Original Article

Comparison of an aspheric monofocal intraocular lens with the new generation monofocal lens using defocus curve

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Purpose: The aim of this study was to compare the visual outcomes of two monofocal intraocular lenses (IOLs), with emphasis on the defocus curve. **Methods:** A total of 116 consecutive eyes with cataract, undergoing phacoemulsification with IOL implantation were included in the observational case series, and divided into two groups. 71 eyes were implanted with Tecnis Eyhance and 45 with Tecnis 1 monofocal IOL. Eyes with ocular comorbidities, previous ocular surgeries and corneal astigmatism >1 Diopters (D) were excluded from the study. Complete ophthalmic evaluation including uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), uncorrected intermediate visual acuity (UIVA), corrected intermediate visual acuity (CIVA), uncorrected visual acuity (UNVA), corrected near visual acuity (CNVA) was noted and defocus levels ranging from -4.00 D to + 1.00 D were plotted postoperatively in both groups. **Results:** Uncorrected intermediate visual acuity (UIVA) and uncorrected near visual acuity (UNVA) was significantly better in Tecnis Eyhance group compared to Tecnis 1 monofocal. Both the IOLs have similar performance for distance vision but visual acuity at intermediate and near is significantly better with Tecnis Eyhance compared to Tecnis 1 piece IOL. **Conclusion:** Tecnis Eyhance IOL with its better defocus curve, not only provides good distance, but intermediate vision as well. With significantly better visual acuity across the range of near and intermediate vision, Tecnis Eyhance IOL can prove to be a viable and reasonable option for patients who are more dependent on intermediate vision in daily activities.

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Intermediate vision zone is defined as –2.00 to –0.50 Diopters (D), from 50 cm (approximately arm's length) to two meters.[1] It is needed to perform tasks such as using computers, viewing the dashboard of car, aisle shopping, applying makeup, playing cards etc., In the current scenario with the changing needs and rising expectations of our patients following cataract surgery, intermediate vision is more important than ever. Unfortunately, monofocal IOLs do not address intermediate vision.[2,3] Monofocal intra ocular lenses (IOLs) provide a single point of focus for far vision, making reading glasses essential. The early multifocal IOLs (MIOL) reduced spectacle dependence after surgery but their patient satisfaction is variable owing to optical side effects, such as photic phenomena (glare, halos), decreased contrast sensitivity and inadequate intermediate vision.[3-8]

So far, IOL manufacturers mainly focused on correcting far and near vision only, but recently newer IOLs such as trifocals and extended depth of focus IOLs (Edof) have been introduced to address intermediate vision and offer greater spectacle independence. The newer multifocal IOLs reportedly have reduced incidence of photic phenomena but nonetheless patients are not free from these symptoms.[9-11] A new monofocal IOL, the Tecnis Eyhance, ICB00 (Eyhance) (Johnson & Johnson Vision), claims to offer better intermediate vision along with full far vision correction. This IOL is based on a similar aspheric platform as the Tecnis 1 single-piece model ZCB00, but features a continuous change in power from periphery to center, forming a unique anterior surface which provides better depth of focus.[12-14]

The performance of any IOL depends on many factors such as corneal astigmatism, biometry, effective lens position, pupil diameter etc., thus, comparing IOLs' performance in clinical practice can be difficult. Defocus curve is a strong, objective clinical measure of efficacy of an IOL in correcting presbyopia[15-18] and is widely used to objectively measure an IOLs performance at various distances.[19-22] Studies comparing visual performance of spheric and aspheric monofocal IOLs found better defocus curve in spheric IOLs. They attribute it to the reduction of spherical aberration to close to zero with aspheric IOLs.[23,24] Except for a few preliminary trials,[14] no peer reviewed literature is available on defocus curve and visual performance of the new Tecnis Eyhance IOL. We chose to compare Tecnis Eyhance with Tecnis 1 single piece IOL as both IOLs are monofocal and based on the same aspheric IOL platform. Hence, the purpose of our study was to measure the visual outcomes and monocular defocus curve of this new Tecnis Eyhance IOL (Tecnis ICB00) and compare it with Tecnis 1 single piece (ZCB00).

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Methods

Study design

In this observational consecutive case series, we enrolled patients undergoing cataract surgery with implantation of the Tecnis Eyhance Monofocal IOL (ICB00) or Tecnis 1 single piece monofocal (ZCB00) IOL between September 2019 and November 2019. A written informed consent was obtained from each study participant and the study adhered to the tenets of the Declaration of Helsinki.

The patients with visually significant, moderate cataract, in the absence of other ocular pathologies and corneal astigmatism less than 1 diopter were in included in the study. The eyes were divided in two groups: Tecnis Eyhance and Tecnis 1 single piece. The visual acuity (distance; 4 m, intermediate; 80 cm and near; 40 cm) and monocular defocus curve at two weeks were noted in both groups.

Intraocular lens

Tecnis 1 single piece: Tecnis 1 (ZCB00) monofocal is an acrylic hydrophobic anterior aspheric lens with an ultraviolet filter with a total diameter of 13.0 mm and an optic diameter of 6.0 mm. It is made on an aspheric platform which consists of wavefront aberrations analysis design and ProTEC 360° biconvex optics system with a square edge and 360° edge frosting to decrease glare. A dioptric range from + 5.0 D to + 34.0 D in 0.5 diopter increments is available. The optical A-constant for Tecnis 1 is 119.3.[12]

Tecnis eyhance

The Tecnis® Eyhance IOL (ICB00), is an acrylic hydrophobic one-piece, foldable, posterior chamber lens with a total diameter of 13.0 mm and an optic diameter of 6.0 mm. It has a spherical posterior surface and a modified aspheric anterior surface that is designed to provide distance vision and extended depth of focus, which provides improved intermediate vision in comparison to a standard aspheric monofocal IOL. There is a continuous increase in power from the periphery to the center of the lens, creating a unique anterior surface that improves intermediate vision, maintains distance image quality comparable to aspheric monofocal IOLs, delivers a profile of photic phenomena similar to the Tecnis 1, and keeps on reducing spherical aberration to near zero. Additionally, the lens compensates for corneal spherical aberration, similar to the Tecnis® monofocal IOL. Under slit lamp examination, this IOL is indistinguishable from Tecnis single piece lens. A dioptric range from + 5.0 D to + 34.0 D, in 0.5 diopter increments is available. The optical A-constant for Tecnis Eyhance is 119.3.[13]

Preoperative examination

All patients underwent a comprehensive preoperative ophthalmological examination including measurement of uncorrected and corrected distant visual acuity (UDVA and CDVA), near and Intermediate visual acuity, manifest refraction, keratometry, optical biometry (IOL Master 700, Carl Zeiss Meditec, Jena, Germany), Slit-lamp biomicroscopy, Goldmann applanation tonometry, and dilated fundoscopy. The target refraction was emmetropia and Barrett Total Keratometry formula (TK) was used in all cases.[21]

Surgical technique

All surgeries were performed under topical anesthesia by same surgeon (SPSG) using the same phacoemulsification technique. A 2.8 mm temporal clear-cornea incision was placed in all cases. Continuous curvilinear capsulorhexis was performed followed by phacoemulsification using Whitestar Signature Pro phaco system (Johnson & Johnson vision). IOL implantation in the bag was done after cortical matter aspiration in all cases.

Visual acuity

Standardized logarithm of the minimum angle of resolution (logMAR) charts were used for visual acuity measurement at 4 m, 80 cm, and 40 cm. The manifest refraction was measured using the 100% contrast Early Treatment Diabetic Retinopathy Study (ETDRS) chart under photopic light conditions (167 candelas/m^2), with the results reported in logMAR notation. The letters on the visual acuity charts were changed to prevent memorization.

Defocus curves

A monocular distance-corrected defocus curve was obtained in all cases, including levels of defocus from +1.00 to −4.00 D in steps of 0.50 D. Viewing a distant object through a -1.00 D lens is optically equivalent to viewing an object at 1 m, and viewing a distant object through a -4.00 D lens is optically equivalent to viewing an object at 25 cm.[15-18] Defocus testing was done with the help of trial frames under mesopic light conditions. The measurement was performed with ETDRS charts at 4 m using trial lenses. First, negative lenses were added in 0.5 D incremental steps. Then, positive lenses were used to test visual acuity at the corresponding defocus level. We noted down the visual acuity at each defocus level. The near zone was defined as between -4.00 and -2.00 D, corresponding with a 25 cm to 50 cm range, commonly referred to as the range of near vision. The intermediate zone was defined as -2.00 to -0.50 D, simulating 50 cm (approximately arm's length) to 2 meters. Beyond this, the distance zone was defined as the distances between -0.50 to +0.1.00 D simulating 2 meters to 6-meters distance.[1] The optometrists performing refractions and visual acuity were masked to the type of implants to prevent examiner's bias.

Outcome measures

Primary outcome measure: The monocular uncorrected (UDVA) and corrected (CDVA) distance visual acuity (6 m), Uncorrected intermediate visual acuity (UIVA), corrected intermediate visual acuity (CIVA) at 80 cm, uncorrected near visual acuity (UNVA) at 40 cm, and distance-corrected near visual acuity (CNVA) at 40 cm were assessed at two weeks following surgery. Monocular defocus curves obtained at the same visit.

Statistical analysis

Data analysis was performed using the software MS Excel 2013 (Microsoft Corporation, Redmond, Washington, USA) and SPSS for Windows version 15.0 (IBM, Armonk, NY, USA). Mean values and standard deviation were calculated for every parameter. Normality of data samples was evaluated by means of the Kolmogorov-Smirnov test. When parametric analysis was possible, Student t test for unpaired data was used for the comparison between groups. When parametric analysis was not possible, Mann-Whitney test was used to compare the analyzed parameters between groups. For all statistical tests, a *P* value of less than 0.05 was considered as statistically significant.

Results

We enrolled 71 eyes in Eyhance group and 45 in Tecnis 1 single piece group. In Eyhance group, there were 33 males and 38 females while in Tecnis 1 single piece group, there were 24 males and 21 females. The mean age of patients in Eyhance group was

65.43 ± 6.76 years (range 51-79) and 62.64 ± 14.41 years (range 29-85) in Tecnis 1 single piece group. Mean axial length in Eyhance group was 23.59 ± 0.44 mm (21.47 to 26.38) and 23.79 ± 1.36 mm (22 to 28.) in Tecnis 1 single piece. There was no significant difference in the preoperative spherical equivalent in both groups i.e., -1.72 ± 3.98 (-14.5 to 3.5D) in Eyhance group and 1.73 ± 4.01 (-17.5 to 3.0D) in Tecnis 1 single piece group (p = 0.72). The sociodemographic and clinical characteristics of the patients are shown in Table 1. There was no significant difference in the pre-operative parameters between both the groups.

Table 2 summarizes the postoperative visual and refractive outcomes in the analyzed sample. In the Eyhance group, the post-operative spherical equivalent ranged from -0.75 to 1.25D (mean -0.05 ± 0.61D) and in Tecnis 1 single piece group it ranged from -1 to 0.50 D (mean -0.09 ± 0.34D) *P* = 0.70. There was no significant difference in the post-operative visual acuity, both uncorrected (UCDVA) and corrected visual acuity (CDVA) i.e., p = 0.84 and *P* = 0.63 respectively in both groups. Eyhance group had a significantly better uncorrected intermediate visual acuity (UCIVA) compared to Tecnis 1 single piece group (*P* < 0.01). Fig. 1 shows the comparative chart of both IOLs, two weeks after surgery, at various distances (Near, intermediate and distance). Eyhance and Tecnis 1 single piece had similar acuity at distance. The visual acuity at intermediate and near were significantly better in Eyhance group compared to Tecnis 1 single piece 1 (*p* < 0.01). 73.2% (52 eyes) in Eyhance group had unaided distance visual acuity of better than 0.1 logMAR while 57.7% (26 eyes) in Tecnis 1 single piece group had better than 0.1 logMAR at two weeks follow up.

Fig. 2 shows the mean, monocular defocus curve of both groups. The mean defocus curve in both groups were similar at 0D which corresponds to distance vision (p = 0.72). The visual acuity was 0 logMAR at 0 defocus. Eyhance group has significantly better visual acuity across defocus levels from -0.50 to -4.00 D (p < 0.01). The defocus at -1.50 D corresponds to intermediate vision and at -2.50 D corresponds to near vision. Hence, Eyhance performed better not only at intermediate distance but also at near (Mann-Whitney; *P* < 0.01). The mean visual acuity was 0.2 logMAR at -1.5D defocus while in Tecnis 1 single piece group it was 0.3 logMAR. Fig. 3 is a scatter plot of attempted distant visual acuity and attained distant visual acuity in both groups. The attempted visual acuity was 0D or emmetropia in both groups.

Discussion

The aim of our study was to compare visual outcomes and defocus curves of two monofocal IOLs Tecnis 1 ZCB00 and Tecnis Eyhance ICB00 respectively. Conventional monofocal lenses provide single point of focus and near add is invariably needed in patients aimed for emmetropia. Even with meticulous biometry measurements, achieving emmetropia may not be possible in all cases with monofocal IOLs. Intermediate vision is not addressed in routine monofocal IOLs and patients need to wear progressive glasses or near vision glasses. Preliminary trials done using Eyhance IOL have shown favorable outcomes in distance and intermediate vision.[14] Visual performance of an IOL depends on various objective and subjective factors. There was no significant difference in both aided and unaided distance vision in both groups (p = 0.84 and 0.63 respectively). Interestingly, the unaided intermediate vision was significantly better in Eyhance group compared to Tecnis 1 single piece group (p < 0.01). Defocus curve is an objective measure of expected vision at different distances. The Tecnis 1 single piece IOL is based on an aspheric profile and is known to reduce total spherical aberration to close to zero across range of pupil sizes from 3 to 6 mm.[11] Eyhance IOL is based on the same aspheric platform as Tecnis 1 single piece IOL. The Eyhance group had significantly better vision across defocus levels of -1.00 to -4.00 diopters (p < 0.01) implying, it provides continuous range of

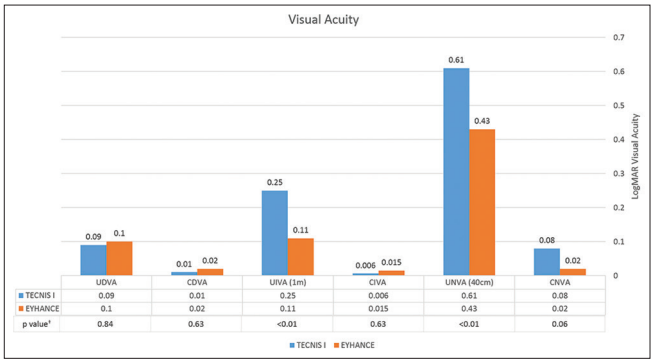

Figure 1: Comparative graph showing post-operative visual acuity at various distances in both groups. (VA- visual acuity, CNVA- corrected near visual acuity, UNVA- uncorrected near visual acuity, CIVA- corrected intermediate visual acuity, UIVA- uncorrected intermediate visual acuity, CDVA- corrected distance visual acuity, UDVA- uncorrected distance visual acuity)

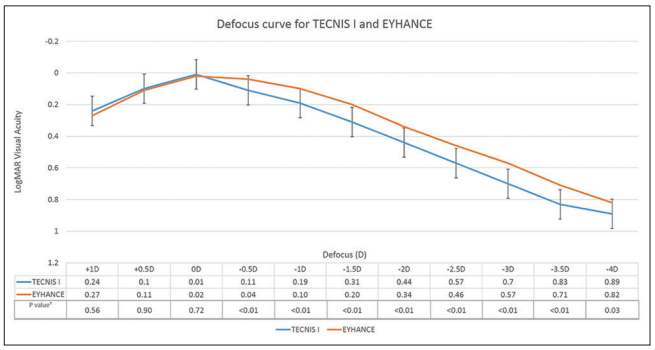

Figure 2: Defocus curve of Tecnis 1 and Eyhance IOL across defocus levels (+1 D to -4 D). †Mann-Whitney Test

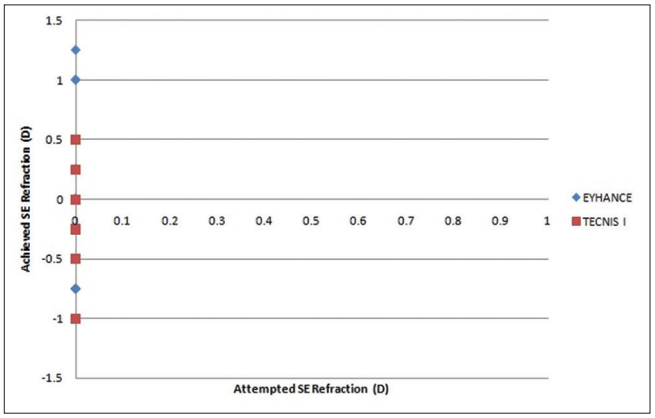

Figure 3: Scatter graph showing attempted distant visual acuity and achieved visual acuity in both groups

Table 1: Pre-operative parameters and patient demographic in each group

Parameter	Eyhance (ICB00) group			Tecnis I (ZCB00) group			*P*
No. of eyes	71			45			
Gender distribution	Male -33, Female- 38			Male -24, Female- 21			
	Mean	Standard deviation	Range	Mean	Standard deviation	Range	
Age (years)	65.43	6.76	51-79	62.64	14.25	29-85	0.08*
AL (mm)	23.59	1.08	21.47-26.38	23.79	1.35	22-28.59	0.19*
ACD (mm)	3.24	0.44	2.25-4.27	3.20	0.43	1.93-4.1	0.32*
Flattest keratometry	43.61	1.65	40.53-48	43.17	1.20	40.3-46	0.06*
Steepest keratometry	44.31	1.75	41.16-50.46	44.18	1.34	41.6-47.65	0.33*
Keratometry average	43.98	1.69	40.99-49.20	43.67	1.22	40.97-46.37	0.15*
LogMAR Uncorrected distance VA	1.06	0.67	0.10-2.00	1.01	0.69	0.10-2.00	0.43†
LogMAR Corrected Distance VA	0.55	0.55	0.00-2.00	0.41	0.46	0.00-2.00	0.15†
Sphere (D)	-1.01	3.04	-16.00-2.50	-0.88	3.08	-14.00-3.25	0.63†
Cylinder (D)	-0.17	0.83	-3.25-1.75	-0.18	0.97	-2.50-2.00	0.93†
Spherical Equivalent (D)	-1.10	3.29	-17.5-3.00	-0.97	3.26	-14.5-3.50	0.72†
LogMAR Corrected Near VA	0.57	0.30	0.30-1.20	0.50	0.28	0.30-1.20	0.31†

ACD=Anterior chamber depth; AL=Axial length; VA=Visual acuity. *Unpaired student *t*-test, †Mann-Whitney test

Table 2: Post-operative visual acuity in each group

Parameter	2 week post-operative		
	Eyhance (ICB00) group	Tecnis I (ZCB00) group	*P*†
LogMAR Uncorrected Distance VA			
Mean (SD)	0.10 (0.13)	0.09 (0.11)	0.84
Range	0.00-0.60	0.00-0.48	
LogMAR Corrected Distance VA			
Mean (SD)	0.02 (0.05)	0.01 (0.04)	0.638
Range	0.00-0.30	0.00-0.18	
Sphere (D)			
Mean (SD)	-0.03 (0.26)	-0.005 (0.19)	0.49
Range	-0.75-1.00	-0.75-0.75	
Cylinder (D)			
Mean (SD)	-0.08 (0.39)	-0.10 (0.37)	0.64
Range	-1.00-1.00	-0.75-0.75	
Spherical Equivalent (D)			
Mean (SD)	-0.017 (0.33)	0.005 (0.24)	0.56
Range	-0.75-1.25	-1.00-0.50	
LogMAR Uncorrected Intermediate VA			
Mean (SD)	0.11 (0.13)	0.25 (0.18)	<0.01
Range	0.00-0.50	0.00-0.50	
LogMAR Corrected Intermediate VA			
Mean (SD)	0.015 (0.057)	0.006 (0.03)	0.631
Range	0.00 to 0.40	0.00 to 0.20	
LogMAR Uncorrected Near VA			
Mean (SD)	0.43 (0.13)	0.61 (0.16)	<0.01
Range	0.00 to 0.80	0.40 to 1.00	
LogMAR Corrected Near VA			
Mean (SD)	0.02 (0.07)	0.08 (0.13)	0.06
Range	0.00 to 0.50	0.00 to 0.30	

SD - Standard deviation, VA - Visual acuity. †Mann-Whitney test

vision from 60 cm up to 25 cm. Rocha *et al*.[23] in a randomized controlled comparative study of defocus curve in spheric and aspheric IOLs found that reduction of total spherical aberration after aspheric IOL implantation may decrease the distance corrected intermediate and near acuity. In another comparative study between spheric and aspheric IOLs, Marcos *et al*.[24] found that even though the optical quality was better in aspheric IOLs, the tolerance to defocus was lesser than spheric IOLs. Eyhance, the new generation aspheric monofocal IOL has significantly better defocus curve at near (-4.00 D) as well as intermediate (-1.50 D) compared to Tecnis 1 single piece IOL. Therefore, Eyhance IOL not only has reduced spherical

aberration but also less degradation of intermediate and near defocus. Petermeier *et al*.[11] studied the influence of pupil size on vision quality and spherical aberration after implantation of Tecnis 1 single piece IOL. They concluded that pupil size did not influence contrast sensitivity and defocus curve after Tecnis 1 single-piece IOL implantation. In the Eyhance group, the post-operative spherical equivalent ranged from -0.75 to 1.25D (mean -0.05 ± 0.61D) and in Tecnis 1 single piece group it ranged from -1 to 0.50 D (mean -0.09 ± 0.34D) $P = 0.70$. The trend toward hyperopia in Eyhance group could be attributed to suboptimal IOL constant. Decentration of IOL may also lead to hyperopic shift. Even though, gross decentration was not noted in any of the eyes in both groups. On evaluation of monocular defocus curves of Eyhance and Tecnis 1 single piece IOLs [Fig. 2], we noted that Eyhance group, visual acuity was better than 20/32 at defocus of -1.50 D corresponding to 80 cm. On the other hand, Tecnis 1 single piece group had visual acuity of 20/40 at defocus of -1.50 D which was similar to results by Petermeier *et al*.[11] Therefore, the new generation IOL proves to be a viable option for patients desiring better intermediate vision. Hence, the defocus curve helps a surgeon in determining the choice of IOLs depending on patient's visual needs. Even though the target refraction in all eyes in both groups was aimed at emmetropia, the distant visual acuity in the Eyhance group was significantly close to emmetropia (73.2%) compared to Tecnis 1 group (57.7%) Fig. 3. This signifies the surgeon can have a broader 'landing zone' for post-operative emmetropia which can be attributed to the broader defocus curve of Eyhance IOL. We focused our study on comparison of visual acuity and defocus curves of two aspheric monofocal IOLs. The defocus curve in all patients were obtained in mesopic light conditions and the possibility of change in the curve in other light conditions cannot be ruled out. Limitations of our study include lack of randomization, factors such as contrast sensitivity, optical phenomena and higher order aberrations were not compared. Future studies with larger sample size, emphasizing on the above parameters and subjective patient satisfaction questionnaire are needed.

Conclusion

To conclude, Eyhance IOL provides significantly better intermediate vision compared to routine aspheric monofocal IOL. The new monofocal IOL, with a broader defocus curve provides better visual acuity across greater range of defocus levels (-0.50 D to -4.00 D).

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Conflicts of interest

There are no conflicts of interest.

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