit. Patient- and examiner masking was maintained per protocol. There were no drop-outs. The mean age at the time of surgery was 59.7 ± 10.6 years. Regarding the implanted IOLs, the AT Lisa Tri had a mean SEQ + 20.45 ± 3.98 D and a mean astigmatism magnitude of 0.2 ± 0.65 D, whereas the Tecnis Synergy had a mean SEQ of + 21.03 ± 4.17 D (P = .402) and a mean astigmatism magnitude of 0.18 ± 0.54 D (P = .536).

• **BINOCULAR VISUAL ACUITY:** The uncorrected and corrected visual acuity outcomes for both IOL groups under photopic conditions are summarized in Table 1. When comparing UDVA, UIVA, UNVA, both IOLs performed similarly, with no statistically significant differences between them (p-values ranging from 0.076 to 0.371). The uncorrected visual acuity deficit (UVAD; difference between corrected and uncorrected visual acuity) was similar in both groups (P = .725 for distance, P = .699 for intermediate, and P = .351 for near) Table 1.

All photopic and mesopic visual acuity results are summarized and compared in Table 2. Both IOLs provided excellent corrected visual acuity at all distances [CDVA: −0.11 ± 0.06 logMAR (AT LISA Tri) vs. −0.08 ± 0.07 logMAR (Tecnis Synergy), P = .05].

TABLE 1. Presents the Postoperative Uncorrected and Corrected Visual Acuity Outcomes for the Tecnis Synergy DFR00V and AT LISA Tri IOLs Under Photopic Conditions (85 cd/m²)

IOL		photopic CDVA	photopic DCIVA	photopic DCNVA	UDVA	UIVA	UNVA	UDVAD	UIVAD	UNVAD
Synergy	**Mean**	−0.08	−0.02	−0.05	0.07	0.05	0.00	0.14	0.06	0.05
	Median	−0.10	0.00	−0.10	0.10	0.00	0.00	0.10	0.05	0.00
	SD	0.07	0.08	0.07	0.12	0.10	0.10	0.13	0.11	0.07
	IQR	0.10	0.10	0.10	0.10	0.10	0.20	0.13	0.10	0.10
Lisa Tri	**Mean**	−0.11	−0.05	−0.06	0.02	0.00	−0.03	0.13	0.05	0.03
	Median	−0.10	−0.10	−0.10	0.00	0.00	0.00	0.10	0.00	0.00
	SD	0.06	0.08	0.07	0.10	0.09	0.09	0.10	0.06	0.07
	IQR	0.03	0.10	0.10	0.10	0.20	0.10	0.03	0.10	0.10
p		**.05**	**.091**	**.765**	.076	.093	.371	.725	.699	.351

The table includes values for corrected (CDVA, DCIVA, DCNVA) and uncorrected distance/intermediate/near visual acuity (UDVA, UIVA, UNVA). Additionally, the uncorrected distance/intermediate/near visual acuity deficit (UDVAD, UIVAD, UNVAD) is reported, representing the difference between uncorrected and corrected visual acuity at each distance. Data are reported as mean, median, standard deviation (SD), and interquartile range (IQR), and p-values indicate statistical significance between the 2 IOL groups.

Visual Acuity Was Assessed Using ETDRS Optotypes At 4 Meters (distance), 0.80 Meters (intermediate), and 0.40 Meters (near) Using the Good-Lite ETDRS Viewer ESV-3000. To Ensure Comparability and Feasibility, Distance Correction Was Performed for 4 Meters Rather Than Infinity, Which Should Be Considered When Interpreting Intermediate and Near Vision Values Under Distance-Corrected Conditions

TABLE 2. Presents the Postoperative Visual Acuity Outcomes for the Tecnis Synergy DFR00V and AT LISA Tri IOLs Under Photopic (85 cd/m²) and Mesopic (3 cd/m²) conditions

		DFR00V				Lisa Tri				p
		Mean	Median	SD	IQR	Mean	Median	SD	IQR	
photopic	**CDVA**	−0.08	−0.1	0.07	0.1	−0.11	−0.1	0.06	0.03	**0.05**
Mesopic	**CDVA**	0.02	0	0.08	0.13	0.01	0	0.06	0	**0.454**
Loss of CDVA		0.09	0.1	0.07	0	0.12	0.1	0.04	0	**0.06**
photopic	**DCIVA**	−0.02	0	0.08	0.1	−0.05	−0.1	0.08	0.1	**0.091**
mesopic	**DCIVA**	0.09	0.1	0.11	0.2	0.05	0	0.08	0.1	**0.069**
Loss of DCIVA		0.11	0.1	0.07	0	0.1	0.1	0.07	0.05	**0.793**
photopic	**DCNVA**	−0.05	−0.1	0.07	0.1	−0.06	−0.1	0.07	0.1	**0.765**
mesopic	**DCNVA**	0.07	0.1	0.07	0.1	0.05	0.1	0.08	0.1	**0.437**
Loss of CDVA		0.09	0.1	0.07	0	0.12	0.1	0.04	0	**0.06**
Loss of DCNVA		0.12	0.1	0.07	0.1	0.11	0.1	0.08	0	**0.478**

To ensure comparability and feasibility, distance correction was performed for 4 meters rather than infinity, which should be considered when interpreting intermediate and near vision values under distance-corrected conditions. Measurements were conducted using the Good-Lite ETDRS viewer ESV-3000.

The table provides mean, median, standard deviation (SD), and interquartile range (IQR) values for each visual acuity parameter. Additionally, the loss of visual acuity from photopic to mesopic conditions is displayed for BCDVA, DCIVA, and DCNVA. The p-values indicate statistical significance between the 2 IOL groups.

Corrected Distance Visual Acuity (CDVA), Distance-Corrected Intermediate Visual Acuity (DCIVA), and Distance-Corrected Near Visual Acuity (DCNVA) Were Measured Using ETDRS Optotypes At 4 Meters, 0.80 Meters, and 0.40 Meters, Respectively.

Under photopic conditions, the AT LISA Tri demonstrated slightly better distance visual acuity compared to the Tecnis Synergy ($P = .05$)., though the difference was only marginally significant ($P = .05$). DCIVA ($P = .091$) and DCNVA ($P = .765$) were comparable between the 2 IOLs.

Under mesopic conditions, both IOLs exhibited a decline in visual acuity. The mean mesopic CDVA was similar for the AT LISA Tri and Synergy IOLs ($P = .454$). DCIVA was similar between the AT LISA Tri and Tecnis Synergy ($P = .069$). DCNVA remained comparable between both lenses ($P = .437$).

The loss of visual acuity from photopic to mesopic conditions was similar between the 2 IOLs. The AT LISA Tri exhibited a CDVA loss of 0.12 logMAR, DCIVA loss of 0.10 logMAR, and DCNVA loss of 0.11 logMAR, whereas the Tecnis Synergy demonstrated a CDVA loss of 0.09 logMAR, DCIVA loss of 0.11 logMAR, and DCNVA loss of 0.12 logMAR. None of these differences between the 2

TABLE 3. Presents the Postoperative Distance Corrected Reading Speed Outcomes for the Tecnis Synergy DFR00V and AT LISA Tri IOLs Under Photopic (85 cd/m²) and Mesopic (3 cd/m²) conditions

IOL		*Photopic Reading speed*	*Mesopic Reading speed*	*Loss of Reading Speed*
DFR00V	***Mean***	136.41	22.43	−113.98
	Median	142.52	0.02	−111.02
	SD	27.02	29.66	28.89
	IQR	32.66	42.52	34.41
Lisa Tri	***Mean***	143.41	38.24	−105.17
	Median	150.50	36.44	−98.58
	SD	40.00	34.20	42.82
	IQR	46.61	64.28	56.95
p		***.266***	***.224***	***.374***

The table includes the mean, median, standard deviation (SD), and interquartile range (IQR) for reading speed in photopic and mesopic conditions, as well as the loss of reading speed when transitioning from photopic to mesopic conditions. The p-values indicate statistical significance between the 2 IOL groups.

Reading Speed Was Assessed Using the International Reading Speed Texts (IReST) Test At 40 cm, with Results Reported in Words Per Minute (wpm).

IOLs were significant ($P = .06$, $P = .793$, and $P = .478$, respectively) [Table 2].

• **BINOCULAR DISTANCE CORRECTED READING SPEED:** Reading speed outcomes for both IOL groups under photopic and mesopic conditions, as well as the loss of reading speed when transitioning from photopic to mesopic lighting are summarized in Table 3. Across both study arms, mesopic reading speed was significantly lower than photopic and fell well below a functional 80-wpm benchmark. Under photopic conditions, reading speeds were 143.4 ± 40.0 wpm (AT LISA Tri) and 136.4 ± 27.0 wpm (Tecnis Synergy); under mesopic conditions, they were 38.2 ± 34.2 and 22.4 ± 29.7 wpm, respectively. The magnitude of the photopic to mesopic loss did not differ between lenses (−105.2 ± 42.8 vs. −114.0 ± 28.9; $P = .374$).

The preferred reading distance under distance-corrected conditions was 40.09 ± 2.04 cm for the AT LISA Tri and 42.32 ± 3.72 cm for the Tecnis Synergy. While the median preferred reading distance was 40 cm for both IOLs, the IQR (IQR) differed, indicating greater variability in the Tecnis Synergy group (IQR = 5.00 cm) when compared to the AT LISA Tri group (IQR = 0.00 cm) [Table 3].

• **BINOCULAR DEFOCUS CURVES:** Table 4 and Figure 1 summarize the postoperative defocus curves for the AT Lisa Tri and Tecnis Synergy under photopic conditions. Overall, the AT LISA Tri seemed to provide more functional vision across a wider range of distances, while the Tecnis Synergy demonstrated selective advantages at specific near vision focal points (−2.0 D and −4.0 D) [Table 4 and Figure 1].

• **RESIDUAL REFRACTIVE ERROR AND LASER VISION CORRECTION:** The distribution of residual refractive error in all patients, as well as in those who underwent LVC, is shown in Table 5 and Figure 2. The AT Lisa Tri group had a mean residual defocus equivalent (DEQ) of −0.5 ± 0.6 D, a residual spherical equivalent of −0.2 ± 0.6 D, and residual astigmatism magnitude (CYL) of −0.6 ± 0.4 D. The Tecnis Synergy group had a mean DEQ of −0.4 ± 0.8 D, SEQ of −0.06 ± 0.6 D, and CYL of −0.6 ± 0.7 D.

The desire for postoperative enhancement in the form of laser vision correction (LVC; wavefront optimized) was lower in the AT LISA group (34%) than the Tecnis Synergy group (61%). Among those who underwent LVC, 45% of patients had bilateral LVC, while 55% underwent unilateral LVC in the AT LISA Tri group, whereas 82% of Tecnis Synergy patients received bilateral LVC and 18% underwent unilateral LVC [Table 5 and Figure 2].

DISCUSSION

This study sought to cf visual acuity in photopic and mesopic conditions of 2 aforementioned multifocal IOLs. Both IOLs demonstrated comparable ETDRS visual acuity under photopic and mesopic conditions, with a mean loss of approximately 1 ETDRS line across all distances when transitioning from photopic to mesopic conditions. No statistically significant differences were observed between the 2 lenses in this regard, suggesting that both IOLs perform similarly in low-light environments.

More importantly, we showed that mesopic reading speed is markedly reduced compared with photopic reading in patients with bilateral diffractive multifocal IOLs. Normal reading speed ranges between 170 and 240 words per minute (wpm) across several languages, but individuals over 60 tend to read 30–40 wpm slower.[4,7-9] In the present study, photopic reading speed was functionally acceptable (136–

TABLE 4. Presents the Postoperative Defocus Curves for the Tecnis Synergy DFR00V and AT LISA Tri IOLs Under Photopic Conditions (85 cd/m²)

IOL		*+1.0*	*+0.5*	*0*	*−0.5*	*−1.0*	*−1.50*	*−2.0*	*−2.5*	*−3.0*	*−3.5*	*−4.0*
Synergy	**Mean**	0.32	0.08	−0.07	0.04	0.09	0.01	−0.01	0.02	0.05	0.17	0.29
	Median	0.30	0.10	−0.10	0.00	0.10	0.00	0.00	0.00	0.10	0.20	0.30
	SD	0.12	0.09	0.07	0.10	0.09	0.08	0.07	0.06	0.06	0.09	0.08
	IQR	0.13	0.13	0.10	0.10	0.03	0.10	0.10	0.10	0.10	0.10	0.18
Lisa Tri	**Mean**	0.21	0.01	−0.11	−0.03	0.02	0.03	0.08	0.02	0.00	0.11	0.27
	Median	0.20	0.00	−0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.10	0.30
	SD	0.07	0.06	0.07	0.07	0.09	0.09	0.09	0.07	0.07	0.13	0.12
	IQR	0.10	0.00	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.20	0.18
p		**<0.001**	**.003**	**.024**	**.003**	**.003**	**.315**	**<0.001**	**.522**	**.035**	**<0.001**	**.514**

To ensure comparability and feasibility, distance correction was applied for 4 meters rather than infinity, which should be considered when interpreting the defocus curves. The measurements were conducted using the Good-Lite ETDRS viewer ESV-3000.

The table reports mean, median, standard deviation (SD), and interquartile range (IQR) values for each defocus level. The *p*-values indicate statistical significance between the 2 IOL groups at different defocus levels, highlighting differences in functional vision across the range of defocus.

Defocus Testing Was Performed Using ETDRS Optotypes At a Fixed Distance of 4 Meters, with Visual Acuity Measured At Defocus Levels Ranging From + 1.0 D to −4.0 D in 0.5 D Steps.

TABLE 5. Presents the Residual Refractive Error for Patients Implanted with the Tecnis Synergy DFR00V and AT LISA Tri Intraocular Lenses (IOL)

Group	IOL		IOL SEQ	IOL Cyl	Obj SEQ	Obj Cyl	Subj SEQ	Subj Cyl	Subj DEQ
All patients	**DFR00V**	**Mean**	21.03	0.18	−0.84	−0.74	−0.06	−0.64	−0.38
		Median	21.50	0.00	−0.75	−0.63	0.00	−0.50	−0.38
		SD	4.17	0.54	0.47	0.40	0.62	0.71	0.83
		IQR	4.88	0.00	0.63	0.50	0.66	0.50	0.75
	Lisa Tri	**Mean**	20.45	0.22	−0.65	−0.77	−0.19	−0.63	−0.50
		Median	22.00	0.00	−0.56	−0.75	−0.13	−0.50	−0.50
		SD	3.98	0.65	0.64	0.35	0.56	0.40	0.56
		IQR	5.81	0.00	0.63	0.50	0.50	0.25	0.50
		p	**.402**	**.536**	**.014**	**.328**	**.351**	**.279**	**.121**
Patients seeking LVC	**DFR00V**	**Mean**	20.58	0.18	−0.82	−0.83	−0.04	−0.84	−0.46
		Median	20.25	0.00	−0.75	−0.75	0.00	−0.50	−0.50
		SD	4.59	0.45	0.56	0.43	0.77	0.87	1.07
		IQR	5.00	0.00	0.69	0.50	0.88	0.38	0.75
	Lisa Tri	**Mean**	19.06	0.44	−1.03	−0.75	−0.48	−0.73	−0.84
		Median	19.00	0.00	−1.06	−0.63	−0.25	−0.50	−0.75
		SD	4.58	0.89	0.94	0.45	0.91	0.47	0.83
		IQR	7.38	0.25	0.66	0.63	0.81	0.50	0.44

The Table Compares All Patients and the Subgroup of Patients Who Underwent Laser Vision Correction (LVC) to Correct Postoperative Refractive errors. The Parameters Reported include: IOL SEQ (Spherical Equivalent Power of the Implanted IOL), IOL Cyl (Cylinder Power of the Implanted IOL), Objective SEQ and Cyl (Objective Spherical Equivalent and Cylinder Power From Autorefraction), Subjective SEQ and Cyl (Subjective Refraction for Spherical Equivalent and Cylinder Power), Subjective Defocus Equivalent (Subj DEQ), Which Accounts for Both Sphere and Cylinder to Assess Total Residual Refractive Error.

143 words per minute, wpm), but mesopic reading speed was significantly reduced (22–38 wpm), falling well below the 80 wpm threshold for recreational reading. [4,7-9]Our results indicate that reading speed under mesopic conditions was comparable to that of patients with age-related maculopathy under photopic conditions.[10,11] It is important to note that the reduction in reading speed was similar between the 2 IOLs. We can conclude from these findings that standard acuity measures overestimate functional near vision in low-luminance settings, where many everyday tasks (e.g., menus, labels, smartphones) are performed. This raises an important question: Does conventional ETDRS visual acu-

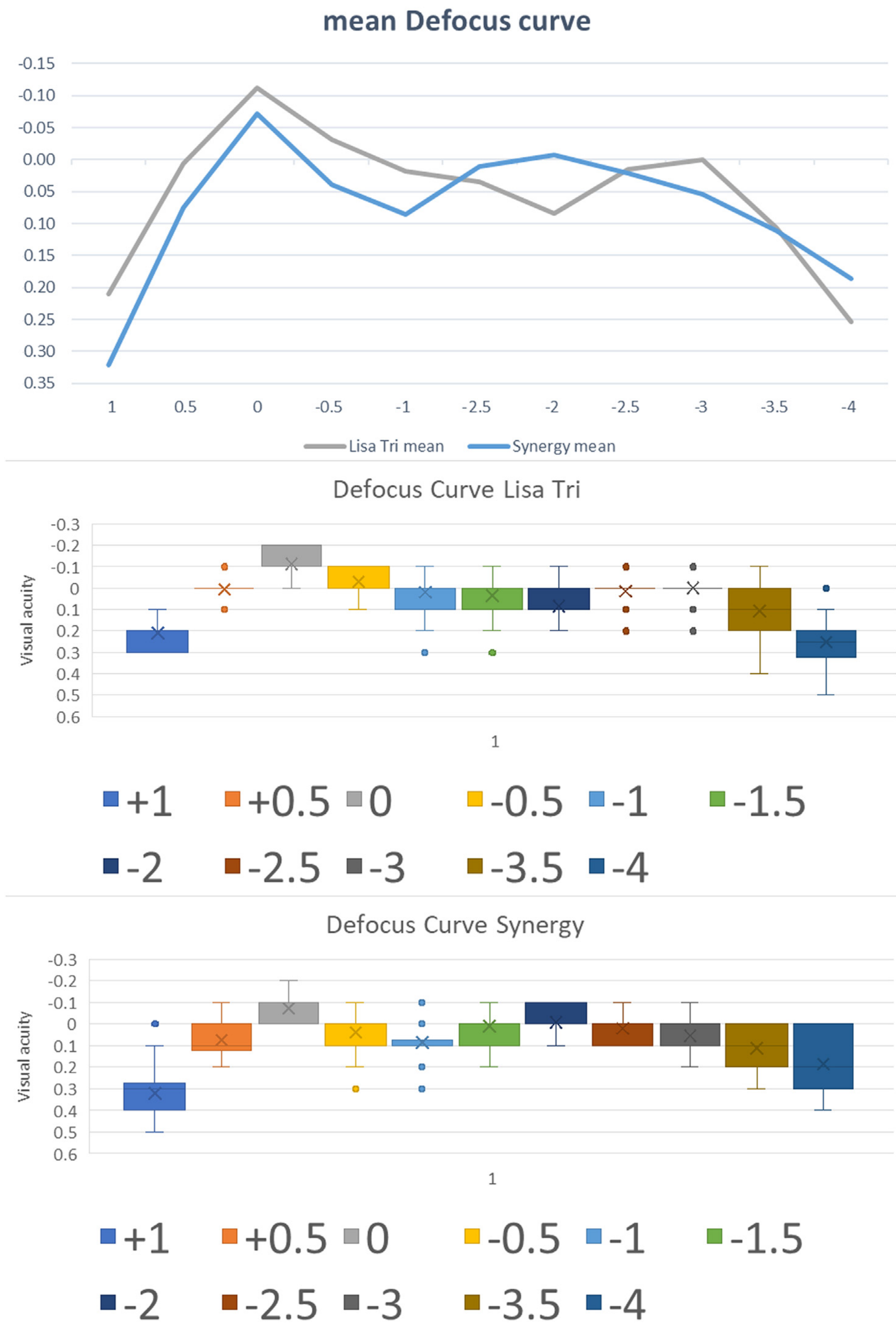

FIGURE 1. This figure presents the defocus curves of the 2 multifocal intraocular lenses (IOL; Tecnis Synergy DFR00V and AT LISA Tri) under photopic conditions. The curves illustrate visual acuity across a range of defocus levels, highlighting the functional performance of each IOL at different focal distances. Boxplots provide additional statistical representation of the variance in defocus performance between the 2 IOL.

ity testing accurately estimate real-world functional vision? Given that contrast sensitivity assessments are difficult to interpret in clinical practice, reading speed appears to be a practical and clinically relevant metric.

Our findings align with reports of reduced mesopic contrast sensitivity in multifocal optics, which likely contributes to the observed decrement in reading speed under dim lighting.[12] Future research should assess whether near correction under mesopic conditions can improve functional near vision. Clinically, these findings underscore the importance of educating patients about their strong dependence on lighting conditions and the like-

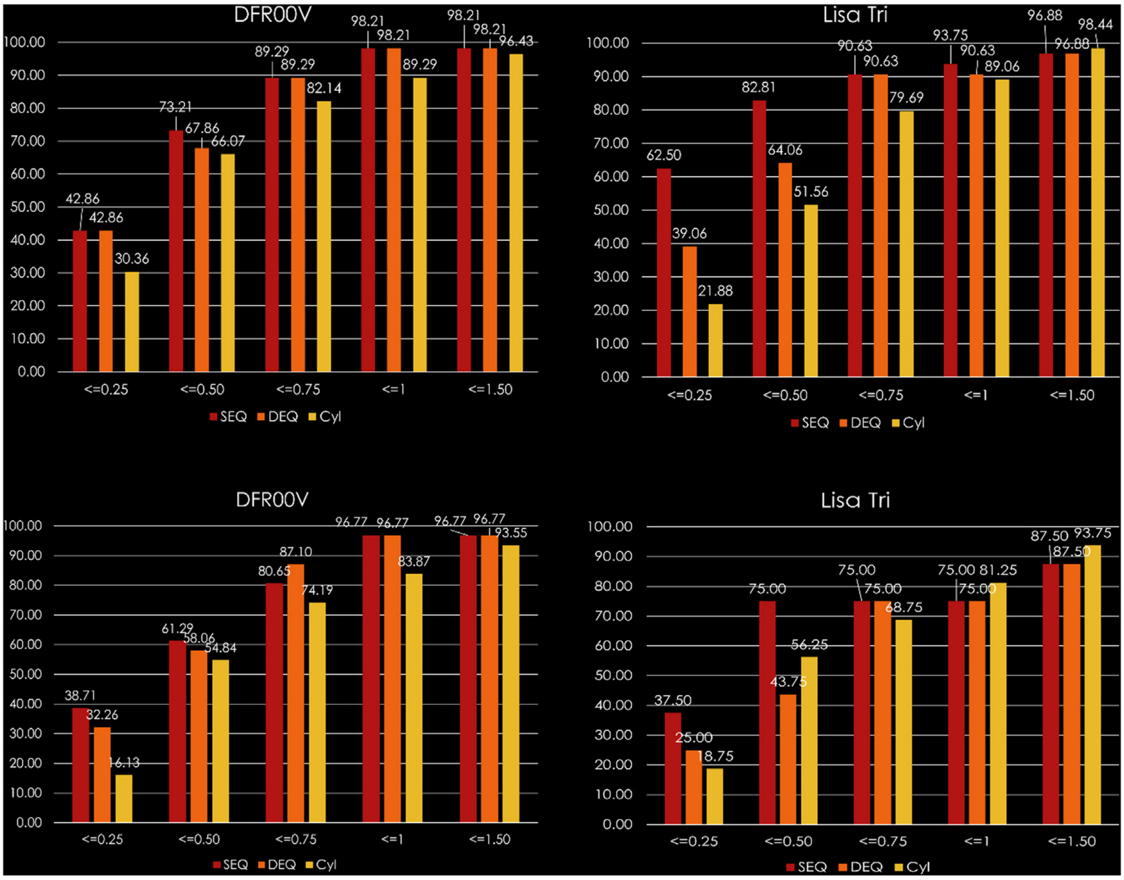

FIGURE 2. The upper row of the figure displays the spherical equivalent (SEQ), defocus equivalent (DEQ), and astigmatism (CYL) values for all patients implanted with either IOL. The lower row presents the same refractive parameters specifically for patients who underwent laser vision correction (LVC) to refine residual refractive errors.

lihood of requiring reading spectacles in dim environments.

Cilino et al. found no between-IOL difference, with reading speed (MNREAD) declining from 248 to 263 to 220–250 wpm and critical print size (CPS) increasing by ~20%–43% (from 0.34 to 0.35 to 0.41–0.50 logRAD) for 3 multifocal IOLs.[13] Other protocols reported lower absolute speeds, i.e. with Radner charts, reporting 184.7 ± 38.5 wpm at 0.4 logRAD for monofocal IOLs, needing an increased mesopic CPS increasing from 0.22 to 0.33 logRAD. [14] A mix-and-match study using DFR00V and DXR00V IOLs reported even lower reading speeds (125.9 wpm) with the Salzburg Reading Desk, while De Rojas et al. found reading speeds of 172 ± 5 vs. 182 ± 4 wpm (mesopic vs. photopic), but with a substantial increase in critical print size (0.2 to 0.6 logRAD). [15,16]

These discrepancies underline the lack of standardization across reading tests, making direct comparisons problematic. Factors such as sentence structure, print size increments, contrast, and correction modality (e.g., use of reading spectacles or distance correction) vary widely. For robust assessment of near vision performance in IOL studies, consistent and validated reading tests are essential. Crucially, if print size is adjusted during testing, reading speed should be reported across the full range of print sizes, not just at a single threshold (e.g., critical print size), to allow more transparent and interpretable comparisons.

The defocus curves of both IOLs closely resemble those reported by manufacturer data, validating their expected optical performance. The Tecnis Synergy demonstrated better intermediate-to-near performance (−2 D) but showed a dip at −1 D, suggesting weaker intermediate-far vision. While the Tecnis Synergy exhibited higher performance at −4 D, it is questionable whether this focal point is clinically relevant for everyday tasks, as most common near-vision activities occur at −3 D. The higher peak at −3 D in the AT LISA Tri correlates with its superior reading speed performance, suggesting that this focal point may be more functionally beneficial. Interestingly, both groups reported identical preferred reading distances, indicating that testing at 40 cm does not favor 1 IOL over the other but is appropriate for both designs. For comparison, Benyoussef et al. noted that the Tecnis Synergy seemed to provide a more dome shaped defocus curve than for the FineVision HP trifocal IOL (PhysIOL), providing higher reading speed and less sensitivity to refractive error.[17]

Given this data, we disagree with the classification of the Tecnis Synergy IOL as an "EDOF/multifocal hybrid." Even though the design has negative SA and also secondary SA to induce depth of field, the defocus curve with a dip at −1 D suggests that it does not provide the continuous characteristic of EDOF IOL. Instead, the defocus curve acts more like a conventional multifocal IOL with distinct focal points.

Among patients who underwent LVC, a higher proportion of Tecnis Synergy patients exhibited residual DEQ within ± 0.5 D, yet they were still more likely to seek LVC than AT LISA Tri patients. This suggests that patients with Tecnis Synergy were less tolerant of minor residual refractive errors, aligning with observations from the defocus curve. Despite the higher LVC rate in the Tecnis Synergy group (61%) compared to the AT LISA Tri group (34%), all patients who underwent LVC were satisfied with their results, and no IOL exchanges were necessary. This finding aligns with previous data from Seiler et al., supporting the efficacy of LVC in optimizing postoperative outcomes for multifocal IOL patients.[18] This also supports our method of testing satisfaction with monofocal distance spectacle prescription, to decide whether LVC enhancement or IOL exchange is warranted.

This study has several limitations. The sample size (60 patients) may restrict the generalizability of the findings, and the follow-up period of 12 weeks may not fully capture long-term stability, or neuroadaptation effects. This trial did not assess contrast sensitivity, particularly under mesopic conditions, and did not include validated patient-reported outcome measures; both should accompany functional endpoints in future work. While we recorded preferred reading distance and used a satisfaction-based algorithm to guide LVC decisions, these do not substitute for homologated PROMs. While PROMs would complement objective outcomes, they principally reflect uncorrected daily function. Finally, because reading speed was measured at a fixed IReST print size, our results isolate functional performance at a common print size rather than across the full print-size range. Additionally, the distance correction was standardized to 4 meters instead of infinity, which should be considered when interpreting distance-corrected intermediate and near vision values, reading speed, and defocus curves. However, this approach is common in clinical studies, ensuring comparability with existing literature. A thorough analysis of all patients seeking LVC will be topic of a future study.

In summary, our findings emphasize the need for including reading speed assessments—particularly under mesopic conditions—when evaluating IOL performance. Both IOLs showed good optical performance in controlled settings, but the significant drop in mesopic reading speed underlines a critical real-world limitation. Future studies should prioritize standardized reading assessments and consider mesopic functionality as a primary endpoint in presbyopia correcting IOL research. Clinicians should also counsel patients regarding the likely need for adequate lighting or reading aids despite high performance on conventional vision charts.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

JASCHA A. WENDELSTEIN: Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis. **KEVIN VALLOTTON:** Writing – original draft, Formal analysis, Data curation. **ALEX ZIÖRJEN:** Resources, Investigation, Data curation. **MAYA MÜLLER:** Supervision, Investigation, Data curation. **KAMRAN M. RIAZ:** Writing – review & editing, Validation, Investigation. **SETH M. PANTANELLI:** Writing – review & editing, Supervision, Investigation. **ACHIM LANGENBUCHER:** Writing – review & editing, Supervision, Methodology, Investigation. **THEO G. SEILER:** Supervision, Project administration, Funding acquisition, Data curation.

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