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ORIGINAL RESEARCH

Visual Outcomes and Patient Satisfaction of Trifocal or Trifocal Toric IOLs in Chinese Cataract Patients: Focus on Near Vision at 33 cm

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Purpose: To examine the visual outcomes, particularly at 33 cm, and assess patient satisfaction following the implantation of a diffractive trifocal intraocular lens (IOL) and its toric variant.

Patients and Methods: This prospective single-arm observational study involved 45 Chinese patients (90 eyes) underwent bilateral cataract surgery and PanOptix or PanOptix toric intraocular lenses (IOLs) implantation. Postoperatively, visual acuity was evaluated at various distances, including 40 cm and 33 cm, for both monocular and binocular outcomes. Patient satisfaction was evaluated using the VF-14 questionnaire.

Results: 72 eyes underwent PanOptix IOLs implantation, and 18 eyes received PanOptix toric IOLs. At 3-month postoperative mark, the mean monocular UDVA, UIVA, and UNVA at 40 cm and 33 cm were −0.02±0.09, 0.00±0.07, 0.02±0.07, and 0.07±0.14 logMAR, respectively, with proportions of visual acuity exceeding 0.1 logMAR were 96.7%, 96.7%, 94.4%, and 74.4%, respectively. The mean binocular UDVA, UIVA, and UNVA at 40 cm and 33 cm were −0.05±0.06, −0.03±0.05, 0.00±0.05, and 0.04±0.07 logMAR, respectively, with proportions of visual acuity exceeding 0.1 logMAR were 97.8%, 100.0%, 100.0%, and 91.1%, respectively. When the near point shifted from 40cm to 33cm, some patients showed a decline for UDVA, but the average reduction was less than one line. The overall VF-14 questionnaire score was 4.02±4.19.

Conclusion: PanOptix can provide Chinese patients with a full range of satisfying visual acuity, near to 33cm. Though the visual acuity of some patients at 33 cm did not match the level at 40 cm, the gap of one line may not carry clinical significant.

Keywords: trifocal IOL, PanOptix, visual acuity at 33 cm

Introduction

Presently, cataract surgery has transitioned from being solely a vision restoration procedure to a refractive intervention.[1] As individuals' living standards rise and working ages extend, the demand for optimal eye function is on the rise. When confronted with cataracts or presbyopia, individuals anticipate achieving excellent vision at both distant and near ranges, with the added benefit of spectacle independence post-surgery. Furthermore, an escalating number of younger patients are opting for refractive lens exchange to address presbyopia and correct refractive issues such as myopia, hyperopia, and astigmatism.[2] The objective of cataract surgery extends beyond mere enhancement of visual acuity; it also aims to enhance overall visual quality.[3]

To enhance visual acuity in daily activities and promote sustained independence from spectacles, the implantation of multifocal intraocular lenses (MIOLs) following phacoemulsification emerges as a viable option.[4] The trifocal intraocular lenses, namely AcrySof IQ PanOptix and PanOptix toric (manufactured by Alcon Laboratories, Fort Worth, Texas, USA), have been developed to afford patients effective vision at near, intermediate, and distance ranges. The lens integrates a diffractive structure within the central 4.5mm of its anterior surface, yielding an addition of +2.17D for intermediate distances and +3.25D for near distances.[5] This design facilitates vision at approximately 60cm for intermediate distances and around 40cm for near distances.[6]

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Additionally, it is important to note that the near working distance for the Chinese population tends to be shorter. Research has indicated that the optimal reading distance is approximately 33cm, equivalent to one "chi", a traditional Chinese length unit.[7] There were several seasons for this phenomenon. Firstly, their average height and arm length are shorter. Secondly, due to the nature of Chinese characters, which need to be 1.54 times larger than English letters to provide equivalent acuity reserve, individuals tend to be closer to books or newspapers.[8] A study evaluating the impact of viewing distance on normal Chinese reading indicated that 35 cm was the optimal viewing distance.[9] The study revealed that the maximum mean reading rate of 494 characters per minute occurred at approximately 35.0 cm, corresponding to an optimal visual angle (horizontal and vertical) of 0.5 degrees for each character. Thirdly, the prevalence of myopia is high in China,[10] and it is positively associated with a shorter distance for near work.[7] Research on the reading behavior of emmetropic schoolchildren in China found that their preferred reading distance was very close to the eyes, averaging 28.5 ± 6.4 cm in the armchair, 25.4 ± 6.6 cm at the desk, and 20.6 ± 6.5 cm in the reading/writing task. This distance was always slightly closer for the smallest font and was identified as a risk factor for developing myopia.[11] People with myopia tend to have a shorter near distance (closer than 33 cm; equivalent to one "chi" in Chinese length units) and a shorter distance when working with a computer (closer than 66 cm; equivalent to two "chis"). High myopes were found to have a significantly shorter reading distance than low myopes or non-myopes (mean ± SD = 35.9 ± 9.8 cm vs 50.9 ± 24.8 cm; $p<0.05$).[12] All these factors suggest that visual acuity at 33 cm, rather than 40 cm, may be more critical for Chinese patients.

Whether the near focus of PanOptix IOL designed at 40 cm meet the demand of Chinese patients was still unknown. To our knowledge, there is no existing study that investigates the visual outcomes, particularly at 33 cm, of AcrySof IQ PanOptix/PanOptix toric in Chinese cataract patients. Therefore, the primary aim of this study was to assess visual outcomes, especially at the 33 cm distance, and evaluate patient satisfaction following the implantation of the PanOptix trifocal intraocular lens and its toric variant.

Patients and Methods

Study Design and Participants

This prospective, single-arm, observational study recruited a consecutive cohort of patients scheduled for bilateral cataract surgery and bilateral implantation of AcrySof IQ PanOptix or PanOptix toric intraocular lenses (IOLs) between February 2023 and September 2023 at Hangzhou MSK Eye Hospital in Hangzhou, China. The study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Medical Ethics Committee of Hangzhou MSK Eye Hospital. Prior to their inclusion, all patients were comprehensively briefed on the potential risks and benefits associated with the procedure, and they provided written informed consent to participate in the study.

Chinese patients with age-related cataracts, expressing willingness to participate, and slated for bilateral implantation of AcrySof IQ PanOptix or PanOptix toric IOLs, were included in the study. Inclusion criteria were as follows: (1) cataract patients with decreased vision; (2) pupil diameter >2.5 mm (Photopic) and <6 mm (Mesopic); (3) total corneal higher-order aberration (HOA) ≤ 0.5 µm (undilated pupil, 4mm diameter); (4) corneal spherical aberration (SA) was in the range of −0.04 to 0.12 µm (undilated pupil, 4mm diameter); (5) PAM (potential acuity meter) ≥ 0.8. Exclusion criteria comprised: (1) ocular surface disorders such as severe dry eye, ectropion, entropion, or trichiasis; (2) presence of corneal disease, uveitis, glaucoma, retinopathy, or neurological lesions; (3) history of trauma or prior ocular surgery; (4) falling outside the applicable range of IOL powers; and (5) absence of 3 months' worth of follow-up data.

Preoperative Examination

All patients underwent a comprehensive ophthalmologic assessment within 2 weeks prior to surgery, encompassing the measurement of uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest and cycloplegic refractions, keratometry, slit-lamp microscopy, intraocular pressure (IOP) measurement, endothelial cell density (ECD) assessment (NSPC; KONAN, Japan), ultrasound A and B scans (Aviso, Quantel Medical, France), dilated indirect fundoscopy, Potential acuity meter (PAM-1; GASUSH, China), anterior segment tomography (Sirius; CSO, Florence, Italy), biometry (IOL Master 700; Carl Zeiss, Jena, Germany), and optical coherence tomography (OCT)

(Cirrus HD-OCT 5000; Carl Zeiss, Jena, Germany). Baseline demographic data, including age, sex, spherical manifest refraction, cylindrical refraction, intraocular pressure, and axial length, were meticulously recorded.

Intraocular Lenses

AcrySof IQ PanOptix or PanOptix toric intraocular lenses (IOLs), manufactured by Alcon, Fort Worth, TX, USA, were employed for implantation in the study participants. These lenses were introduced in China in 2020 and 2022, respectively. Despite the PanOptix IOL possessing a quadrifocal design, functionally, it operates as a trifocal intraocular lens.[13] The SA value for both PanOptix and PanOptix toric intraocular lenses was −0.1μm. Eyes with preoperative regular corneal astigmatism ≤1.00D qualified for AcrySof IQ PanOptix IOLs. The IOL calculation was carried out utilizing the Zhang & Zheng IOL power formula (ZZ IOL), which was distinct from conventional or AI-driven approaches, and functioning as a ray-tracing-based formula.[14] The chosen IOL power aimed to achieve emmetropia. Eyes with preoperative regular corneal astigmatism >1.00D were suitable candidates for PanOptix Toric T3-T6 IOLs, with a predicted residual astigmatism of <0.50D. The power of toric IOLs and their implantation axis were determined using the Alcon online toric IOL calculator, while spherical power calculations were performed using the ZZ IOL formula.

Surgical Procedures

All surgeries were performed by experienced surgeons utilizing standard femtosecond laser-assisted phacoemulsification techniques. After administering topical anesthesia (Alcaine; Alcon, Fort Worth, TX, USA), the femtosecond laser (LenSx; Alcon, Fort Worth, TX, USA) was employed for capsulorhexis, lens fragmentation, and the creation of dual incisions (primary incision and lateral incision). Subsequently, the surgeon opened the incisions with a bladeless hook and introduced ophthalmic viscoelastic devices (OVDs) (DisCoVisc; Alcon, Fort Worth, TX, USA) to maintain the anterior chamber. Following this, free-floating anterior capsule removal was conducted, along with cortical-cleaving hydrodissection and the stop-and-chop technique for phacoemulsification. The irrigation-aspiration (I/A) probe was utilized for cortical removal and polishing, and a multifocal IOL (AcrySof IQ PanOptix or PanOptix Toric) was implanted. After removing OVDs with the I/A probe, stromal hydration was employed to close the incisions. Postoperative eye drops, including topical antibiotics and corticosteroids (levofloxacin, Santen, Japan, and Tobradex, Alcon, Fort Worth, TX, USA), were administered.

Outcome Assessment

Follow-up examinations were scheduled at 1 day, 1 week, 1 month, and 3 months postoperatively. The study evaluated the following outcome measures: (1) monocular and binocular uncorrected distance visual acuity (UDVA) at 5 meters, uncorrected intermediate visual acuity (UIVA) at 60 centimeters, and uncorrected near visual acuity (UNVA) at 40 centimeters and 33 centimeters; (2) monocular and binocular corrected distance visual acuity (CDVA) at 5 meters, distance-corrected intermediate visual acuity (DCIVA) at 60 centimeters, and distance-corrected near visual acuity (DCNVA) at 40 centimeters and 33 centimeters; (3) spherical manifest refraction and cylindrical refraction; (4) patient satisfaction assessed using the VF-14 questionnaire.

Statistical Analysis

Statistical analysis was performed utilizing SPSS software (version 22.0, SPSS, Inc., USA). Descriptive summaries were provided for all parameters. Descriptive statistics, encompassing numbers and percentages within categories, means, medians, standard deviations (SD), minimum and maximum values, along with two-sided 95% confidence intervals (CIs), will be reported for continuous parameters. Visual acuity data were transformed into logMAR values. A Kolmogorov–Smirnov test was used to test the normality of the data. Continuous variables of visual acuity at 40 cm and 33 cm that followed a normal distribution were compared using *t*-tests. Continuous variables that had a skewed distribution were compared using the Wilcoxon signed-rank test.

Results

A total of 90 eyes from 45 patients (mean age, 61.69±7.26 years; 13 males) were included in the final analysis. Among the patients, 72 eyes (80.00%) underwent AcrySof IQ PanOptix implantation, while 18 eyes (20.00%) received PanOptix toric IOLs. The baseline data for the patients are presented in Table 1. All surgical procedures were uneventful, and no intraoperative or postoperative complications were observed.

At the 3-month postoperative mark, the mean refractive spherical equivalent was 0.07±0.53D. A notable 82% of eyes were within ±0.50 D, and 97% were within ±1.0 D of emmetropia (Figure 1A). The mean refractive cylinder was 0.55 ±0.31D, with 70% of eyes falling within ±0.50 D and 93% within ±1.0 D of emmetropia (Figure 1B).

Figure 2 illustrates the visual acuity outcomes at different distances during the follow-up period. At 3 months postoperatively, the mean monocular UDVA, UIVA, and UNVA at 40 cm and 33 cm were −0.02±0.09, 0.00±0.07, 0.02 ±0.07, and 0.07±0.14 logMAR, respectively (Figure 2A). In these cases, the proportions of visual acuity exceeding 0.1 logMAR were 96.7%, 96.7%, 94.4%, and 74.4%, respectively (Figure 3A). A statistically significant difference was observed in monocular UNVA between the distances of 40cm and 33cm ($P<0.05$) (Figure 4A). When the near point for ophthalmic examination shifted from 40cm to 33cm, 71.1% of eyes shows a decline, but the average reduction is less than one line. The mean binocular UDVA, UIVA, and UNVA at 40 cm and 33 cm were −0.05±0.06, −0.03±0.05, 0.00 ±0.05, and 0.04±0.07 logMAR, respectively (Figure 2B). The proportions of visual acuity exceeding 0.1 logMAR were 97.8%, 100.0%, 100.0%, and 91.1%, respectively (Figure 3B). Similarly, a statistically significant difference was noted in binocular UNVA between the distances of 40cm and 33cm ($P<0.05$) (Figure 4B). When the near point for ophthalmic examination changed from 40cm to 33cm, 57.8% of eyes shows a decline, but the average reduction is less than one line.

Additionally, the mean monocular CDVA, DCIVA, and DCNVA at 40 cm and 33 cm were −0.04±0.06, −0.01±0.06, 0.02±0.06, and 0.08±0.09 logMAR, respectively (Figure 2C). In these cases, the proportions of visual acuity exceeding 0.1 logMAR were 100.0%, 96.7%, 96.7%, and 76.7%, respectively (Figure 3C). The mean binocular CDVA, DCIVA, and DCNVA at 40 cm and 33 cm were −0.07±0.04, −0.04±0.05, −0.01±0.06, and 0.03±0.06 logMAR, respectively (Figure 2D). The proportions of visual acuity exceeding 0.1 logMAR were 100.0%, 100.0%, 100.0%, and 91.1%, respectively (Figure 3D).

Table 1 Patients' Baseline Demographic Data

Parameter	Mean ± SD	Minimum	Maximum
Eyes (Number of patients)	90 (45)		
Gender			
Male (Number of patients)	13 (28.89%)		
Female (Number of patients)	32 (71.11%)		
Age (years)	61.69±7.26	52	80
MRSE (D)	−1.33±4.97	−18.75	4.38
Refractive Cylinder (D)	−0.74±0.56	−2.75	0
UDVA (LogMAR)	0.61±0.62	0.05	2
IOP (mm Hg)	13.33±2.39	9.0	20.3
Pupil diameter (mm)	5.05±0.69	3.4	6.61
Axial length (mm)	24.08± 2.14	20.17	30.60
ACD (mm)	3.08±0.43	2.11	4.01
Lens thickness (mm)	4.44±0.31	3.90	5.11
White to white (mm)	11.95±0.45	11.2	14.4
IOL Power	19.53±5.58	6.0	29.5
IOL selection			
PanOptix (number of eyes)	72 (80.00%)		
PanOptix Toric (number of eyes)	18 (20.00%)		

Abbreviations: SD, standard deviations; MRSE, mean refractive spherical equivalent; UDVA, uncorrected distance visual acuity; LogMAR, logarithm of the minimum angle of resolution; IOP, intraocular pressure; ACD, anterior chamber depth; IOL, intraocular lens.

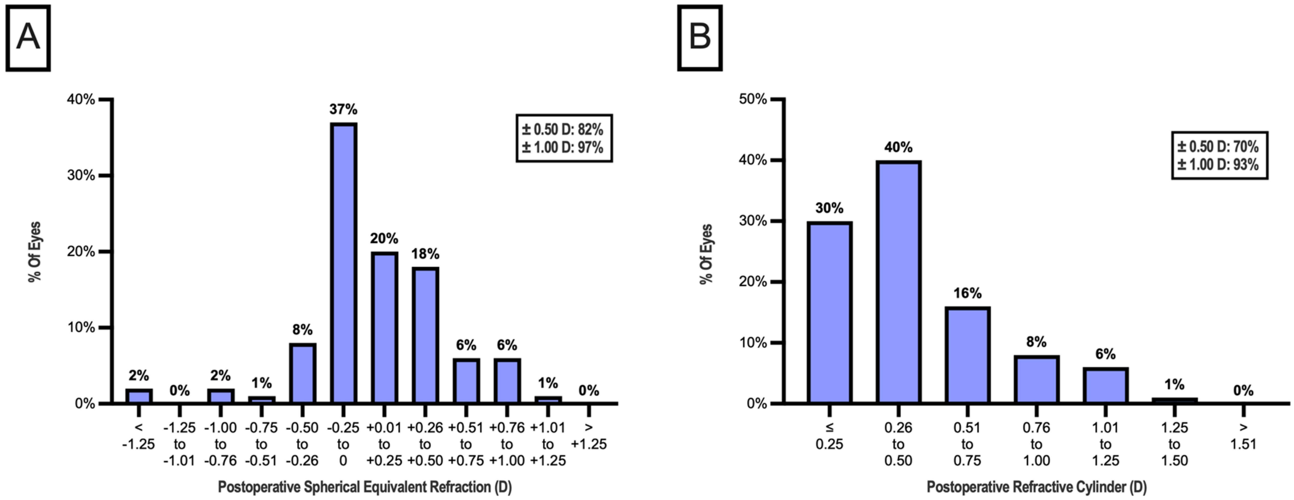

Figure 1 (**A**) Spherical equivalent refraction at 3 months after surgery. (**B**) Refractive cylinder at 3 months after surgery.

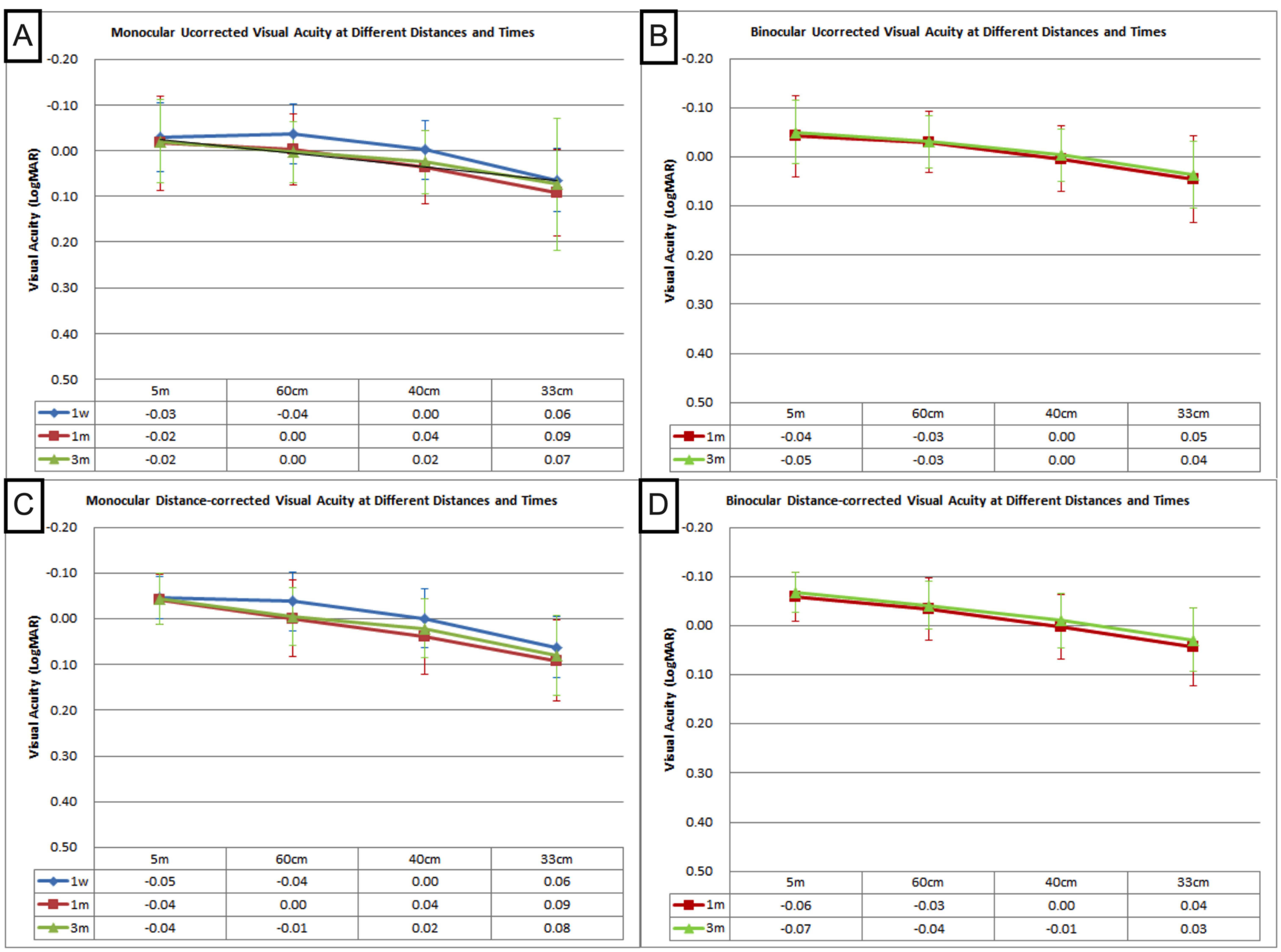

Figure 2 Visual acuity at different distances and times. (**A**) Monocular uncorrected visual acuity at different distances and times. (**B**) Binocular uncorrected visual acuity at different distances and times. (**C**) Monocular distance-corrected visual acuity at different distances and times. (**D**) Binocular distance-corrected visual acuity at different distances and times.

Abbreviations: 1w, 1 week after surgery; 1m, 1 month after surgery; 3m, 3 months after surgery.

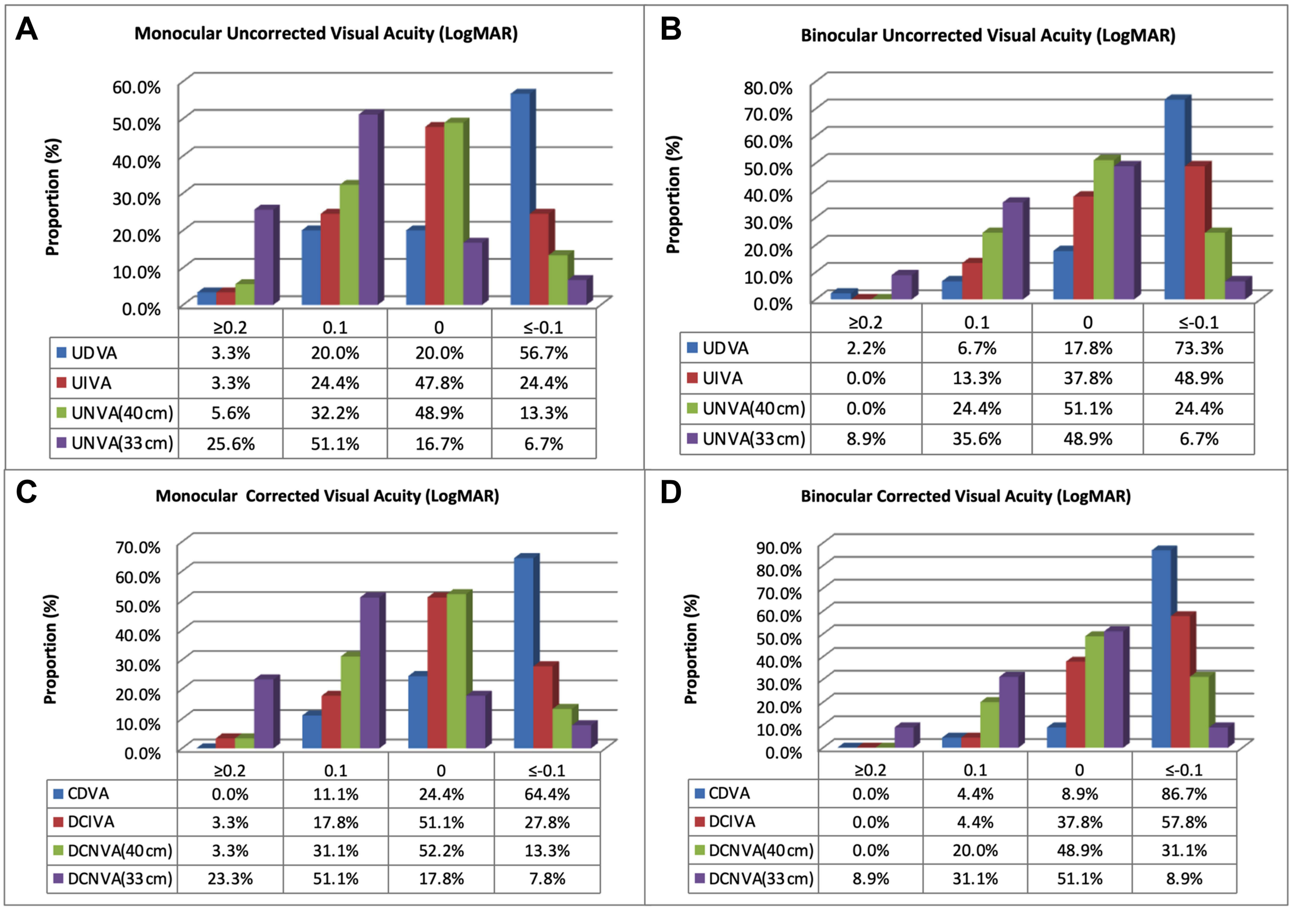

Figure 3 Distribution of visual acuity for different distances at 3 months after surgery. (**A**) Monocular uncorrected visual acuity for different distances. (**B**) Binocular uncorrected visual acuity for different distances. (**C**) Monocular distance-corrected visual acuity for different distances. (**D**) Binocular distance-corrected visual acuity for different distances.

Abbreviations: UDVA, uncorrected distance visual acuity; UIVA, uncorrected intermediate visual acuity; UNVA, uncorrected near visual acuity; CDVA, corrected distance visual acuity; DCIVA, distance-corrected intermediate visual acuity; DCNVA, distance-corrected near visual acuity; LogMAR, logarithm of the minimum angle of resolution.

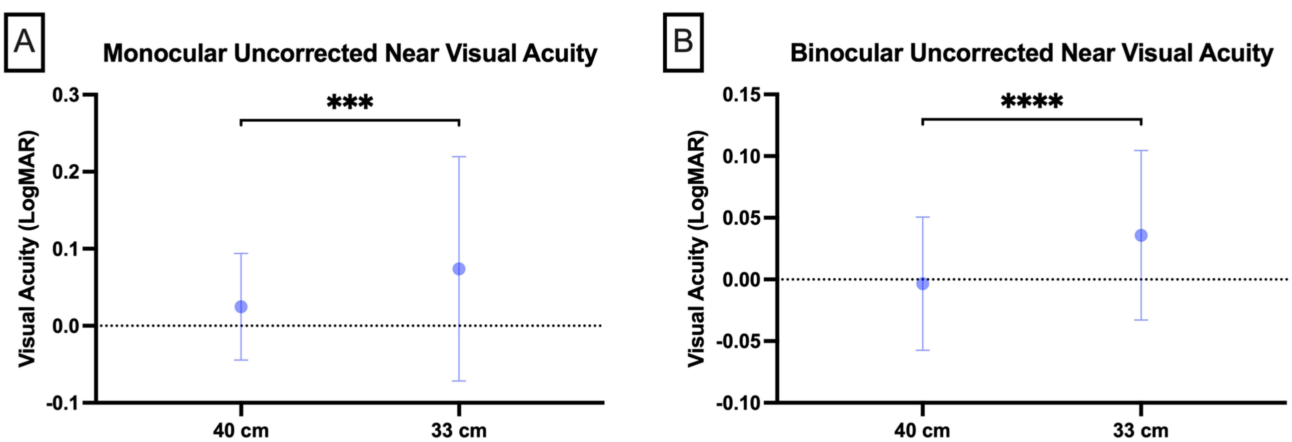

Figure 4 Comparison of uncorrected near visual acuity between the distances of 40cm and 33cm at 3 months after surgery. (**A**) Monocular uncorrected near visual acuity between the distances of 40cm and 33cm. (**B**) Binocular uncorrected near visual acuity between the distances of 40cm and 33cm. ***P=0.0002, ****P<0.0001.

Table 2 Visual Function Questionnaire (VF-14)

Item
Reading small print
Doing fine handwork like sewing
Reading a newspaper or book
Writing checks or filling out forms
Reading a large-print book or numbers on telephone
Recognizing people when they are close to you
Watching television
Playing games such as card games, mahjong
Cooking
Seeing steps, stairs
Reading traffic, street, or store signs
Taking part in sports like bowling, tennis, golf
Driving during the day
Driving at night
Total

Notes: Score scale: 0, no difficulty; 1, a little difficulty; 2, moderate difficulty; 3, quite difficult; 4, impossible to perform.

At the 3-month follow-up, a substantial degree of satisfaction was reported by the majority of patients. Patient satisfaction was assessed using the VF-14 questionnaire (Table 2), and the distribution of scores is illustrated in Figure 5. The mean overall score of the VF-14 questionnaire was 4.02±4.19. Specifically, 11.1% of patients had a a score of zero; 84.4% reported scores ranging from 1 to 9; and only 4.4% of patients indicated scores ≥10.

Discussion

In this study, we systematically investigated the visual outcomes across the full range, with particular emphasis on performance at 33 cm. Visual acuity for distance, intermediate, and near demonstrated notable improvement after the implantation of PanOptix IOLs, consistent with findings in prior research.[15,16] Binocular visual acuity was highly favorable, with 97.8%, 100.0%, 100.0%, and 91.1% of patients exceeding 0.1 logMAR for UDVA, UIVA, and UNVA at 40 cm and 33 cm, respectively. Furthermore, a high percentage (95.6%) of patients reported satisfaction with the surgery and had no difficulty in daily life.

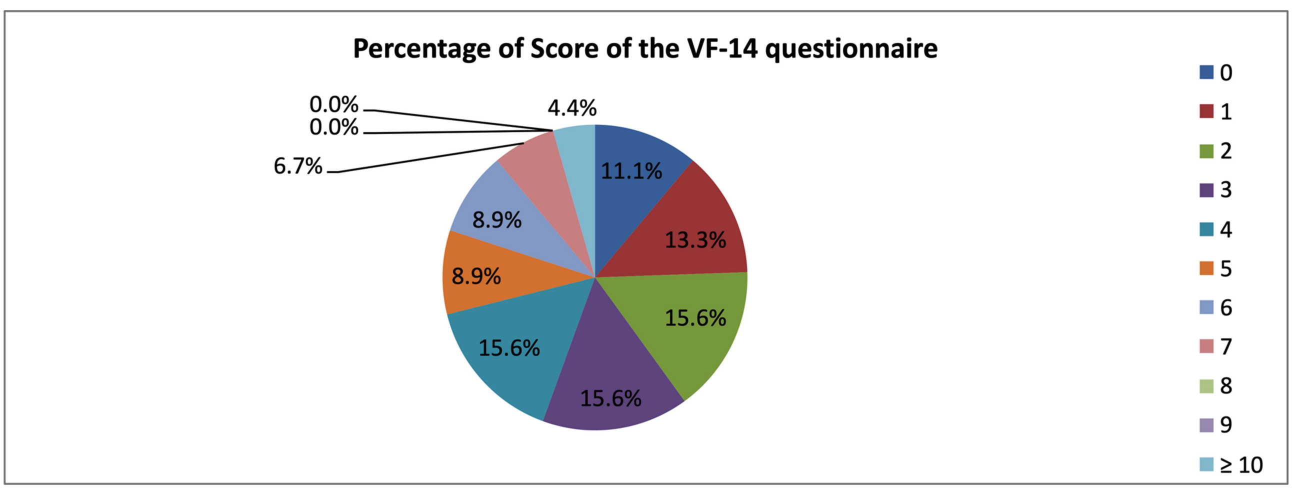

Figure 5 Distribution of scores of the VF-14 questionnaire.

Trifocal intraocular lenses, incorporating diffractive technologies, are engineered to deliver excellent distance visual acuity while ensuring a seamless transition to high-quality vision across intermediate and near distances.[17] The design of the two optimal foci for intermediate and near vision is tailored to meet the demands of individuals. Crucial factors influencing these working distances include arm length and reading behavior. In Western countries, individuals working with computers or playing cards typically engage at distances ranging from 60cm to 80cm. Consequently, the AT Lisa tri 839 MP (Carl Zeiss Meditec AG) provides an optimal intermediate focus at 80 cm, while the AcrySof IQ PanOptix TFNT00 (Alcon Vision LLC) is designed for a distance of 60 cm. As the height and arm length of Chinese people are generally shorter, a distance of 60 cm is more suitable for intermediate distance working than 80 cm. In fact, the patients in this study did achieve good intermediate distance visual acuity with PanOptix or PanOptix toric IOL. So the intermediate focus of PanOptix IOL designed at 60 cm meet the demand of Chinese patients.

For activities such as using mobile phones or reading books, the distance is approximately 40 cm for patients in Western countries. Therefore, PanOptix IOL is designed to optimize near focus at 40 cm. While, Chinese populations exhibit distinct characteristics compared to Westerners. Their near working distance might be shorter, about 33 cm. In China, the conventional near point for ophthalmic examinations is 33 cm, which differs from the Western standard of 40 cm.[9]

In this study, the mean binocular UNVA at 40 cm was 0.00±0.05 logMAR, and the proportions of visual acuity exceeding 0.1 logMAR was 100.0%. This result was pretty good. Additionally, we also investigated the near visual performance at 33 cm, an important near working distance for Chinese patients. The mean binocular UNVA at 33 cm was 0.04±0.07 logMAR, and the proportions of visual acuity exceeding 0.1 logMAR was 91.1%. Though the near focus of the trifocal IOL was designed at 40 cm, most patients can also see clearly at 33 cm. We assumed that aspherical aberration may play a role, which allowed for an extension of the depth of focus, enabling improved near vision without significantly compromising distance vision.[18] We also conducted a comparative analysis of near visual acuity at 33 cm and 40 cm, revealing a statistically significant difference between them ($P<0.05$). When the near point for ophthalmic examinations decreased from 40 cm to 33 cm, some patients showed a decline in monocular/binocular UDVA, but the average reduction was less than one line. Limited studies have addressed near vision at 33 cm. Dick's study reported proportions of DCNVA exceeding 0.1 logMAR at 40 cm and 33 cm as 75.0% and 51.9%, respectively.[17] Nearly 23.1% of patients experienced a reduction in visual acuity when the near point reduced from 40 cm to 33 cm, aligning with our findings.

Though there was significant difference of near visual acuity between 33 cm and 40 cm, the gap of one line may not carry clinical significant. Patients' satisfaction was generally high after implantation of PanOptix or PanOptix toric IOL. To enhance fine near visual acuity, especially at 33 cm, patients can potentially adapt to IOLs by adjusting their near work distance, actively finding a comfortable reading distance for clear vision. Furthermore, the development of IOLs tailored to the specific characteristics of Chinese patients emerges as a promising solution.

In order to achieve satisfactory visual outcomes and high satisfaction, we were strict about the indications for surgery. We conducted PAM visual function test for routine visual function examination before cataract surgery and intraocular lens implantation. Patients with PAM < 0.8 had potential retinal dysfunction and then trifocal IOL was not recommended. On the other hand, total corneal higher-order aberration (HOA), was also an important indicator. We recommended patients with HOA ≤ 0.5 μm received trifocal IOLs implantation, for high HOA might affect visual quality after surgery.[19]

A primary limitation of this study is the absence of a comparison group. The PanOptix IOLs utilized in this investigation were not contrasted with other presbyopia-correcting intraocular lenses, such as AT Lisa tri 839 MP or TECNIS Synergy. Additionally, the follow-up duration of 3 months was relatively short, warranting the need for long-term evaluations.

Conclusion

In conclusion, PanOptix can provide Chinese patients with a full range of satisfying visual acuity, near to 33cm. Though the visual acuity of some patients at 33 cm did not match the level at 40 cm, the gap of one line may not carry clinical significant.

Data Sharing Statement

The data used during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The study was performed according to the tenets of the Declaration of Helsinki, and approved by the Medical Ethics Committee of Hangzhou MSK Eye Hospital. Informed consent was obtained from all individual participants included in the study.

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Disclosure

All authors declare no conflicts of interest in this work.

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