Original Article

A comparative study and review of visual outcomes with enhanced versus standard monofocal intraocular lenses following cataract surgery

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ABSTRACT

Background: Recent innovations in intraocular lens (IOL) design have introduced extended depth of focus lenses, which has shown promise in improving visual acuity at multiple distances while preserving the distance vision provided by a standard monofocal IOL. This study aimed to evaluate the visual outcomes of TECNIS Eyhance, a monofocal IOL with enhanced intermediate function, and a standard TECNIS monofocal 1-piece IOL, and to review published studies comparing the clinical performance between the TECNIS Eyhance and standard IOLs.

Methods: A retrospective analysis was conducted on patients who underwent cataract extraction with bilateral implantation of either TECNIS Eyhance IOLs or TECNIS Monofocal 1-Piece IOLs. Primary outcomes included monocular and binocular uncorrected distance visual acuity (UDVA), uncorrected near visual acuity (UNVA), and corrected distance visual acuity (CDVA), and manifest refraction. Outcomes such as glare, halos, and dry eye were also assessed. A literature review was performed to identify studies evaluating the clinical outcomes of TECNIS Eyhance and standard TECNIS monofocal IOLs.

Results: In total 108 patients (216 eyes) underwent bilateral implantation with either TECNIS Eyhance (104 eyes) or TECNIS Monofocal 1-Piece (112 eyes) IOLs. The mean (standard deviation [SD]) binocular UNVA was better in the Eyhance group at 1 month (0.18 [0.13] logMAR) compared to the standard monofocal group (0.24 [0.14] logMAR; $P < 0.05$). A greater proportion of Eyhance patients achieved binocular UNVA of 20/25 or better (46.9% vs 21.8%; $P < 0.01$), and 20/32 or better (65.3% vs 45.5%; $P < 0.05$). However, there was no significant difference for 20/20 visual acuity (20.4% vs 18.2%; $P > 0.05$). No significant differences were observed in postoperative UDVA or CDVA between groups (both $P > 0.05$). The mean (SD) monocular UNVA showed a slight, but non-significant, advantage in the Eyhance group (0.26 [0.15] logMAR vs 0.29 [0.15] logMAR; $P > 0.05$). Eyhance eyes demonstrated less residual refractive cylinder at 1 month ($P < 0.01$), which may be attributed to a higher rate of toric IOL use ($P < 0.01$). Patient-reported visual symptoms did not differ between groups. Thirteen studies were identified that compared the Eyhance and standard monofocal IOLs. Across the studies analyzed, the Eyhance group showed better monocular and binocular UNVA with mean (SD) differences of - 0.10 (0.20) logMAR and - 0.10 (0.21) logMAR, respectively (both $P < 0.01$), as well as improved binocular uncorrected intermediate visual acuity (UIVA) (mean difference [SD]: -0.10 [0.18] logMAR; $P < 0.01$). These studies also showed low rates of glare and halos for both IOLs.

Conclusions: Patients receiving the TECNIS Eyhance IOL had better binocular UNVA compared to those with a standard monofocal IOL, consistent with published literature. The Eyhance IOL also showed better binocular UIVA and monocular UNVA across the studies reviewed. Both enhanced and standard monofocal IOLs demonstrate excellent distance vision and have similar levels of photic phenomena. Nevertheless, the Eyhance IOL shows promising potential for improving intermediate and near vision.

KEYWORDS

phacoemulsification, intraocular lenses, enhanced monofocal, Eyhance, extended depth of focus (EDOF), multifocal intraocular lens, ocular vision, vision, monocular vision, binocular vision, corneal astigmatism, myopic astigmatism, near vision, intermediate vision, depth of field

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INTRODUCTION

Cataract surgery with implantation of an intraocular lens (IOL) is not only among the most performed surgical procedures worldwide but it is also one of the safest, with postoperative visual improvement reported in up to 95% of cases [1, 2]. Recent innovations in IOL design include extended depth of focus (EDOF) lenses, which generate an elongated focal point [3]. In contrast, a standard monofocal IOL corrects vision at a single distant focal point [3]. The EDOF optical design results in comparable benefits to multifocal lenses, such as spectacle independence and improved visual acuity at multiple distances, while minimizing visual disturbances such as glare and halos to a greater extent [3-5].

Some IOLs, such as TECNIS Eyhance (Johnson&Johnson Surgical Vision, Santa Ana, CA, USA), have been developed to extend depth of focus in a similar way to EDOF lenses. Although they are not officially classified as EDOF IOLs, they are categorized as a new generation of monofocal IOLs known as enhanced monofocals [6]. The TECNIS Eyhance IOL builds upon the standard monofocal design of the same platform, the TECNIS Monofocal 1-Piece IOL (ZCB00). Its design is intended to improve intermediate visual acuity while preserving monofocal-like distance vision [7]. The TECNIS Eyhance IOL is available in two models: DIB00 (preloaded with the TECNIS Simplicity system) and ICB00 (non-preloaded) [7, 8], which began to be used clinically following European Conformity mark approval in 2019 [9].

TECNIS Eyhance achieves its intermediate vision benefit through a higher-order aspheric anterior surface that introduces a gradual increase in optical power from the periphery toward the center [10]. Thereby, the TECNIS Eyhance is able to enhance the depth of focus without compromising distance vision. Although this design was intended to improve intermediate vision, its impact on near vision was not addressed [7]; however, several studies have shown an improvement in near vision with the TECNIS Eyhance compared to the TECNIS Monofocal 1-Piece IOL [11-15].

This study aims to evaluate visual outcomes, including monocular and binocular vision, between TECNIS Eyhance and TECNIS Monofocal 1-Piece IOLs in a U.S. cohort, as well as compare our findings to other published studies.

METHODS

This non-randomized, retrospective study compared preoperative and 1-month postoperative data of patients at a single refractive surgery center in Draper, Utah, USA. All patients underwent phacoemulsification with bilateral implantation of either TECNIS Eyhance DIB00 IOLs or TECNIS Monofocal 1-Piece ZCB00 IOLs, performed by a single surgeon (M.M.). The protocol of study was approved by the Hoopes Vision Ethics Committee and the Biomedical Research Alliance of New York Institutional Review Board (# A20-12-547-823). The study was conducted in accordance with the tenets of the Declaration of Helsinki, and all patients provided written informed consent prior to the study.

Inclusion criteria included patients underwent phacoemulsification and targeted for emmetropia, use of identical lens models in both eyes, and at least one month of postoperative follow-up. Patients were excluded if they were targeted for monovision or if they had a history of ocular comorbidities affecting vision, such as glaucoma, Fuchs' dystrophy, macular degeneration, epiretinal membrane, retinal disease, corneal disease, clinically significant dry eye, and Salzmann nodular degeneration.

A comprehensive examination of the anterior and posterior ocular segments was performed on all participants using a slit-lamp biomicroscope. Primary postoperative outcomes included: monocular uncorrected distance visual acuity (UDVA), monocular uncorrected near visual acuity (UNVA), binocular UDVA, binocular UNVA, corrected distance visual acuity (CDVA), spherical component of manifest refraction (sphere), cylindrical component of manifest refraction (cylinder), and spherical equivalent (SEQ). Corrected and uncorrected visual acuities were obtained by an optometrist using a Snellen chart (M&S Technologies Inc., Niels, IL, USA) displayed on a high-resolution screen at 4 meters. UNVA was measured at 40 cm. All near vision measurements were converted from Jaeger scores to Snellen visual acuity [16], and all visual acuity measurements were further converted from Snellen visual acuity to logarithm of the minimum angle of resolution (logMAR) using a standard formula, $LA = (\frac{1}{S})$, for statistical analysis [16]. Secondary outcomes included patient-reported visual outcomes such as dry eyes, glare, halos, night vision difficulties, and photophobia. These subjective outcomes were recorded at the 1-month postoperative visit.

To identify articles that have previously compared TECNIS Eyhance and TECNIS Monofocal 1-Piece IOLs, we performed a literature search using PubMed, Embase, and MEDLINE databases on June 23, 2025, considering studies from 2009 onwards (Figure 1), using the following keywords: ("Eyhance" OR "DIB00" OR "ICB00" OR "ZCB00" OR "DCB00"). The keywords ("Extended depth of focus" OR "EDOF") were not included because TECNIS Eyhance is not officially classified as an EDOF.

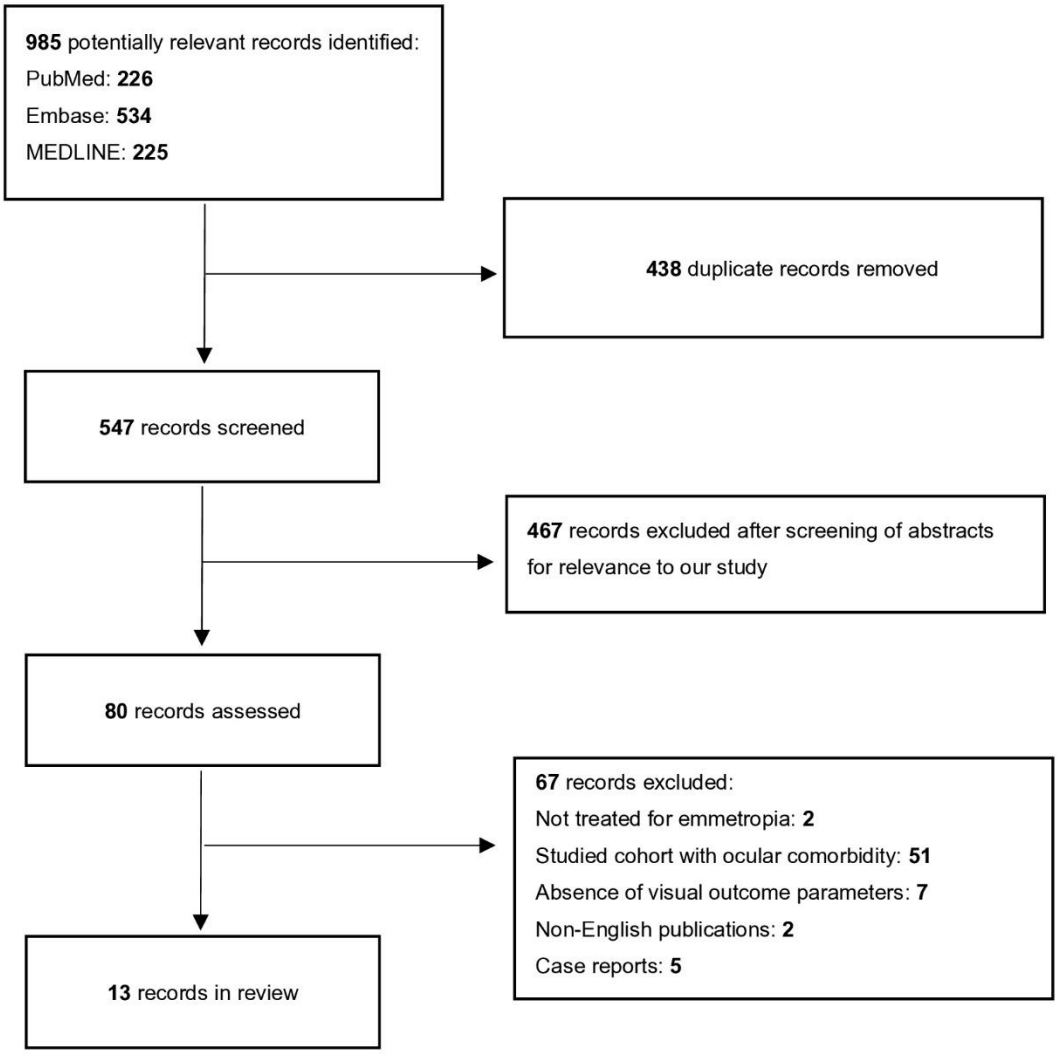

Figure 1. Flowchart of literature review process and selection of publications to include in this study.

We extracted data from studies that met the following selection criteria: direct comparison of TECNIS Eyhance and TECNIS Monofocal 1-Piece IOLs, reported visual outcomes for at least UNVA, uncorrected intermediate visual acuity (UIVA), or UDVA, involved bilateral implantation and target for emmetropia, and had at least 1 month of follow-up data. Studies were excluded if they were duplicates, case reports, non-English, compared patients with ocular comorbidities, lacked visual outcome parameters, or were irrelevant to the study objective. We used a standardized form to record the authors of the study, year of publication, country of the study, sample size, duration of follow-up, and outcome measures (SEQ, CDVA, UDVA, UIVA, UNVA, binocular UDVA, binocular UIVA, and binocular UNVA). The summary of included studies is represented in Table 1. For continuous data such as visual acuity, the mean values and standard deviations (SDs) were extracted. If the visual acuity was reported using Snellen or decimal notation, it was converted into logMAR units. The data from the last follow-up point was used.

TECNIS Eyhance and TECNIS Monofocal 1-Piece IOL will hereafter be referred to as Eyhance and standard monofocal, respectively, throughout the study.

Cataract extraction was done in the operating room under sterile conditions. A manual 2.25 mm clear corneal incision was made using a keratome, after which a 5.0–5.5 mm continuous curvilinear capsulorhexis was performed. Phacoemulsification was executed in a horizontal chop or divide-and-conquer fashion using the Infiniti Vision System (Alcon Laboratories, Inc., Fort Worth, TX, USA). No complications occurred, and all wounds were confirmed to be self-healing.

For IOL power calculation, each patient received biometric scans before surgery from both the Lenstar LS 900 (Haag-Streit, Mason, OH, USA) and the IOLMaster 700 (Carl Zeiss Meditec Ag, Jena, Germany) to measure axial length, anterior chamber depth, lens thickness, central corneal thickness, white-to-white, flat keratometry, and steep keratometry. The average of each measurement was imported into the European Society of Cataract and Refractive Surgeons IOL calculator, which calculates IOL power using the following formulas: Barrett Universal II, Cooke K6, EVO, Hill-RBF, Kane, Hoffer QST, and PEARL-DGS [17]. Given a target for emmetropia, the IOL power that produced a predicted postoperative refraction closest to 0.00 diopter (D) across all seven formulas was selected.

A priori power analysis was performed using G*Power (v3.1), which determined a required sample size of 86 eyes in each group (172 total eyes), with a power of 0.9 and a significance level of 0.05. However, as both eyes from a singular patient were included, inter-eye correlation is expected. The effective sample size is therefore lower than the total number of eyes, as calculated using Python (version 3.13.2). When accounting for this correlation using generalized estimating equations, the estimated power of the study is approximately 0.73 rather than the intended 0.9.

The Analysis ToolPak and RealStats add-ins for Microsoft Excel software (version 2506; Microsoft Corporation, Redmond, WA, USA) were used to calculate summary descriptive statistics and perform all statistical tests. All data were tested for normality using a Shapiro–Wilk test. Two-tailed independent *t*-tests were used to compare means of normally distributed continuous data. Mann–Whitney tests were used to compare means of continuous data that were not normally distributed. Chi-square tests were used for categorical comparisons, with Fisher's Exact Test applied in cases where the assumptions of the chi-square test were not met (expected frequencies < 5). Weighted means and SDs were calculated, and two-tailed independent z-tests were performed to evaluate the difference in means between groups from Table 1. A *P*-value < 0.05 was considered to be statistically significant.

RESULTS

In total 108 patients (216 eyes) underwent bilateral implantation with either TECNIS Eyhance (52 patients, 104 eyes [48.1%]) or TECNIS Monofocal 1-Piece (56 patients, 112 eyes [51.9%]) IOLs. Preoperative characteristics for each treatment group are summarized in Table 2. The proportion of eyes receiving toric lenses was significantly higher in the Eyhance group (n = 33, 31.73%) compared to the standard monofocal group (n = 21, 18.75%; $P < 0.01$). Although toric lenses were selected more frequently in the Eyhance group, there was no significant difference in corneal astigmatism, measured as the difference between steep and flat keratometry (Δ K) ($P > 0.05$). This held true even when evaluating patients with astigmatism of 1.00 D or greater ($P > 0.05$), suggesting that the higher rate in the Eyhance group reflects patient choice rather than necessity (Table 2). Sex, age, refractive error (sphere, cylinder, and SEQ), intraocular pressure, axial length, anterior chamber depth, central corneal thickness, lens thickness, IOL power, and cylinder power of toric lenses demonstrated no significant differences preoperatively between groups (all $P > 0.05$) (Table 2).

The mean (SD) preoperative monocular UDVA for the Eyhance group was 0.73 (0.40) logMAR compared to 0.73 (0.44) logMAR for the standard monofocal group (Table 1) ($P = 0.62$). At 1 month postoperatively, the Eyhance group showed an improvement to 0.13 (0.13) logMAR (Table 1) ($P < 0.01$), and the standard monofocal group improved to 0.12 (0.12) logMAR (Table 1) ($P < 0.01$). However, the difference between groups at 1 month was not statistically significant ($P = 0.75$). In addition, 31.7% (n = 33/104) of Eyhance eyes and 33.9% (n = 38/112) of standard monofocal eyes achieved 20/20 or better ($P = 0.73$), while 96.2% (n = 100/104) and 94.6% (n = 106/112), respectively, achieved 20/40 or better ($P = 0.60$; Figure 2B).

In the Eyhance group, the mean (SD) monocular UNVA was 0.49 (0.23) logMAR at baseline, which was better than monocular UNVA for the standard monofocal group (0.55 [0.20] logMAR; $P = 0.04$). Both Eyhance (mean [SD]: 0.26 [0.15] logMAR) and standard monofocal (0.29 [0.15] logMAR) groups (Table 1) had significantly better 1-month postoperative monocular UNVA compared to preoperatively (both $P < 0.01$), yet no statistically significant difference between groups was apparent ($P = 0.10$). Both Eyhance and standard monofocal eyes showed a comparable proportion of eyes achieving 20/20 or better (10.5% [n = 10/95] and 10.0% [n = 11/110], respectively; $P = 0.90$). Similarly, 68.4% (n = 65/95) of Eyhance eyes and 57.3% (n = 63/110) of standard monofocal eyes achieved 20/40 or better ($P = 0.10$; Figure 2D).

At 1-month postop, the Eyhance group had a mean (SD) binocular UDVA of 0.06 (0.10) logMAR and the standard monofocal group had a mean (SD) of 0.08 (0.11) logMAR (Table 1) ($P = 0.27$). In addition, 62.5% (n = 30/48) of Eyhance patients and 55.4% (n = 31/56) of standard monofocal patients achieved 20/20 or better ($P = 0.46$), while 97.9% (n = 47/48) of Eyhance patients and 98.2% (n = 55/56) of standard monofocal patients achieved 20/40 or better ($P = 0.91$; Figure 3A).

When comparing binocular UNVA, the mean (SD) for Eyhance IOL was significantly better at 1 month (0.18 [0.13] logMAR) relative to the standard monofocal IOL (0.24 [0.14] logMAR; $P = 0.03$) (Table 1). At that time, 20.4% (n = 10/49) of Eyhance patients achieved 20/20 or better, which was comparable to standard monofocal patients (18.2% [10/55]; $P = 0.77$). For the Eyhance group, 89.8% (n = 44/ 49) of patients achieved 20/40 or better in comparison to 80.0% (n = 44/55) of patients in the standard monofocal cohort ($P = 0.17$). However, a greater percentage of Eyhance patients (n = 23/49, 46.9%) achieved 20/25 or better compared to standard monofocal patients (n = 12/55, 21.8%; $P < 0.01$). A similar trend was observed with a binocular UNVA of 20/32 or better, with 65.3% (n = 32/49) of Eyhance patients achieving this outcome compared to 45.5% (n = 25/55) in the standard monofocal group ($P = 0.04$; Figure 3B).

The mean (SD) preoperative CDVA for Eyhance eyes (0.15 [0.13] logMAR) was significantly better than standard monofocal eyes (0.21 [0.16]; $P = 0.02$) (Table 1). By 1 month, there was no significant difference in mean (SD) CDVA between Eyhance eyes (0.03 [0.09] logMAR) and standard monofocal eyes (0.03 [0.07]; $P = 0.81$) (Table 1). There was also no difference in the proportion of eyes achieving CDVA of 20/20 and 20/40 or better between groups. Specifically, 83.5% (n = 81/97) of Eyhance eyes and 84.6% (n = 93/110) of standard monofocal eyes achieved 20/20 or better ($P = 0.84$), while 97.9% (n = 95/97) and 98.2% (n = 108/110), respectively, achieved 20/40 or better ($P = 0.90$; Figure 2F).

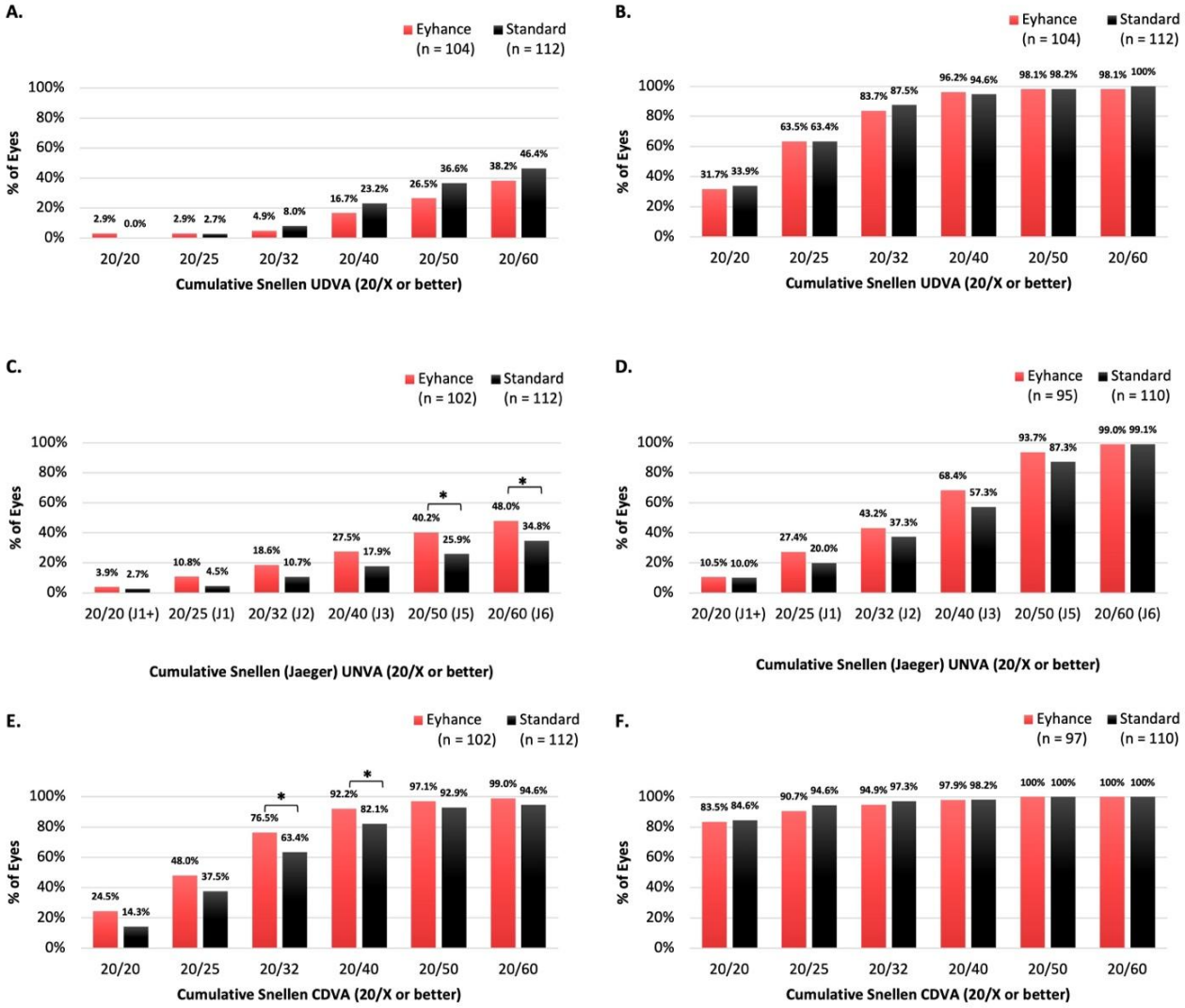

Figure 2. Percentage of eyes achieving a cumulative Snellen 20/X or better for (A) preoperative monocular UDVA, (B) 1-month postoperative monocular UDVA, (C) preoperative monocular UNVA, (D) 1-month postoperative monocular UNVA, (E) preoperative CDVA, and (F) 1-month postoperative CDVA for TECNIS Eyhance (Eyhance) and TECNIS Monofocal 1-Piece (Standard) IOLs. Abbreviations: n, number of eyes; %, percentage; UDVA, uncorrected distance visual acuity; UNVA, uncorrected near visual acuity; CDVA, corrected distance visual acuity. Note: * , an asterisk indicates statistically significant difference ($P < 0.05$); Due to the retrospective nature of the study and its limited one-month evaluation period, complete visual acuity data were not available for all included eyes.

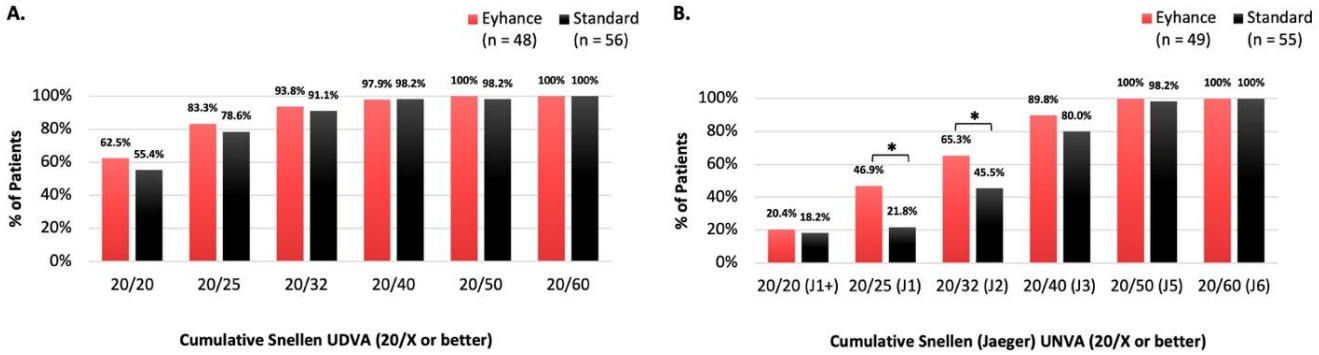

Figure 3. Percentage of patients achieving a cumulative Snellen 20/X or better for (A) 1-month postoperative binocular UDVA and (B) 1-month postoperative binocular UNVA for TECNIS Eyhance (Eyhance) and TECNIS Monofocal 1-Piece (Standard) IOLs. Abbreviations: n, number of eyes; %, percentage; UDVA, uncorrected distance visual acuity; UNVA, uncorrected near visual acuity. Note: *, an asterisk indicates statistically significant difference (*P* < 0.05); Due to the retrospective nature of the study and its limited one-month evaluation period, complete visual acuity data were not available for all included eyes.

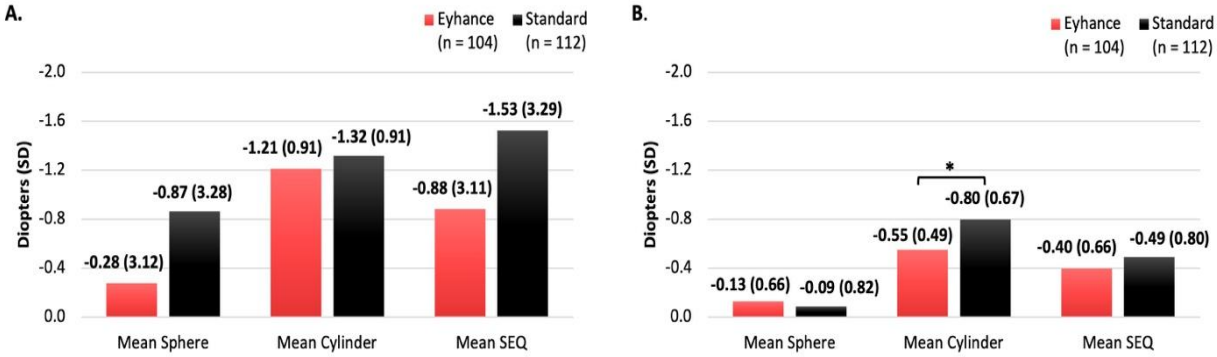

Figure 4. Mean manifest refraction (sphere, cylinder, and SEQ) measurements (A) preoperatively and (B) at 1-month postoperatively for TECNIS Eyhance (Eyhance) and TECNIS Monofocal 1-Piece (Standard) IOLs. Abbreviations: n, number of eyes; sphere, spherical component of manifest refraction in diopters; cylinder, cylindrical component of manifest refraction in diopter cylinder; SEQ, spherical equivalent. Note: * , an asterisk indicates statistically significant difference (P < 0.05); Mean values are shown outside parentheses, with corresponding standard deviations presented within parentheses; Spherical equivalent was calculated as the spherical component plus half of the cylindrical component of the manifest refraction.

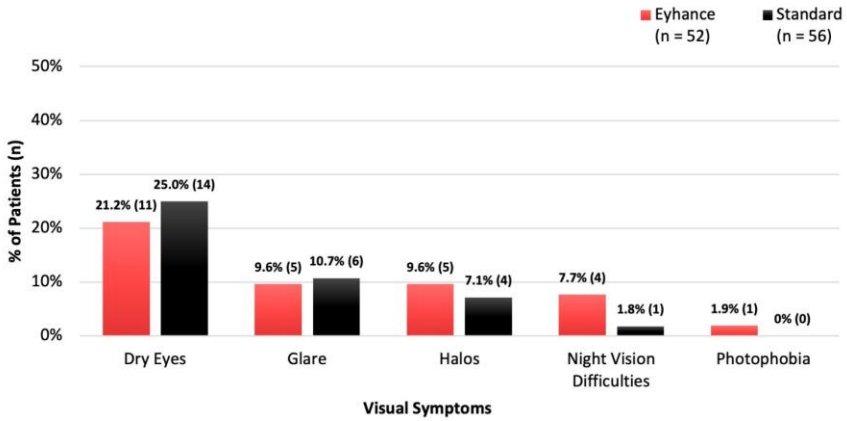

Figure 5. Percentage of patients reporting various visual symptoms at 1-month postoperatively for TECNIS Eyhance (Eyhance) and TECNIS Monofocal 1-Piece (Standard) IOLs. Note: Percentages are shown outside parentheses, while the corresponding frequencies (n) are presented within parentheses; Due to the retrospective nature of the study and its limited one-month evaluation period, complete visual acuity data were not available for all included eyes.

Table 1. Preoperative characteristics and postoperative visual outcomes of the current and previous studies

Preoperative									Postoperative							
Study	Country	n	F/U (m)	Age (y)	AL (mm)	SEQ (D)	UDVA	CDVA	SEQ (D)	CDVA	UDVA	UIVA	UNVA	Bi-UDVA	Bi-UIVA	Bi-UNVA
Current Study (2025)																
Eyhance		104	1	72 ± 9.8	24.34 ± 1.52	-0.88 ± 3.11	0.73 ± 0.40	0.15 ± 0.13	-0.40 ± 0.66	0.03 ± 0.09	0.13 ± 0.13	-	0.26 ± 0.15	0.06 ± 0.10	-	0.18 ± 0.13
Standard	U.S.	112	1	74 ± 6.7	24.06 ± 1.32	-1.53 ± 3.29	0.73 ± 0.44	0.21 ± 0.16	-0.49 ± 0.80	0.03 ± 0.07	0.12 ± 0.12	-	0.29 ± 0.15	0.08 ± 0.11	-	0.24 ± 0.14
Auffarth et al. (2021) [10]																
Eyhance	European	136	6	69 ± 8.7	-	-	-	-	-0.25 ± 0.05	-0.02 ± 0.01	-	0.16 ± 0.02	-	-	0.07 ± 0.12	-
Standard	Multi-Center	148	6	72 ± 6.8	-	-	-	-	-0.18 ± 0.04	-0.06 ± 0.02	-	0.27 ± 0.02	-	-	0.17 ± 0.16	-
Choi et al. (2023) [12]																
Eyhance	South	50	3	70 ± 5.8	-	0.28 ± 1.87	0.39 ± 0.32	0.18 ± 0.27	-0.47 ± 0.29	-0.02 ± 0.07	0.03 ± 0.05	0.05 ± 0.05	0.20 ± 0.14	0.01 ± 0.03	0.04 ± 0.05	0.14 ± 0.13
Standard	Korea	50	3	71 ± 5.8	-	0.07 ± 1.77	0.36 ± 0.36	0.22 ± 0.24	-0.45 ± 0.25	0.02 ± 0.10	0.07 ± 0.09	0.12 ± 0.13	0.33 ± 0.14	0.04 ± 0.07	0.10 ± 0.14	0.29 ± 0.14
Corbelli et al. (2022) [13]																
Eyhance		50	6	72 ± 4.3	23.72 ± 0.63	-0.06 ± 1.54	-	0.44 ± 0.14	-	0.00 ± 0.02	0.01 ± 0.02	0.28 ± 0.06	0.32 ± 0.04	0.01 ± 0.03	0.04 ± 0.04	0.28 ± 0.05
Standard	Italy	50	6	70 ± 11.2	23.64 ± 0.67	-0.44 ± 1.63	-	0.47 ± 0.15	-	0.01 ± 0.02	0.01 ± 0.02	0.38 ± 0.05	0.49 ± 0.09	0.01 ± 0.02	0.35 ± 0.09	0.49 ± 0.06
Dell et al. (2024) [11]																
Eyhance		766	1	60 ± 8.4	-	1.10 ± 3.03	-	-0.01 ± 0.10	-0.02 ± 0.40	-0.05 ± 0.07	0.02 ± 0.12	0.23 ± 0.18	0.51 ± 0.20	-0.03 ± 0.10	0.18 ± 0.18	0.42 ± 0.19
Standard	UK	766	1	60 ± 8.2	-	1.12 ± 3.50	-	-0.01 ± 0.10	-0.01 ± 0.43	-0.05 ± 0.09	0.01 ± 0.13	0.33 ± 0.19	0.61 ± 0.18	-0.04 ± 0.09	0.26 ± 0.20	0.51 ± 0.22
Donoso et al. (2023) [14]																
Eyhance		58	3	71 ± 6	23.41 ± 0.94	-	-	0.41 ± 0.24	-0.02 ± 0.84	0.02 ± 0.06	0.14 ± 0.24	0.43 ± 0.10	0.62 ± 0.15	0.06 ± 0.11	0.37 ± 0.12	0.58 ± 0.15
Standard	Chile	62	3	70 ± 7	23.41 ± 0.74	-	-	0.42 ± 0.21	0.04 ± 0.45	0.006 ± 0.06	0.11 ± 0.11	0.48 ± 0.10	0.69 ± 0.08	0.04 ± 0.07	0.45 ± 0.10	0.67 ± 0.09
Giglio et al. (2024) [31]																
Eyhance		60	3	75 ± 10.3	23.15 ± 0.61	-	-	-	0.03 ± 0.31	-0.03 ± 0.05	0.003 ± 0.09	0.2 ± 0.13	-	-0.03 ± 0.07	0.17 ± 0.12	-
Standard	Italy	60	3	77 ± 6.1	23.30 ± 0.88	-	-	-	-0.18 ± 0.41	-0.03 ± 0.04	0.03 ± 0.08	0.32 ± 0.1	-	-0.05 ± 0.06	0.32 ± 0.11	-
Gigon et al. (2022) [30]																
Eyhance		22	1 to 12	76	23.74	0.0	-	0.3	-	-	0	0.3	0.3	-	-	-
Standard	Switzerland	38	1 to 12	65	23.55	0.63	-	0.2	-	-	0	0.35	0.4	-	-	-
Huh et al. (2021) [18]																
Eyhance	South	30	1	70 ± 7.3	24.13 ± 1.38	-	0.37 ± 0.32	-	-	-0.01 ± 0.09	0.06 ± 0.10	-	-	-	0.03 ± 0.06	0.09 ± 0.14
Standard	Korea	30	1	71 ± 7.2	23.36 ± 0.66	-	0.33 ± 0.34	-	-	-0.02 ± 0.09	0.07 ± 0.09	-	-	-	0.25 ± 0.18	0.35 ± 0.14
Lopes et al. (2022) [22]																
Eyhance		60	3	71 ± 5.4	23.1 ± 0.8	-	-	-	-0.48 ± 0.4	0.03 ± 0.09	0.04 ± 0.18	0.21 ± 0.12	-	0.04 ± 0.12	0.17 ± 0.10	-
Standard	Portugal	60	3	72 ± 4.9	22.9 ± 1.0	-	-	-	-0.39 ± 0.5	-0.02 ± 0.07	0.04 ± 0.16	0.30 ± 0.15	-	0.01 ± 0.10	0.30 ± 0.13	-
Mencucci et al. (2020) [21]																
Eyhance		40	6	72 ± 6.7	-	0.30 ± 2.25	-	0.37 ± 0.16	-0.05 ± 0.27	0.02 ± 0.04	0.04 ± 0.05	0.28 ± 0.11	0.46 ± 0.13	0.03 ± 0.05	0.16 ± 0.10	0.33 ± 0.05
Standard	Italy	40	6	74 ± 6.8	-	-0.16 ± 2.15	-	0.34 ± 0.13	-0.16 ± 0.13	0.03 ± 0.05	0.05 ± 0.07	0.40 ± 0.10	0.50 ± 0.11	0.04 ± 0.05	0.27 ± 0.06	0.38 ± 0.05
Negishi et al. (2023) [39]																
Eyhance		60	1	70 ± 7.7	-	-	0.71 ± 0.52	0.11 ± 0.25	-0.69 ± 1.05	-0.06 ± 0.05	0.13 ± 0.24	-	-	-	-	-
Standard	Japan	60	1	70 ± 7.6	-	-	0.76 ± 0.50	0.07 ± 0.13	-0.81 ± 1.35	-0.07 ± 0.03	0.22 ± 0.38	-	-	-	-	-
Steinmuller et al. (2022) [15]																
Eyhance		30	3	66 ± 9.5	23.84 ± 1.75	-0.99 ± 2.27	-	0.27 ± 0.14	-0.24 ± 0.35	-0.15 ± 0.09	-0.05 ± 0.11	0.07 ± 0.12	0.26 ± 0.11	-0.12 ± 0.10	-0.04 ± 0.06	0.08 ± 0.10
Standard	Germany	30	3	72 ± 7.8	22.98 ± 0.93	1.02 ± 2.04	-	0.37 ± 0.21	-0.29 ± 0.48	-0.14 ± 0.09	-0.08 ± 0.09	0.20 ± 0.17	0.36 ± 0.23	-0.13 ± 0.10	0.07 ± 0.17	0.28 ± 0.20
Unsal et al. (2021) [25]																
Eyhance		32	1	56 ± 7.8	-	-1.75 ± 1.00	0.75 ± 0.46	0.51 ± 0.42	-0.36 ± 0.52	0.03 ± 0.05	0.04 ± 0.07	0.24 ± 0.16	-	-	-	-
Standard	Turkey	32	1	57 ± 8.1	-	-2.00 ± 1.25	0.80 ± 0.38	0.56 ± 0.52	-0.29 ± 0.23	0.02 ± 0.07	0.06 ± 0.08	0.39 ± 0.24	-	-	-	-

Abbreviations: n, number of eyes; F/U, follow-up; m, months; y, years; AL, axial length; mm, millimeters; SEQ, spherical equivalent; D, diopters; CDVA, corrected distance visual acuity; UDVA, uncorrected distance visual acuity; UIVA, uncorrected intermediate visual acuity; UNVA, uncorrected near visual acuity; Bi UDVA, binocular uncorrected distance visual acuity; Bi UIVA, binocular uncorrected intermediate visual acuity; Bi UNVA, binocular uncorrected near visual acuity; logMAR, logarithm of the minimum angle of resolution. Note: Values expressed as mean ± standard deviation; UDVA, CDVA, UIVA, and UNVA are reported in logMAR; UNVA was converted from Jaeger scores to logMAR, while all other visual acuities were converted from Snellen visual acuity to logMAR; Spherical equivalent was calculated as the spherical component plus half of the cylindrical component of the manifest refraction.

In the Eyhance group, the 1-month postoperative mean (SD) SEQ was - 0.40 [0.66] D, whereas the standard monofocal group was slightly more myopic at - 0.49 [0.80] D, although this difference was not statistically significant (P = 0.37). Postoperative mean (SD) sphere was comparable for both the Eyhance group (- 0.13 [0.66] D) and the standard monofocal group (- 0.09 [0.82] D; P = 0.73). However, Eyhance eyes showed less mean (SD) magnitude of cylinder at 1 month (- 0.55 [0.49] D) when compared to standard monofocal (- 0.80 [0.67] D; P < 0.01). These outcomes are displayed in Figure 4B.

At 1 month postoperatively, there were no significant differences between the Eyhance and standard monofocal groups in the frequency of dry eyes, glare, halos, night vision difficulties, or photophobia (all P > 0.05; Figure 5). Dry eye symptoms were the most reported among both cohorts, affecting 21.2% (n = 11/52) of patients in the Eyhance group and 25.0% (n = 14/ 56) in the standard monofocal group (P = 0.64).

Table 2. Preoperative characteristics of study groups

Preoperative parameters	Eyhance	Standard	*P*-value
Patients (n)	52	56	-
Eyes (n)	104	112	-
Sex (Male / Female), n, %	22 (42.31) / 30 (57.69)	27 (48.21) / 29 (51.79)	0.54
Age (y), Mean ± SD (Range)	72.00 ± 9.76 (36 to 86)	74.27 ± 6.71 (60 to 93)	0.64
Sphere (D), Mean ± SD (Range)	- 0.28 ± 3.12 (- 10.25 to 6.00)	- 0.87 ± 3.28 (- 10.75 to 4.00)	0.23
Cylinder (D), Mean ± SD (Range)	- 1.21 ± 0.91 (- 5.00 to 0)	- 1.32 ± 0.91 (- 4.75 to 0)	0.26
SEQ (D), Mean ± SD (Range)	- 0.88 ± 3.11 (- 10.50 to 4.63)	- 1.53 ± 3.29 (-10.88, 3.25)	0.14
Δ K (D), Mean ± SD (Range)	1.11 ± 0.92 (0 to 4.46)	1.19 ± 0.90 (0 to 4.51)	0.53
Δ K (< 1.00 D / ≥ 1.00 D), n (%)	57 (54.81) / 47 (45.19)	57 (50.89) / 55 (49.11)	0.57
IOP (mmHg), Mean ± SD (Range)	13.55 ± 3.48 (7 to 26)	14.43 ± 3.37 (7 to 25)	0.07
AL (mm), Mean ± SD (Range)	24.34 ± 1.52 (20.14 to 28.11)	24.06 ± 1.32 (21.58 to 28.38)	0.09
ACD (mm), Mean ± SD (Range)	3.22 ± 0.46 (2.00 to 5.76)	3.26 ± 0.44 (2.53 to 5.55)	0.54
CCT (μm), Mean ± SD (Range)	541.94 ± 50.34 (416 to 642)	552.23 ± 38.41 (462 to 648)	0.09
LT (mm), Mean ± SD (Range)	4.63 ± 0.47 (3.66 to 5.67)	4.64 ± 0.45 (3.55 to 5.92)	0.78
IOL Power (D), Mean ± SD (Range)	20.5 ± 5.39 (7.5, 34)	19.5 ± 4.13 (5 to 29.5)	0.12
Toric (Toric / Non-Toric), n (%)	33 (31.73) / 71 (62.27)	21 (18.75) / 91 (81.25)	**< 0.01**
Toric Cylinder Power, n (%)			
+ 1.50 D	12 (36.36)	5 (23.81)	0.33
+ 2.25 D	12 (36.36)	9 (42.86)	0.63
+ 3.00 D	7 (21.21)	1 (4.76)	0.13
+ 3.75 D	2 (6.06)	1 (4.76)	1.00
+ 4.50 D	0 (0.00)	3 (14.29)	0.05
+ 5.25 D	0 (0.00)	1 (4.76)	0.39
+ 6.00 D	0 (0.00)	1 (4.76)	0.39

Abbreviations: n, numbers; %, percentage; y, years; SD, standard deviation; D, diopters; SEQ, spherical equivalent; Δ K, corneal astigmatism, calculated as the difference between mean steep (K2) and mean flat keratometry (K1) values; IOP, intraocular pressure; mmHg, millimeters of mercury; AL, axial length; mm, millimeters; ACD, anterior chamber depth; CCT, central corneal thickness; LT, lens thickness; IOL, intraocular lens. Note: *P*-value < 0.05 is shown in bold; Spherical equivalent was calculated as the spherical component plus half of the cylindrical component of the manifest refraction.

Table 1 demonstrates the visual outcomes of published studies that were compared to the present study. In the 13 studies identified, a total of 1394 eyes (697 patients) received the Eyhance IOL, and 1426 eyes (713 patients) were implanted with the standard monofocal IOL. Eight studies were conducted in Europe, four in Asia, and one in South America. The follow-up period ranged from 1 month to 12 months for both groups. The weighted mean (SD) age for Eyhance patients (65 [9.78] years) was comparable to standard monofocal patients (65 [9.72] years; $P = 0.78$). In terms of visual outcomes, Eyhance eyes and standard monofocal eyes had similar results for mean (SD) postoperative monocular UDVA (0.03 [0.13] vs. 0.03 [0.15] logMAR; $P = 0.86$) and binocular UDVA (- 0.02 [0.10] vs. - 0.02 [0.09] logMAR; $P = 0.80$). Postoperative monocular mean (SD) UNVA was better in the Eyhance group (0.48 [0.21] logMAR) than the standard monofocal group (0.58 [0.19] logMAR; $P < 0.01$). In addition, mean (SD) of binocular UIVA and UNVA were significantly better in Eyhance eyes (0.16 [0.17] and 0.39 [0.21] logMAR, respectively) compared to standard monofocal eyes (0.26 [0.19] and 0.49 [0.21] logMAR, respectively; both $P < 0.01$). None of the studies showed a significant difference between groups in terms of patient-reported visual outcomes, such as glare and halos.

DISCUSSION

This study compared the visual and refractive outcomes between the TECNIS Eyhance and TECNIS Monofocal 1-Piece IOLs and compared our results to previously published literature. Both lenses showed a similar proportion of eyes achieving a binocular UNVA of 20/20 or better, indicating that the enhanced design of Eyhance may not yield the expected improvement in near vision at the 20/20 visual acuity level. Nevertheless, the Eyhance lens demonstrated better binocular near vision at the 20/25 and 20/32 levels.

Our findings are similar to the findings of Dell et al., who also reported improved binocular UNVA in the Eyhance group [11]. However, the authors did not find a significant difference between Eyhance and standard monofocal eyes at the 20/32 visual acuity level ($P = 0.06$). All other visual acuity thresholds (20/40, 20/50, 20/63, and 20/80) showed better

outcomes with the Eyhance group, with the exception of 20/20 and 20/25, which were not reported. Several other studies also report that Eyhance has significantly better binocular UNVA compared to the standard monofocal lens [12-15, 18]. Among these studies, Huh et al. reported the largest difference in binocular near vision between the two IOLs, with the Eyhance IOL achieving a mean (SD) binocular UNVA of 0.09 (0.14) logMAR and the standard monofocal IOL achieving 0.35 (0.14) logMAR ($P < 0.001$) [18].

Despite our significant binocular near vision findings, our monocular UNVA results yielded no difference between groups. The absolute mean (SD) monocular UNVA for the Eyhance IOL was slightly better than that of the standard monofocal lens (0.26 [0.15] logMAR vs 0.29 [0.15] logMAR), although this difference was not statistically significant. In contrast, prior studies have reported statistically significant improvements of both monocular and binocular UNVA in Eyhance patients relative to standard monofocal patients [11-15]. These findings may be attributed to the longer postoperative time frames in these studies compared to our 1-month study [12-15]. This may be further explained by binocular summation and neuroadaptation following bilateral implantation of EDOF IOLs. It is proposed that the success of such IOLs relies on the ability of the human brain to select a primary in-focus image among superimposed images, while suppressing those that are out of focus [19, 20]. Nevertheless, another study by Menucci et al. found conflicting results, showing no statistically significant difference in either monocular or binocular UNVA between the Eyhance IOL (mean [SD]: 0.33 [0.05] logMAR) and standard monofocal IOL (0.38 [0.20] logMAR; $P = 0.07$) [21].

This study found no difference between Eyhance and standard monofocal IOLs in terms of UDVA (monocular and binocular). Across the analyzed studies, neither monocular nor binocular distance vision was significantly better with either of the two IOLs [11-15, 21, 22]. In one study, Corbelli et al. found that the Eyhance group and the standard monofocal group had almost identical monocular and binocular distance vision outcomes [13]. Specifically, the reported mean (SD) monocular UDVA was 0.01 [0.02] logMAR for both groups, while binocular UDVA was 0.01 [0.03] logMAR for Eyhance eyes and 0.01 [0.02] logMAR for standard monofocal eyes [13]. This finding is consistent with what is expected, given that the design of the TECNIS Eyhance IOL aims to improve intermediate vision without compromising the distance clarity associated with other aspheric monofocal lenses, such as the TECNIS Monofocal 1-Piece IOL [7].

It is well-established that the depth of focus can be enhanced by inducing defocus, through spherical, astigmatic, or higher order aberrations [23]. While this may compromise visual acuity, it is compensated for by an enhanced depth of focus. Consequently, postoperative astigmatism has been associated with increased depth of focus and improved near vision, with the axis orientation influencing this effect [23, 24].

To account for potential bias introduced by astigmatism on depth of focus, we compared the postoperative astigmatism between the two IOLS. In our study, the standard monofocal IOL had a greater magnitude of postoperative astigmatism compared to the Eyhance IOL. Conversely, Steinmuller et al. and Unsal et al. found no significant difference in postoperative cylinder between the two IOLs [15, 25]. It could be argued that the higher use of toric IOLs in our Eyhance group contributed to the superior correction of cylinder and subsequent improved binocular near vision. However, the authors contend that if toricity were the primary factor, we would also expect a corresponding statistically significant improvement in distance vision relative to the standard monofocal IOL, which was not observed in our study. Therefore, we believe that the improved binocular near vision with the Eyhance lens is due to the design of the lens itself. A previous study has shown that both EDOF and enhanced monofocal IOLs have better tolerance to residual refractive error [25]. One study found that enhanced monofocal IOLs (DIB00 IOL) were more likely to maintain 20/40 or better with up to + 2.00 D of induced against-the-rule and oblique astigmatism than those with standard monofocal ZCB00 IOLs [26]. However, due to the retrospective nature of our study, axis orientation was not available for all patients; therefore, this could not be analyzed.

Prior studies have also shown that corneal astigmatism (preexisting or surgically induced) as small as 0.50 D can produce detectable changes in image quality perceived by patients, leading to reduced patient satisfaction [27]. However, our study found no significant difference in these patient-reported outcomes between the IOL types, irrespective of residual astigmatism. Several other studies have corroborated our findings [11-14, 21], including a study by Unsal et al., which reported no difference between TECNIS Eyhance and TECNIS Monofocal 1-Piece IOLs in terms of postoperative photic phenomena (glare, halos, starbursts, etc.) experienced by patients [25].

Auffarth et al. supported this by showing that less than 10% of patients reported visual disturbances such as glare, halos, and starbursts [10]. None of these studies reported on the incidence of dry eye, which we found to be the most commonly experienced symptom postoperatively for both treatment groups. These results signify to patients that no difference in glare and halo symptoms can be expected when choosing between TECNIS Eyhance and TECNIS

Monofocal 1-Piece IOLs. Nonetheless, Dolowiec-Kwapisz et al. and Hovanesian et al. have both reported that fewer photic phenomena occur after implantation of enhanced IOLs compared to multifocal lenses [28, 29]. This makes EDOFs and enhanced monofocal IOLs, such as TECNIS Eyhance, an appealing option for patients who wish for an extended range of vision and a lower likelihood of undesired visual symptoms, especially compared to multifocal IOLs.

The current study has a few limitations. This study was conducted retrospectively and only evaluates data up to one month. Due to these reasons, not all visual acuity measurements were performed across all patients, and other measurements such as UIVA were not performed. Previous studies have already compared these measures and found that the TECNIS Eyhance provides significantly better UIVA than TECNIS Monofocal 1-Piece IOL [10-15, 21, 22, 25, 30, 31]. However, the primary objective of this study was to assess near vision outcomes between IOLs and compare these outcomes with other comparative studies.

Despite the technology of the TECNIS Eyhance extending the depth of focus similar to EDOF IOLs, it is cleared under monofocal product codes *HQL* and *MPJ*, and not the EDOF code *POE*, according to its U.S. Food and Drug Administration (FDA) pre-market approval (PMA) [32, 33]. Therefore, TECNIS Eyhance was not required to demonstrate the extended depth of focus performance endpoints outlined for *POE* devices and is thereby not officially classified as an EDOF IOL [34]. AcrySof IQ Vivity (Alcon Laboratories, Inc., Fort Worth, TX, USA) and TECNIS Symfony (Johnson&Johnson Surgical Vision, Santa Ana, CA, USA;) are both FDA-approved EDOF IOLs, and their visual outcomes have been directly compared to TECNIS Eyhance [35, 36]. In a comparative analysis, Sabur et al. evaluated visual outcomes of both TECNIS Eyhance and AcrySof IQ Vivity and found that although UDVA and UIVA outcomes were comparable, AcrySof IQ Vivity yielded superior UNVA and spectacle independence results [37]. In addition, Lee et al. found TECNIS Eyhance to have similar UDVA and UIVA compared to TECNIS Symfony, but significantly worse UNVA and spectacle independence [38]. Neither study found any significant difference in patient-reported glare or halos between Eyhance and the respective EDOF [37, 38]. At length, TECNIS Eyhance provides superior near vision outcomes compared to standard monofocal IOLs; however, it still underperforms in near visual acuity when evaluated next to true EDOF lenses.

This study's strengths include its comparative design, standardized surgical technique, and comprehensive assessment of visual outcomes, enhancing the clinical relevance of the findings. However, the retrospective nature of the study and its limited one-month evaluation period resulted in incomplete visual acuity data for all included eyes, potentially affecting the robustness of the results. Additionally, non-randomized IOL allocation and the absence of contrast sensitivity testing limit the generalizability and functional interpretation of the outcomes. Future research should focus on prospective, randomized controlled trials with larger cohorts, longer follow-up periods, and inclusion of quality-of-life metrics to better assess real-world performance. Evaluating outcomes across diverse patient populations may further guide optimal IOL selection in cataract surgery.

CONCLUSIONS

The TECNIS Eyhance IOL provides significantly better binocular UNVA than the standard TECNIS Monofocal 1-Piece IOL, while preserving excellent distance vision and causing minimal photic phenomena. The Eyhance IOL also showed better binocular UIVA and monocular UNVA across the studies reviewed. Nevertheless, the Eyhance IOL shows promising potential for improving intermediate and near vision. Enhanced monofocal IOLs may present a satisfactory option for patients seeking improved near and intermediate visual acuity without compromising distance vision. Further studies with longer follow-ups should be conducted to evaluate the longevity of the Eyhance IOL and assess its clinical performance in comparison to other newer EDOF and enhanced monofocal IOLs.

ETHICAL DECLARATIONS

Ethical approval: This study was approved by the Hoopes Vision Ethics Committee and the Biomedical Research Alliance of New York Institutional Review Board (# A20-12-547-823). The study was conducted in accordance with the tenets of the Declaration of Helsinki, and all patients provided written informed consent prior to the study.

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