

Optical and Clinical Outcomes of an Enhanced Monofocal Intraocular Lens for High Hyperopia

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ABSTRACT

PURPOSE: To evaluate the optical and clinical performance of an enhanced monofocal intraocular lens (IOL) (TECNIS Eyhance ICB00; Johnson & Johnson Vision) in patients with high hyperopia and a short axial length.

METHODS: Power mapping, wavefront analysis, and the through-focus modulation transfer function area (TF-MTFa) were measured in vitro for three IOL powers (10.00, 20.00, and 30.00 diopters [D]). The clinical study included 22 patients with an axial length of less than 22.5 mm. Uncorrected (UDVA) and corrected (CDVA) distance visual acuity and binocular defocus curve were evaluated 6 months postoperatively.

RESULTS: For the three IOL powers, the power mapping revealed an increase in positive power from the periphery to the center of the lens, providing an extra positive correction

of 1.00 D for a 2-mm pupil size. The TF-MTFa curves showed only a peak of maximum MTFa at the distance focus. As the pupil size became smaller, there was a focus extension effect, providing an extended depth of focus of up to -1.50 D for a 2-mm pupil size. No significant dependency of the IOL base power on the power profile, wavefront, or optical quality was found. The clinical outcomes showed that all patients achieved a binocular CDVA of 0.1 logMAR or better. The mean visual acuity was better than 0.1 logMAR between +0.50 and -1.50 D of defocus. At a vergence of -2.00 D, the visual acuity was 0.11 ± 0.13 logMAR.

CONCLUSIONS: The monofocal enhanced IOL provided good distance optical and visual quality and optimal visual acuity up to an intermediate-near vision distance of 50 to 40 cm in patients with high hyperopia and a short axial length.

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A new generation of the so-called enhanced monofocal IOLs has been developed to provide satisfactory intermediate-distance spectacle independence while preserving the visual quality of the standard monofocal IOL.¹⁻¹² However, no previous studies have evaluated the performance of these enhanced IOLs in patients with high hyperopia and a short axial length. We hypothesize that an enhanced monofocal IOL could be a promising approach for eyes with high hyperopia and a short axial length based on the following previous reported findings: (1) high IOL dioptric power and a short axial length do not involve a significant degradation in the distance visual qual-

ity with a standard monofocal IOL¹³; (2) a short axial length has been proposed as a good prognosis factor to reach a good near visual acuity with a standard monofocal IOL¹⁴; and (3) multifocal IOLs provide a higher effective addition power in short hyperopic eyes owing to a closer distance between cornea and IOL.¹⁵

The current study developed a comprehensive analysis of the optical and clinical performance of an enhanced monofocal IOL (TECNIS Eyhance ICB00; Johnson & Johnson Vision) in patients with hyperopia and a short axial length. To this extent, we first assessed the effect of changing the IOL power on the optical performance of the enhanced IOL; to this end, we

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characterized in vitro the IOL power profile and evaluated the optical quality of the IOL with base powers of 10.00, 20.00, and 30.00 D. In a second phase, we analyzed the clinical outcomes in a sample of patients with hyperopia and a short ocular axial length who had undergone bilateral lensectomy with TECNIS Eyhance ICB00 implantation.

PATIENTS AND METHODS

IOL

The IOL studied was the TECNIS Eyhance ICB00. It is categorized as an enhanced monofocal IOL. The IOL is a one-piece, hydrophobic acrylic lens that uses a higher order aspheric anterior surface (which creates a continuous power gradient, increasing progressively from the periphery toward the center) and a spherical posterior surface. The lens is designed to provide $-0.27 \mu\text{m}$ of primary spherical aberration for a 6-mm pupil.⁸ It has a total length of 13 mm and an optical zone of 6 mm. In this study, the optical bench analysis was done with lenses of 10.00, 20.00, and 30.00 D base power.

POWER PROFILE MAPPING AND WAVEFRONT ANALYSIS

The NIMO TR1504 device (Lambda-X SA) was used to map the power distribution and measure wavefront aberrations within the optic zone of the IOLs. The instrument uses a measuring light source with radiance peaking at 546 nm. The working principle of the NIMO instrument is based on a phase-shifting Schlieren technique.¹⁶ By combining this principle with a phase-shifting method, the NIMO instrument allows the measurement of light beam deviations, which can be used to calculate the power characteristics of the lenses and their wavefront considering 36 Zernike coefficients. This technology proves to be useful to effectively measure in vitro the optical quality of contact lenses and IOLs.¹⁷⁻²¹

For the three IOL powers studied (10.00, 20.00, and 30.00 D), we evaluated the power profile, root mean square (RMS) of the total higher order aberrations (HOAs) (third to seventh order, excluding Z_4^0 coefficient), and primary spherical aberration (Z_4^0) at six different aperture diameters (from 2 to 4.5 mm in steps of 0.5 mm).

OPTICAL PERFORMANCE

The optical performance of the IOLs was evaluated with a test bench that has been described in detail elsewhere^{1,22} and mainly consists of three parts: the illumination system, the model eye, and the image acquisition system. We have considered green illumination ($530 \pm 20 \text{ nm}$) as fixed by the International Organization for Standardization standard to $546 \pm 10 \text{ nm}$.²³ A high-

power green LED source illuminated a four-slit test located at the front focal plane of a collimator (200 mm focal length) for modulation transfer function (MTF) measurements.^{22,24}

The model eye was formed by an artificial cornea and a wet cell where the IOL was immersed. A variable aperture diaphragm, placed in front of the artificial cornea, was used as the entrance pupil to control the size of the collimated beam on the artificial cornea and hence the level of corneal spherical aberration of the converging wavefront that impinged on the IOL. Additionally, the entrance pupil size also determined the beam size on the IOL plane (hereafter referred to as IOL-pupil). The ratio of the IOL-pupil to the entrance pupil was experimentally calibrated to be 0.56. From now on, all pupil diameters are referred to as the IOL plane.^{25,26} The cornea was an achromatic doublet lens (Lambda-X) that induced $+0.175 \mu\text{m}$ of fourth-order spherical aberration for a 5-mm IOL-pupil. The model eye with the IOL formed an image of the four-slit test object at its best focus that was magnified through a $10\times$ infinity-corrected microscope and projected onto an 8-bit charge-coupled device camera. We fixed the capturing parameters of the charge-coupled device camera so as to avoid saturation. All optical elements in the set-up were mounted in high-precision mechanical holders with three-axis (x, y, and z) micrometer precision adjustments.

The MTF was measured at the best focus plane of the IOL for distance vision. This focus plane was experimentally determined for each IOL as the one that maximized the MTF for a 3-mm IOL-pupil and was set as the origin for defocus (ie, 0.00 D).

The through-focus MTF curves were obtained between -3.00 and $+1.00 \text{ D}$ in 0.10-D steps with three IOL pupil sizes: 2, 3, and 4.5 mm. Moreover, the optical quality of the lenses was also evaluated with the area under the MTF metric (MTFa) given its potential significance as a preclinical metric.^{22,27} The MTFa was obtained by integrating the MTF values of the model eye from 0 to 50 cycles/mm as reported elsewhere.²⁷ The MTF was computed from the images of the four-slit object and, more specifically, from the modulus of the Fourier transform of the line spread function of each slit²⁴ (ie, four MTF curves). The mean and standard deviation of the MTF and MTFa were derived from these four measurements. The higher the MTFa value, the better the optical quality of the IOL.

CLINICAL ASSESSMENT

The retrospective, observational study examined 44 eyes of 22 patients who underwent bilateral cataract surgery with implantation of the TECNIS Eyhance

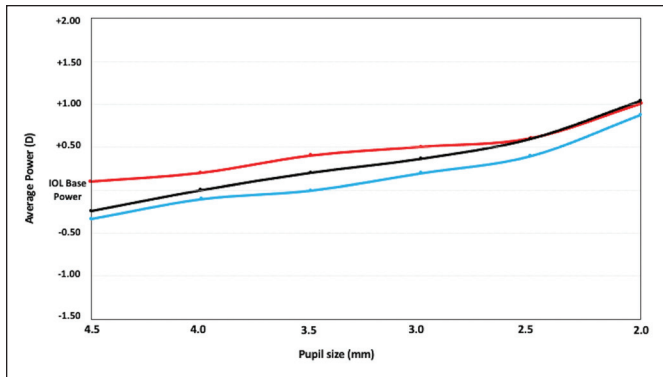


Figure 1. Plot showing the overlapping of the average intraocular lens (IOL) power curves of the three IOL powers for comparison purposes (30.00 diopters [D] = red line; 20.00 D = black line; 10.00 D = blue line).

ICB00 at Fernández-Vega Ophthalmological Institute, Oviedo, Spain. All patients provided written informed consent, and the nature and possible consequences of the study were explained fully in accordance with the tenets of the Declaration of Helsinki. Inclusion criteria were patients with ages between 55 and 75 years, corneal astigmatism of 2.00 D or less, axial length of less than 22.5 mm, and willingness of attending the postoperative follow-up of 6 months. Exclusion criteria were previous ocular surgery, irregular corneal astigmatism, abnormal iris, or any ocular conditions contraindicating presbyopia-correcting IOL implantation.

Before surgery, all patients had a complete ophthalmologic examination including manifest refraction, corneal topography-tomography (Sirius; CSO Ophthalmic), slit-lamp biomicroscopy, Goldmann applanation tonometry, and binocular indirect ophthalmoscopy through dilated pupils. Pupil diameter in distance vision was measured at two different levels of illumination using a pupillometer (Colvard; Oasis). Axial length and anterior segment size were measured with a non-contact optical biometer (IOLMaster 700; Carl Zeiss Meditec). The Barrett Universal II formula was used for IOL power calculation. The targeted refraction was emmetropia.

The same experienced surgeon (JFA) performed all surgeries. All eyes underwent phacoemulsification with the Centurion Vision System (Alcon Laboratories, Inc) using topical anesthesia. Clear corneal incision (CCI) was performed in the steep axis using the Callisto system (Carl Zeiss Meditec) to reduce preexisting astigmatism. One CCI (3.2 mm) was performed in eyes with astigmatism between 1.00 and 1.25 D, whereas two opposite CCIs (3.2 mm) were performed in eyes with astigmatism between 1.50 and 2.00 D. All eyes underwent femtosecond laser-assisted lens surgery with the CATALYS Precision System (Johnson & Johnson Vision) to perform the anterior capsulotomy and fragment

of the nucleus. A 14C Morcher capsular tension ring was implanted in all cases, aiming to provide capsular bag stability and facilitate the IOL centration.

Postoperative follow-up visits were scheduled at 1 day and 1, 3, and 6 months. At 6 months postoperatively, the clinical protocol to evaluate the visual and refractive outcomes included the following measurements: monocular and binocular uncorrected (UDVA) and corrected (CDVA) distance visual acuity at 100% contrast under photopic conditions (85 cd/m²). Binocular through-focus logMAR visual acuity (defocus curve; range from -3.00 to +1.00 D in 0.50-D steps) was measured in patients with a binocular CDVA better than 0.1 logMAR.

Data analysis was performed using SPSS for Windows software, version 14.0 (SPSS, Inc). Normality was checked with the Kolmogorov-Smirnov test. Visual and refractive outcomes were analyzed at the 6-month postoperative visit. Means and standard deviations or percentages were used to report postoperative visual and refractive results. The cumulative binocular UDVA and CDVA were calculated at 6 months postoperatively.

RESULTS

POWER PROFILE AND WAVEFRONT ANALYSIS

The power profiles measured for the three IOL powers studied (base powers of 10.00, 20.00, and 30.00 D) are shown in **Figure AA** (available in the online version of this article) The graphs reveal a change toward more positive power values from the periphery to the center of the lens for all three base powers. Analyzing the average IOL power for each pupil aperture (**Figure AB**), for a 2.5- and 2-mm pupil size, the IOL provided an extra positive correction of 0.50 and 1.00 D, respectively, over the nominal base power. The joint analysis of the three IOLs' base power (**Figure 1**) revealed no significant dependency of the IOL base power (10.00, 20.00, and 30.00 D) on the power profile. Similarly, the differences between the three IOL powers in spherical aberration (Z_4^0) (**Figure BA**, available in the online version of this article) and the RMS of HOAs (third to seventh order, excluding Z_4^0 coefficient) (**Figure BB**) were not significant for the six different aperture diameters analyzed.

OPTICAL PERFORMANCE

Figure 2 illustrates the TF-MTFa curves for a 2-, 3-, and 4.5-mm pupil size (**Figures 2A, 2B, and 2C**, respectively) for the three IOL powers studied. The curves for all three base powers and the three pupils showed just one peak of maximum MTFa (ie, best optical quality) corresponding to the best focus of the lenses for distance vision. Moreover, as pupil size became

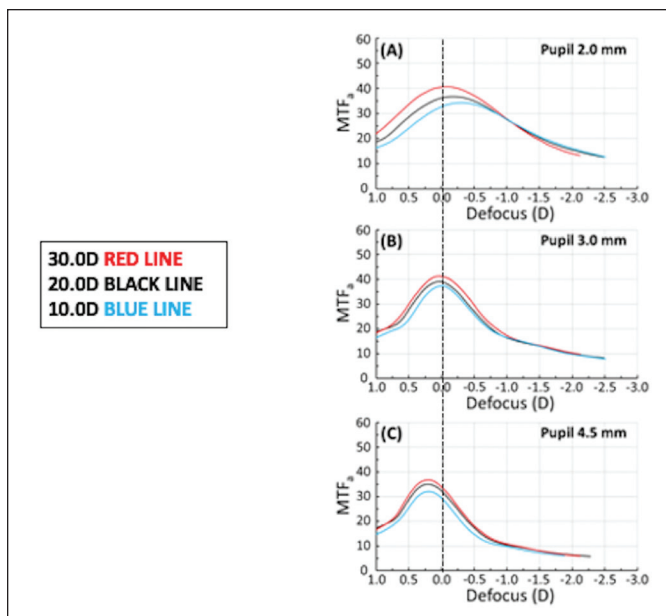


Figure 2. Through-focus area under the modulation transfer function (MTF_a) curves obtained with the three intraocular lens powers (30.00 diopters [D] = red line; 20.00 D = black line, and 10.00 D = blue line) and for three pupil diameters (A) 2; (B) 3, and (C) 4.5 mm. D = diopters

smaller there was a focus extension effect (widening of the peak and the curve shape) accompanied by a myopic shift of the position of the MTF_a peak (compare **Figures 1A** and **1C**). Overall and for each studied pupil, the curves showed a similar optical behavior for the three IOL powers and revealed that the IOL with the highest IOL dioptric power (30.00 D, red line) provided even better optical quality than the lenses with lower base power. The defocus value from which the MTF falls below 20 units was +0.75 D in the hyperopic side of the through-focus curves for all pupils, and -0.50, -0.75, and -1.50 D in the myopic side for a 4.5-, 3-, and 2-mm pupil size, respectively.

CLINICAL OUTCOMES

This study comprised 44 eyes of 22 patients (11 men and 11 women). All patients completed the follow-up period of 6 months. Preoperative demographic data of the patients are summarized in **Table 1**. The mean IOL power was $+28.58 \pm 2.53$ D (range: +26.00 to +34.00 D). The mean axial length was 21.74 ± 0.65 mm (range: 20.53 to 22.47 mm).

The mean postoperative monocular and binocular UDVA were 0.20 ± 0.20 and 0.10 ± 0.11 logMAR, respectively. In turn, the mean monocular and binocular CDVAs 6 months after surgery were 0.04 ± 0.08 and 0.01 ± 0.03 logMAR, respectively. No eyes lost lines of CDVA compared to the preoperative assessment, and 50% of the eyes experienced a gain of lines of CDVA. Of note, the preoperative CDVA in the eyes that did

TABLE 1
Preoperative Patient Data

Characteristic	Mean \pm SD (Range)
Age (years)	67.86 \pm 6.22 (55 to 75)
Refraction sphere (D)	+4.87 \pm 1.91 (+3.00 to +8.00)
Refraction cylinder (D)	-0.93 \pm 0.60 (-2.00 to 0.00)
Spherical equivalent (D)	+4.38 \pm 1.86 (+2.00 to +7.90)
CDVA (logMAR)	
Monocular	0.16 \pm 0.19 (0.00 to 0.70)
Binocular	0.10 \pm 0.16 (0.00 to 0.70)
UDVA (logMAR)	
Monocular	0.86 \pm 0.41 (0.15 to 2.00)
Binocular	0.78 \pm 0.45 (0.15 to 2.00)
Minimum keratometry (D)	43.41 \pm 1.63 (41.25 to 47.50)
Maximum keratometry (D)	44.18 \pm 1.46 (41.50 to 48.00)
ACD (mm)	2.38 \pm 0.36 (1.62 to 3.22)
Pupil diameter (mm)	
Photopic (85 cd/m ²)	3.03 \pm 0.53 (2.15 to 3.83)
Mesopic (3 cd/m ²)	4.68 \pm 0.67 (3.08 to 5.60)
Axial length (mm)	21.74 \pm 0.65 (20.53 to 22.47)
IOL power (D)	28.58 \pm 2.53 (26.00 to 34.00)

ACD = anterior chamber depth; CDVA = corrected distance visual acuity; D = diopters; IOL = intraocular lens; SD = standard deviation; UDVA = uncorrected distance visual acuity

not gain lines of CDVA after surgery was 0.05 ± 0.09 logMAR. **Figure 3** illustrates the cumulative binocular UDVA and CDVA. All patients achieved a binocular CDVA of 0.1 logMAR or better (20/25 or better) and 90.9% had a value of 0.0 logMAR (20/20).

Regarding refractive outcomes, 86.4% of the eyes (38 eyes) had a refractive sphere within ± 0.50 D and 100% within ± 1.00 D at 6 months after surgery (**Figure 4**). The postoperative refractive astigmatism was -0.68 ± 0.58 D. Twenty-nine eyes (65.9%) had a postoperative refractive astigmatism of less than 1.00 D and 15 eyes (34.1%) were between 1.00 and 2.00 D.

Figure 5 plots the postoperative binocular defocus curve after the bilateral TECNIS Eyhance ICB00 IOL implantation. As expected, the curve shows the best performance at the distance focus (0.00 D of vergence) and a progressive but smooth decay in visual acuity with increased negative defocus. A mean visual acuity better than 0.1 logMAR (20/25) was achieved in the vergence range from +0.50 to -1.50 D (the latter corresponding to 66 cm from the eye). At a vergence of -2.00 D (50 cm from the eye), the visual acuity was still 0.11 ± 0.13 logMAR, and at a vergence of -2.50 D (40 cm from the eye), the visual acuity worsened to 0.21 ± 0.11 logMAR.

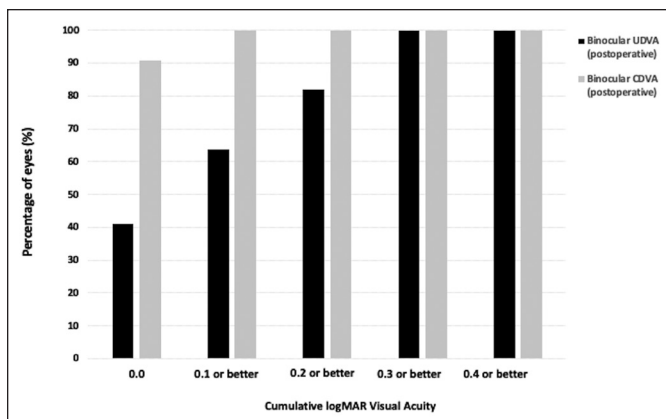


Figure 3. Cumulative binocular uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) at 6 months postoperatively.

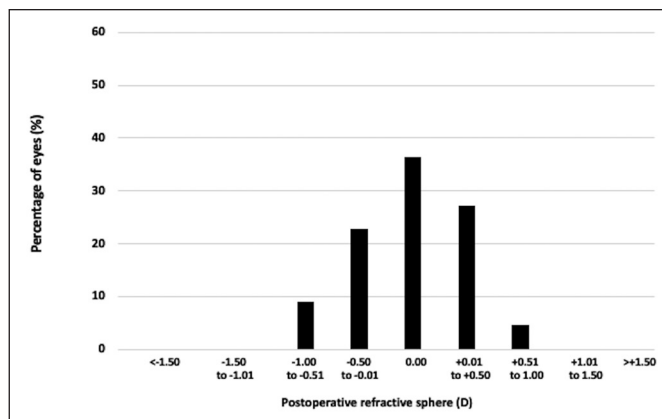


Figure 4. Postoperative manifest refractive sphere accuracy. D = diopters

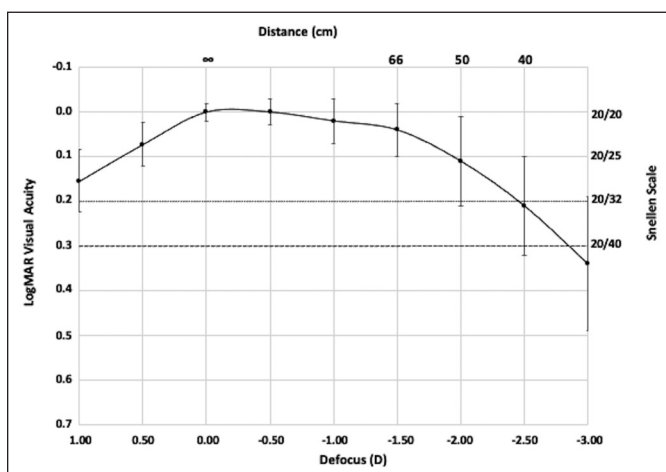


Figure 5. Mean binocular visual acuity (logMAR) with best correction for distance, as a function of the chart vergence. Y-axis on the right shows the Snellen feet equivalent of visual acuity, and X-axis vergence (bottom diopters and top equivalence in cm). Error bars represent the standard deviation. D = diopters

DISCUSSION

The paradigm of what should be considered successful cataract surgery is changing due to the visual requirements of the patients. Currently, in routine lensectomy (without considering refractive lens exchange with presbyopia correction purposes), the aim of the visual restoration after surgery is to achieve a good distance visual quality but also obtain a functional visual quality at closer distances. This study focused on visual rehabilitation after cataract surgery in patients with hyperopia and a short axial length through an enhanced monofocal IOL. The first part of this study assessed whether a high IOL base power affects the optical quality of this IOL, which could induce degradation in the visual quality after surgery attributable to the high IOL power.

The analysis of the power profile reveals that, no matter the lens base power, this IOL design provides

a gradient of power, increasing in positive power toward the center of the lens (Figure 1). This IOL design would favor the intermediate vision by providing an over-positive correction of 1.00 D (intermediate addition) when the pupil reaches a size of 2 mm. The joint analysis of the three IOLs (Figure 2) showed similar features for the three powers evaluated. Furthermore, wavefront analysis showed similar RMS HOAs and primary spherical aberration values at the three IOL powers and six pupil apertures studied, although, of note, the highest IOL dioptric power (30.00 D) yielded the lowest values in spherical aberration and RMS HOAs. These findings confirm that the optical design of the IOL remained without significant variations regardless of IOL power.

Regarding optical performance, previous studies have evaluated this enhanced monofocal IOL with a +20.00 D base power^{1,7} and reported that this design provides an optical quality comparable to a monofocal IOL in the distance focus and improved at intermediate foci when the pupil size becomes smaller, being the largest extension of focus achieved for a 2-mm pupil size. Our optical quality analysis with the TF-MTFa curve agrees with these previous outcomes, showing that as pupil size reduced, there was a focus extension effect accompanied by a myopic shift of the position of the MTFa peak. Considering 20 units as the MTFa threshold from which the visual acuity might decrease,²² this IOL would provide an extended range of vision up to -0.50, -0.75, and -1.50 D for a 4.5-, 3-, and 2-mm pupil size, respectively. Considering the pupil dynamic, which implies larger pupils for distance activities and a progressive pupil constriction at intermediate and near vision due to the accommodation reflex, which usually is performed under photopic lighting conditions, this IOL would have optical behavior comparable to a monofocal IOL for distance vision and an extended range of focus up to -1.50 D

(equivalent to 66 cm from the eye). Focusing on the aim of this study, for patients who require a high IOL power, the optical quality was not penalized in lenses having the highest base power (30.00 D). On the contrary, they provided even better optical quality than the lenses with a lower base power.

The in vitro analysis of this enhanced monofocal IOL allows us to conclude that there is no worsening in the optical quality or changes in the design attributable to the high IOL power. Hence, it should be expected that similar to that reported in patients with low ametropia, in patients with high hyperopia and a short axial length, this IOL will provide a distance visual quality comparable to a standard monofocal IOL and an improvement in intermediate distance vision up to 66 cm. To confirm this, in the second phase of this study, we retrospectively evaluated the clinical outcomes of bilateral TECNIS Eyhance ICB00 IOL implantation in a selected sample of patients with high hyperopia and short axial length.

One of the most important assessments for the success of this procedure is that residual refractive error after IOL implantation should be near to emmetropia. To do so, biometric measurements and IOL power calculation should be as accurate as possible, and one should choose the appropriate formula. The use of different formulas has been evaluated for short eyes. Kane and Melles²⁸ found that the Kane or EVO 2.0 formula yielded the more accurate IOL estimation in patients with an IOL power of 30.00 D or more. In turn, Melles et al²⁹ reported that the Barrett Universal II formula had the lowest mean absolute prediction error in a sample of 1,270 eyes with an axial length of less than 22.5 mm. In the current study, we chose the Barrett Universal II formula. At 6 months postoperatively, our results showed that 86.4% of the eyes had a refractive sphere within ± 0.50 D and 100% within ± 1.00 D. Evidence-based guidelines based on the analysis of the database of the European Registry of Quality Outcomes for Cataract and Refractive Surgery, which included 282,811 cataract extractions, recommended an absolute biometry prediction error of 0.45 D or less and that at least 90% of cases should fall within an absolute error of ± 1.00 D.³⁰ Short eyes represent a challenge for IOL power estimation and therefore reaching these standards of quality might be more difficult, but our refractive outcomes met these recommendations. Note that we included patients with corneal astigmatism of 2.00 D or less and postoperatively 34.1% (15 eyes) had refractive astigmatism between 1.00 and 2.00 D, which could limit the UDVA restoration.³¹ An excimer laser touch-up might be programmed for those cases in which UDVA is not well tolerated.

The results at 6 months revealed a satisfactory visual acuity after the implantation of the TECNIS Eyhance ICB00 IOL. Concerning distance visual acuity outcomes, 6 months after surgery, the mean binocular UDVA and CDVA were 0.10 ± 0.11 and 0.01 ± 0.03 logMAR, respectively. No eyes lost lines of CDVA compared to preoperatively; all patients achieved a binocular CDVA of 0.1 logMAR (20/25) or better, and 90.9% achieved a value of 0.0 logMAR (20/20). The analysis of the defocus curve (**Figure 7**) clearly shows the extension of depth of focus; the mean visual acuity was better than 0.1 logMAR (20/25) across the vergence range from +0.50 to -1.50 D (equivalent to 66 cm from the eye). The visual acuity was 0.11 ± 0.13 logMAR at a vergence of -2.00 D (50 cm from the eye) and 0.21 ± 0.11 logMAR at a vergence of -2.50 D (40 cm from the eye). These results showed that this enhanced monofocal IOL provides a good distance visual acuity, optimal and functional up to a distance between 50 and 40 cm from the eye in patients with high hyperopia.

We did not include a sample of patients with low ametropia to compare with these visual outcomes in patients with high hyperopia. For patients with low ametropia, we recommend this IOL if the patient presents comorbidities (eg, pseudoexfoliation syndrome, glaucoma, or macular disease), which represents a bias for visual outcome comparison purposes. However, earlier studies have evaluated this IOL in patients with low ametropia. Comparing our results with those reported in previous studies in low ametropia,^{3-7,9-12} we could conclude that this IOL provides similar visual acuity at distance vision in patients with high hyperopia as in patients with low ametropia (approximately 0.0 logMAR). Hence the clinical study outcomes confirm what we found in the in vitro analysis; there is no visual acuity degradation attributable to the high IOL power.

Interestingly, the defocus curve in our study was significantly better in the intermediate distances than that reported in low ametropia.^{4-6,10-12} This finding can certainly not be attributable to differences in the IOL design because, as the in vitro analysis revealed, the power profile was similar among the three IOL powers, providing an extra positive addition of 1.00 D. This difference probably derives from the reason proposed by Savini et al,¹⁵ who found that effective addition power provided by multifocal IOLs in short hyperopic eyes is higher owing to a closer distance between the cornea and IOL. However, this hypothesis should be explicitly confirmed for this IOL.

A limitation of the current study was not evaluating photic phenomena such as halo, which is a potential

drawback of some presbyopia-correcting IOLs. However, previous *in vitro*^{1,8} and clinical^{3,4,7,10-12} studies have shown that this enhanced monofocal IOL does not increase these phenomena compared with standard monofocal IOLs. Considering that our *in vitro* analysis showed no dependency on the power of the IOL design or optical quality, we should expect similar results in terms of halo induction in patients with high hyperopia. Furthermore, despite this limitation, in our routine practice after cataract surgery, all patients are asked if they perceive disturbing halos and glare and how bothersome these visual disturbances are. No patients have reported disturbing halos or glare.

In current routine cataract surgery, the targeting of visual restoration should be such that it satisfies the visual demands of the patient, which involve a good distance visual quality but also an intermediate vision of good quality. Our findings showed that the enhanced IOL evaluated provided good distance optical and visual quality and obtained an optimal or functional visual acuity up to a distance between 50 and 40 cm in patients with high hyperopia and a short axial length. All of these findings suggest that this enhanced monofocal IOL could be a good indication for patients with high hyperopic for whom, up to now, a standard monofocal IOL would have been the indication.

AUTHOR CONTRIBUTIONS

Study concept and design (LF-V-C, FV, DM-C, JFA); data collection (LF-V-C, FV, RG-V, MSM); analysis and interpretation of data (LF-V-C, FV, RG-V, MSM, DM-C, JFA); writing the manuscript (LF-V-C); critical revision of the manuscript (LF-V-C, FV, RG-V, MSM, DM-C, JFA); statistical expertise (DM-C); supervision (DM-C, JFA)

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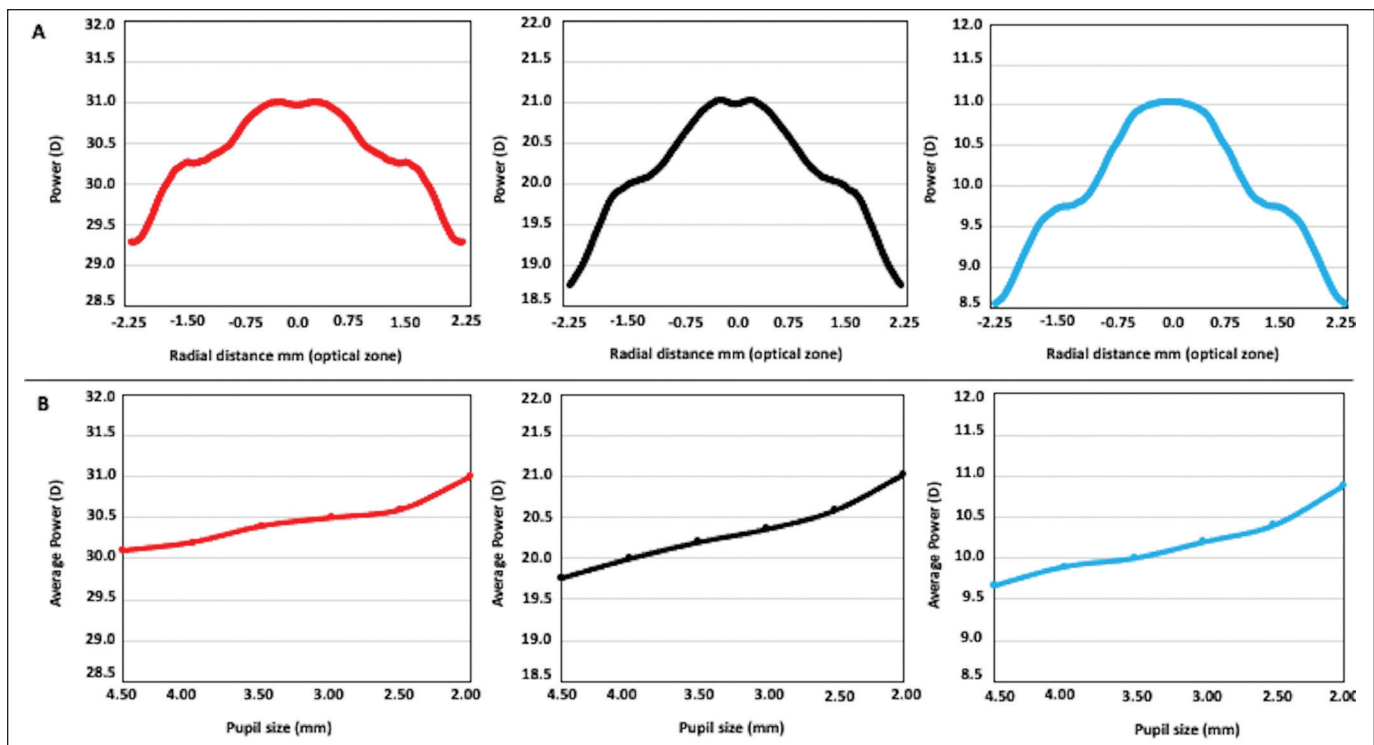


Figure A. (A) Power profile of three intraocular lens (IOL) powers evaluated (left = 30.00 diopters [D]; middle = 20.00 D; right = 10.00 D). (B) The average IOL power for each pupil diameter (left = 30.00 D; middle = 20.00 D; right = 10.00 D).

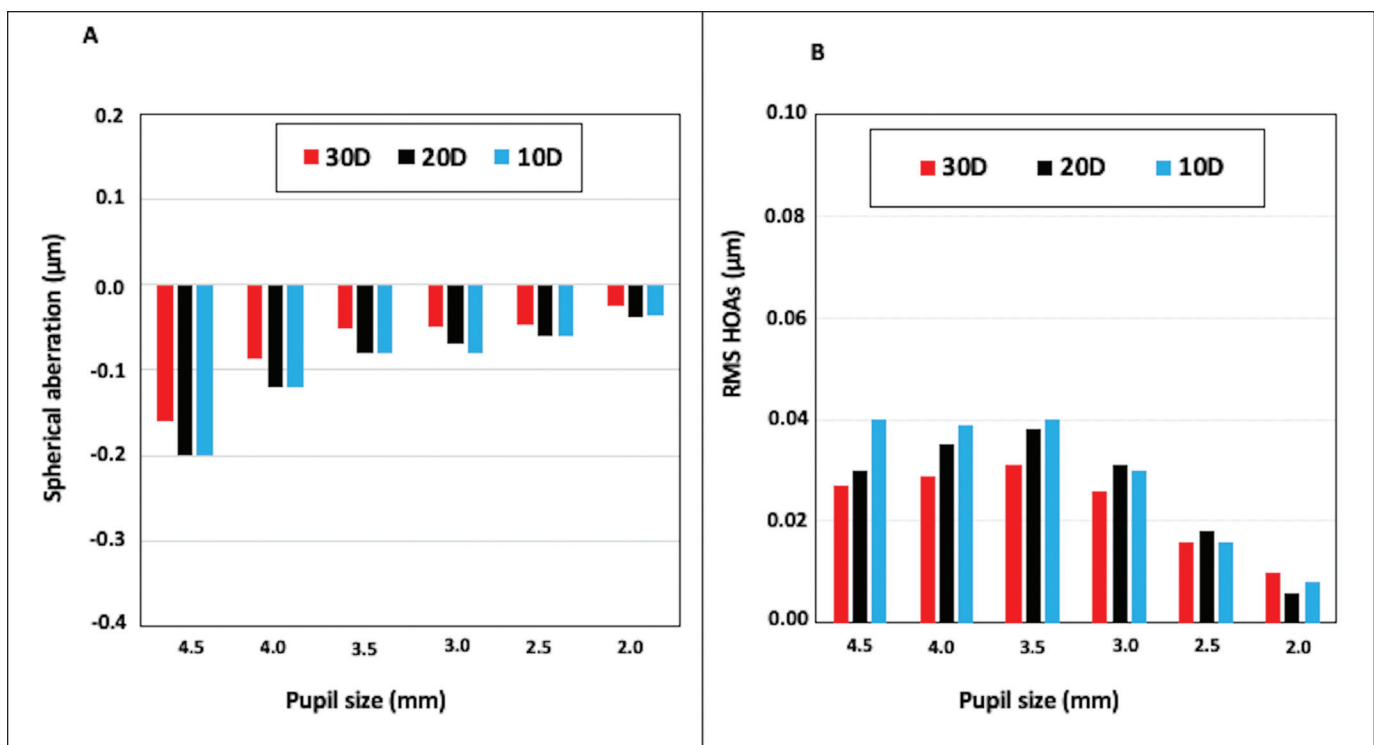


Figure B. (A) Primary spherical aberration (Z_4^0) and (B) the root mean square (RMS) of the total higher order aberrations (HOAs) (third to seventh order, excluding Z_4^0 coefficient) for the three IOL powers at six different aperture diameters (from 2 to 4.5 mm in steps of 0.5 mm). D = diopters