Am J Transl Res 2024;16(7):2995-3004
www.ajtr.org /ISSN:1943-8141/AJTR0156683

Original Article

Analysis of visual quality improvement after implantation of PanOptix trifocal intraocular lens in cataract patients with different axial lengths

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Received March 20, 2024; Accepted May 28, 2024; Epub July 15, 2024; Published July 30, 2024

Abstract: Objective: To assess the visual quality, both subjective and objective, of cataract patients with varying axial lengths (AL) after PanOptix trifocal intraocular lens (IOL) implantation and investigated the lens tilt and its correlation with visual outcomes. Methods: From July 2020 to June 2022, 70 patients (140 eyes) diagnosed with age-related cataracts and undergoing PanOptix implantation at Chongqing Eye and Vision Care Hospital, Aier Eye Hospital Group, were included. Patients were assigned to either the observation group (35 cases, 70 eyes with PanOptix trifocal IOL) or the control group (35 cases, 70 eyes with bifocal IOL). Patients were further subdivided based on AL into AL < 24 mm (observation group: 23 eyes; control group: 26 eyes) and AL ≥ 24 mm (observation group: 47 eyes; control group: 44 eyes). Postoperative follow-up lasted three months. Visual acuity (distant, intermediate, near), objective visual quality (Strehl ratio: SR, total eye modulation transfer function (MTF)), and visual aberrations were measured preoperatively and at 3 months post-operation. Results: Postoperatively, all groups saw significant improvements in uncorrected distance visual acuity (UCDVA), uncorrected intermediate visual acuity (UCIVA), and uncorrected near visual acuity (UCNVA) compared to preoperative values (T0) (all $P < 0.05$). Notably, UCIVA was significantly better in the observation group than in the control group ($P < 0.05$). At three months (T1), reductions in total high-order aberration (tHOA), internal high-order aberration (iHOA), coma, and trefoil aberrations were observed in both groups compared to baseline, with more significant decreases in the observation group (all $P < 0.05$). Both SR and MTF cutoff showed marked improvement from T0 to T1, with the observation group experiencing greater enhancements (both $P < 0.05$). The defocus curve of the observation group showed a gentle slope between +0.5 D and -3.0 D, maintaining superior visual acuity compared to the control group ($P < 0.05$). Subjective visual quality scores at T1 were significantly higher than at T0 for both groups ($P < 0.05$), with patients in the observation group scoring higher than those in the control group across all AL categories ($P < 0.05$). Spearman correlation analysis indicated that the tilt after PanOptix trifocal IOL implantation was associated with tHOA ($r = 0.273$, $P = 0.022$), iHOA ($r = 0.433$, $P < 0.001$), Trefoil ($r = 0.360$, $P = 0.002$) and coma ($r = 0.688$, $P < 0.001$). Conclusion: PanOptix trifocal IOL implantation in cataract patients across different AL significantly enhances visual quality compared to bifocal IOLs, suggesting a strong case for its clinical adoption.

Keywords: Different axial length, cataract, PanOptix trifocal intraocular lens, visual quality, defocusing curve

Introduction

Cataract, a prevalent blinding condition in clinical ophthalmology, is primarily caused by metabolic disorders that lead to lens protein degeneration and clouding [1]. This disease progressively impairs vision, increases refractive errors, and induces glare [2, 3]. Cataract patients experience significantly diminished visual quality of life compared to those without the disease, with an increased risk of accidents and mortality [4]. Although treatments for cataract include medications, phacoemulsification, and extracapsular cataract extraction, surgery remains the preferred option. As medical technology advances and living standards improve, cataract patients increasingly expect excellent postoperative visual outcomes, aspiring to

https://doi.org/10.62347/FRJZ4885

independence from glasses for activities at various distances [5, 6]. Traditional monofocal and bifocal intraocular lenses (IOLs) often fall short of these expectations.

The PanOptix trifocal IOL, utilizing a four-focus technique, innovatively enhances intermediate vision by setting the focus at 60 cm, thus facilitating clear vision at near (40 cm), intermediate (60 cm), and far (infinity) distances [7]. In addition, cataract patients with varying axial lengths (AL) exhibit distinct disease characteristics and visual acuity recovery post-surgery, influenced significantly by AL [8]. Despite the wide clinical use of various types of IOLs, research on the PanOptix trifocal IOL in patients with different AL remains limited.

This study aims to assess the impact of PanOptix trifocal IOL implantation in cataract patients across a spectrum of AL, exploring improvements in both subjective and objective visual quality post-surgery and investigate the association between lens tilt and visual outcomes. These findings are intended to inform clinical treatment choices and enhance patient satisfaction with visual acuity post-cataract surgery.

Materials and methods

Study population

This retrospective analysis included 70 patients (140 eyes) diagnosed and treated for cataract at Chongqing Eye and Vision Care Hospital, Aier Eye Hospital Group, from July 2020 to June 2022. The participants were categorized into two groups based on the type of IOL implanted: the observation group received the PanOptix trifocal IOL (35 patients, 70 eyes), and the control group received a bifocal IOL (35 patients, 70 eyes). Further subdivision was based on AL, with 23 eyes in the observation group and 26 eyes in the control group having AL of less than 24 mm, and 47 eyes in the observation group and 44 eyes in the control group having AL of 24 mm or more.

Inclusion criteria: patients with a cataract across various AL; availability for follow-up visits at any time; willingness and ability to undergo surgery.

Exclusion criteria: presence of any ocular or systemic condition, previous eye surgery, or eye pathology (such as amblyopia, trauma, macular degeneration, or other retinal injuries, refractive surgery) that could compromise postoperative vision outcomes.

The study was approved by the Ethics Committee of the Chongqing Eye and Vision Care Hospital·Aier Eye Hospital Group.

Methods

Preoperative examination: Prior to surgery (T0), all patients underwent a comprehensive preoperative assessment, which included measurements of AL using IOL Master 500, assessment of visual acuity, and evaluation of pupil size and aberrations with a Corneal Refractive Analyzer (Opticalpass difference OPD)-Scan III.

Intraocular lens implantation procedure: All surgical procedures were performed by the same experienced chief physician. The preoperative preparation involved: (1) Dilating the pupils with compound tropicamide eye drops (Baiyunshan Hejigong Pharmaceutical Co., Ltd., Sinopharm Approval No. H20063360) and preparing the ocular surface by washing the lacrimal duct and trimming the eyelashes. (2) Administering levofloxacin eye drops (Yangtze River Pharmaceutical Group Co., Ltd., Sinopharm Approval No. H20203092) for infection prophylaxis. (3) Administering surface anesthesia with oxybuprocaine eye drops (Shandong Boshi Lunfu Ruida Pharmaceutical Co., Ltd., Sinopharm Approval No. J20100128). (4) Employing a femtosecond laser (LenSX, Alcon) for capsulorhexis and lens pre-chopping with the following parameters: a centered capsulorhexis with a 5.3 mm diameter, pre-chopping in ‘Frag’ mode with a 6.0 mm nuclear diameter. (5) Making a 2.2 mm limbal primary incision and a 1.2 mm limbal side incision, followed by viscoelastic injection into the anterior chamber, anterior capsule removal, hydrodissection, phacoemulsification of the lens nucleus and cortex, and polishing of the anterior and posterior capsules.

The observation group received the PanOptix trifocal IOL (TFNT00), a single-piece foldable trifocal lens with a blue-light-filtering chromo-

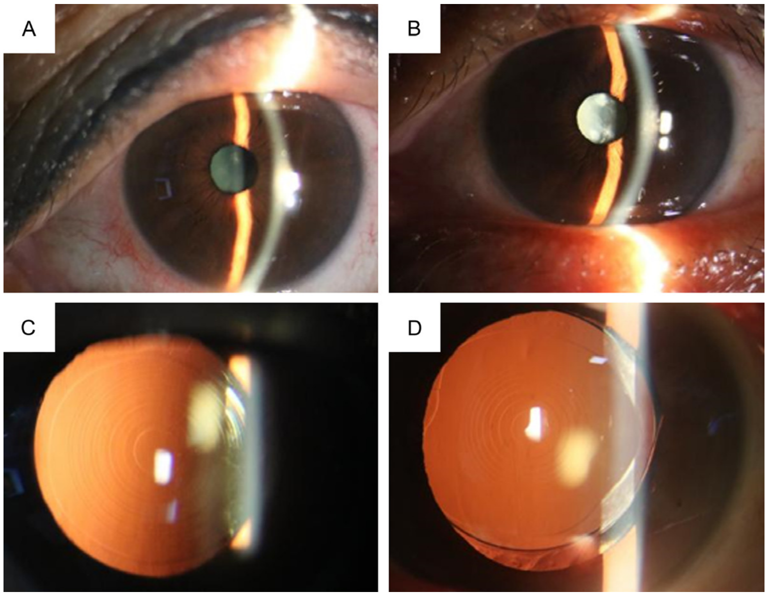

Figure 1. Eye structure before and after intraocular lens implantation. Note: A, B: Preoperative eye pictures of cataract patients; C: Patients implanted TFNT00 crystal eye picture; D: Patients implanted SN6AD1 crystal eye picture.

phore, designed with a non-refractive diffractive pattern in its central 4.5 mm optical zone, providing +2.17 D for intermediate and +3.25 D for near focal powers. The control group received the AcrySof ReSTOR +3 D (SN6AD1), a stepwise progressive monolithic diffractive multifocal lens with a double convex optical surface and a diffraction function on the front surface, designed to provide +3.0 D near additional optical power. Both lenses are made from hydrophobic acrylate material, with a 6.0 mm optical zone and a 13.0 mm total diameter. The power range for both lenses span from 6.0 D to 30.0 D in 0.5 D increments and from 31.0 D to 34.0 D in 1.0 D increments. See **Figure 1**.

Postoperative medication protocol: Following surgery, patients were prescribed tobramycin dexamethasone eye ointment (Qilu Pharmaceutical Co., Ltd., Approval No. H20020496). On the day of surgery, levofloxacin eye drops were administered every two hours and then reduced to four times per day for one month. Tobramycin and dexamethasone eye drops (Jiangxi Zhenshiming Pharmaceutical Co., Ltd., Approval No. H20083299) were applied every two hours on the day of surgery, followed by four times daily for 2-4 weeks. Additionally, tobramycin dexamethasone eye ointment was applied nightly for 2-4 weeks.

Outcome measures

Vision assessment: Three months post-operation (T1), far, intermediate, and near visual acuity were assessed using a decimal visual acuity chart at distances of 5 meters, 60 centimeters, and 40 centimeters, respectively. Uncorrected distance visual acuity (UCDVA), uncorrected intermediate visual acuity (UCIVA), and uncorrected near visual acuity (UCNVA) were recorded using the LogMAR scale.

Objective visual quality: At T1, wavefront aberrations were measured using an OPD-Scan II aberration analyzer. Total ocular higher-order aberrations (tHOA), internal higher-order aberrations (iHOA), coma, and trefoil aberrations were documented. The total eye modulation transfer function (MTF) (area under the curve) and Strehl ratio (SR) were also recorded.

Defocusing curve: At T1, a comprehensive refractometer was used to adjust the spherical diopter from +1.0 to -4.0 D in 0.5 D increments. Visual acuity at each diopter was measured, and the average visual acuity across all patients was used to construct a defocus curve, with the X-axis representing the additional diopter and the Y-axis representing visual acuity, to evaluate postoperative visual quality.

Subjective visual quality: A follow-up at T1 involved administering the Catquest-9SF-CN-questionnaire to assess visual function-related quality of life in Chinese cataract patients [9]. Each question was scored from 1 to 5 (where 5 represents ‘never’, 4 ‘very rarely’, 3 ‘sometimes’, 2 ‘often’, and 1 ‘always’). The average of the subjective visual symptom scores was calculated to obtain the subjective visual quality score.

Table 1. Comparison of general information of patients

Groups	n	Age	Males	Females
Observation group	35	61.52±5.12	20 (57.14)	15 (42.86)
Control group	35	61.24±4.18	19 (54.29)	16 (45.71)
t/χ^2	-	0.251	0.058	
P	-	0.803	0.810	

Table 2. Comparison of visual acuity [M(P25, P75)] (LogMAR)

Groups	AL	Times	UCDVA	UCIVA	UCNVA
Observation group	≤ 24 (n = 23)	T0	1.12 (1.10, 1.40)	0.90 (0.90, 1.00)	0.40 (0.25, 0.50)
		T1	0.00 (0.00, 0.10)	0.10 (0.00, 0.10)*	0.10 (0.05, 0.10)
	Z		-4.215	-4.241	-4.156
	P		< 0.001	< 0.001	< 0.001
	> 24 (n = 47)	T0	1.30 (1.10, 1.45)	0.90 (0.90, 1.00)	0.20 (0.10, 0.35)
		T1	0.00 (0.00, 0.00)	0.10 (0.00, 0.10)*	0.10 (0.00, 0.10)
	Z		-5.987	-6.028	-5.000
	P		< 0.001	< 0.001	< 0.001
Control group	≤ 24 (n = 26)	T0	1.30 (1.20, 1.40)	0.95 (0.80, 1.00)	0.45 (0.30, 0.50)
		T1	0.00 (0.00, 0.10)	0.20 (0.10, 0.20)	0.10 (0.08, 0.20)
	Z		-4.479	-4.482	-4.336
	P		< 0.001	< 0.001	< 0.001
	> 24 (n = 44)	T0	1.30 (1.10, 1.50)	0.90 (0.90, 1.00)	0.20 (0.10, 0.40)
		T1	0.00 (0.00, 0.00)	0.10 (0.00, 0.10)	0.10 (0.00, 0.10)
	Z		-5.798	-5.838	-4.624
	P		< 0.001	< 0.001	< 0.001

Note: VS Control group with the same level AL: *P < 0.05; AL: axial length; UCDVA: uncorrected distance visual acuity; UCIVA: uncorrected intermediate visual acuity; UCNVA: uncorrected near visual acuity.

IOL tilt and its correlation with visual quality: The tilt of the PanOptix IOL was measured at T1 using a high-precision biomicroscope. Subsequently, the relationship between IOL tilt and visual quality was analyzed.

Statistical analysis

Statistical analysis was performed using SPSS version 22.0. Data adhering to homogeneity of variance were presented as mean ± standard deviation ($\bar{x}$ ± sd), and the LSD-t test was used for pairwise comparisons. For data not following a normal distribution, the median and interquartile range [M(P25, P75)] were reported, and the Mann-Whitney U test was applied for comparisons between two groups. Categorical data were expressed as frequencies (n), and the chi-square test was used for group comparisons. Spearman's rank correlation coefficient was employed for correlation analyses. A *P*-value less than 0.05 was considered statistically significant.

Results

Comparison of general information of patients

No significant differences in baseline demographic data were observed between the groups (all P > 0.05), ensuring comparability. See **Table 1**.

Comparison of visual acuity

At T1, UCDVA, UCIVA, and UCNVA significantly improved in both groups of patients with different AL compared to T0 (all P < 0.05). While there was no significant difference in UCDVA and UCNVA between the two groups at T1 (both P > 0.05), UCIVA was significantly better in the observation group compared to the control group (P < 0.05), as shown in **Table 2**.

Comparison of aberrations

At T1, tHOA, iHOA, coma, and trefoil aberrations decreased in both groups compared to T0 (all P

Table 3. Comparison of aberrations in the two groups [M(P25, P75)]

Groups	AL	Times	tHOA	iHOA	Coma	Trefoil
Observation group	≤ 24 mm (n = 23)	T0	0.39 (0.35, 0.41)	0.33 (0.28, 0.38)	0.09 (0.07, 0.14)	0.15 (0.03, 0.22)
		T1	0.11 (0.09, 0.16)*	0.11 (0.09, 0.14)*	0.04 (0.03, 0.07)*	0.08 (0.04, 0.10)*
	Z		-4.197	-4.045	-2.631	-2.068
	P		< 0.001	< 0.001	0.009	0.039
	> 24 mm (n = 47)	T0	0.41 (0.39, 0.42)	0.38 (0.36, 0.40)	0.10 (0.08, 0.12)	0.19 (0.16, 0.24)
		T1	0.13 (0.11, 0.17)*	0.13 (0.11, 0.18)*	0.04 (0.03, 0.08)*	0.08 (0.04, 0.12)*
	Z		-5.969	-5.810	-4.256	-4.878
	P		< 0.001	< 0.001	< 0.001	< 0.001
Control group	≤ 24 mm (n = 26)	T0	0.39 (0.34, 0.42)	0.34 (0.29, 0.38)	0.1 (0.08, 0.14)	0.17 (0.06, 0.23)
		T1	0.14 (0.12, 0.19)	0.13 (0.12, 0.18)	0.06 (0.03, 0.09)	0.08 (0.05, 0.11)
	Z		-4.407	-3.797	-2.462	-2.032
	P		< 0.001	< 0.001	0.014	0.042
	> 24 mm (n = 44)	T0	0.40 (0.39, 0.42)	0.38 (0.36, 0.40)	0.10 (0.08, 0.12)	0.18 (0.16, 0.24)
		T1	0.15 (0.12, 0.22)	0.16 (0.11, 0.21)	0.06 (0.04, 0.08)	0.10 (0.06, 0.15)
	Z		-5.777	-5.543	-3.745	-4.155
	P		< 0.01	< 0.01	< 0.01	< 0.01

Note: VS Control group with the same level AL: *P < 0.05; AL: axial length; tHOA: total high order aberration; iHOA: internal HOA.

Table 4. MTF-cutoff and SR of patients

Groups	AL	Times	MTF-cutoff	SR
Observation group	≤ 24 mm (n = 23)	T0	35.71±16.58	0.12±0.03
		T1	58.19±10.77*	0.24±0.08*
	t		-4.592	-5.652
	P		< 0.001	< 0.001
	> 24 mm (n = 47)	T0	35.29±16.42	0.21±0.07
		T1	58.42±15.16*	0.25±0.12*
	t		-44.453	-3.189
	P		< 0.001	0.003
Control group	≤ 24 mm (n = 26)	T0	35.73±11.84	0.13±0.04
		T1	45.94±10.17	0.21±0.04
	t		-3.157	-5.117
	P		0.004	< 0.001
	> 24 mm (n = 44)	T0	35.46±11.76	0.20±0.05
		T1	46.98±11.48	0.23±0.05
	t		-8.678	-2.266
	P		< 0.001	0.029

Note: VS Control group with the same level AL: *P < 0.05; AL: axial length; MTF: modulation transfer function; SR: strehl ratio.

< 0.05). The observation group exhibited lower aberrations than the control group (P < 0.05), as detailed in **Table 3**.

Comparison of MTF-cutoff and SR

The SR and MTF cutoff for patients with different AL in both groups improved post-operatively and were significantly higher at T1 than at T0 (both P < 0.05). The improvement in these indices was more pronounced in the observation group than in the control group at T1 (both P < 0.05), but no significant differences were found between the groups when comparing different ALs at T1 (both P > 0.05). Refer to **Table 4**.

Comparison of postoperative defocus curve

At T1, the defocus curve for the observation group displayed a bimodal shape with peaks at

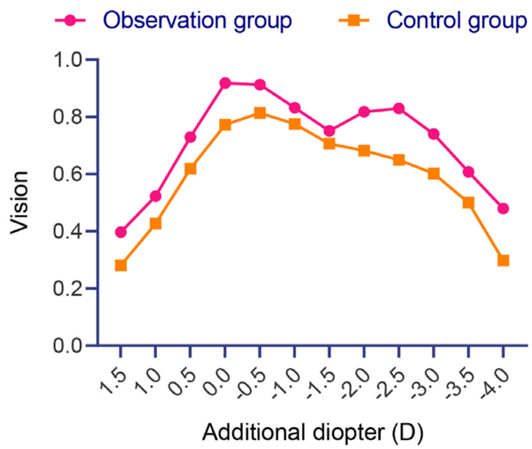

Figure 2. Defocusing curve at 3 months after operation.

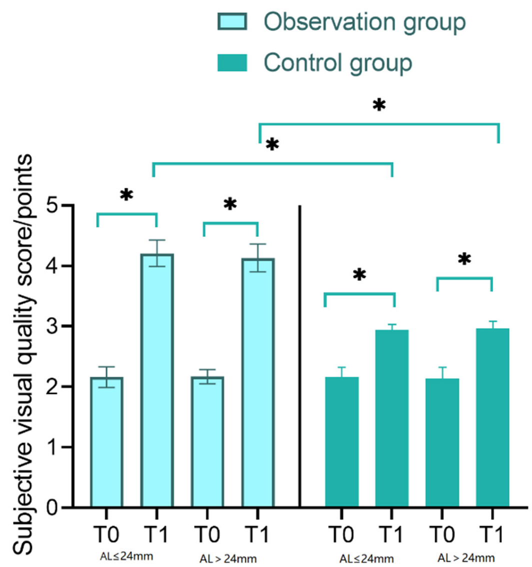

Figure 3. Comparison of subjective visual quality scores. Note: *P < 0.05; AL: axial length.

0 D and -2.5 D, and a smooth transition between +0.5 D and -3.0 D, achieving a visual acuity better than 0.73. In contrast, the peak segment of the control group ranged from 0 to -1 D, with a declining trend from -0.5 D to -3.0 D; overall, visual acuity in the observation group consistently exceeded that of the control group, as illustrated in **Figure 2**.

Comparison of subjective visual quality scores

Subjective visual quality scores improved for both groups at T1 compared to T0 ($P < 0.05$). Specifically, patients with AL ≤ 24 mm and AL > 24 mm in the observation group had higher scores at T1 compared to those in the control group ($P < 0.05$). However, no significant differences were found between AL ≤ 24 mm and AL > 24 mm within two groups at T1 ($P > 0.05$), as shown in **Figure 3**.

PanOptix tilt and its relationship with visual quality

The panoramic tilt measured post-implantation of the PanOptix trifocal IOL was less than 0.6, indicating minimal tilt. Spearman correlation analysis revealed significant correlations between the PanOptix tilt and tHOA ($r = 0.273$, $P = 0.022$), iHOA ($r = 0.433$, $P < 0.001$), trefoil ($r = 0.360$, $P = 0.002$), and coma ($r = 0.688$, $P < 0.001$). Details are provided in **Table 5** and **Figure 4**.

Discussion

Cataracts are the leading cause of blindness worldwide, with its prevalence increasing with age [10, 11]. Currently, the standard treatment for cataracts involves extraction followed by IOL implantation. The trifocal IOL, particularly the PanOptix trifocal IOL, provides high-quality, clear vision at far, intermediate, and near distances, significantly enhancing postoperative quality of life [12, 13]. Unlike traditional IOL, the PanOptix trifocal IOL features a high light energy utilization rate and a unique 4.5 mm diffraction zone design that optimizes 60 cm intermediate vision while ensuring excellent near and far vision [14]. This 60 cm intermediate vision is ideally suited to the visual habits of Asian populations, a benefit not matched by other trifocal IOLs [15]. Moreover, the PanOptix trifocal IOL is designed to provide lasting clarity and closely align with everyday visual needs and habits [16].

The study's findings indicate significant improvements in UCDVA, UCIVA, and UCNVA in both groups of patients with varying AL at T1 compared to T0. At T1, the UCDVA, UCIVA, and UCNVA in the observation group were consistently better than 0.1 (LogMAR), with UCIVA being significantly superior in the observation group compared to the control group. No significant differences were observed in UCDVA and UCNVA between the groups. Supporting literature from Nicula et al. [17] reports that patients who received the PanOptix trifocal IOL exhibited superior UCIVA at 60 cm and UCNVA at 40 cm. Similarly, Yoon et al. [18] and Martínez de

Table 5. PanOptix Tilt and its relationship with visual quality

		tHOA	iHOA	Coma	Trefoil	SR	MTF-cutoff	Subjective quality
Tilt	r	0.273	0.433	0.688	0.360	-0.131	-0.172	0.118
0.10 (0.07, 0.18)	P	0.022	< 0.001	< 0.001	0.002	0.279	0.155	0.330

Note: tHOA: total high order aberration; iHOA: internal HOA; SR: strehl ratio; MTF: modulation transfer function.

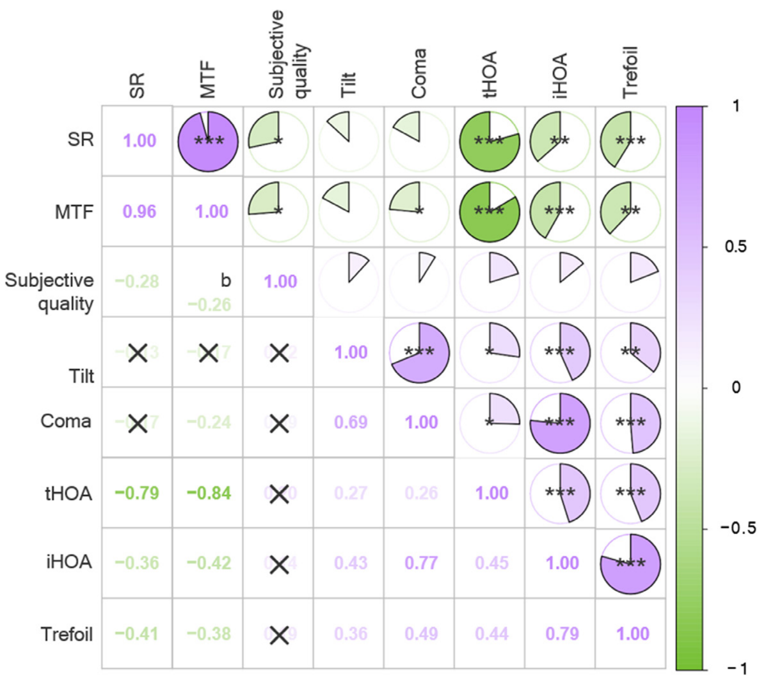

Figure 4. The correlation heat map between panoramic tilt and visual quality after PanOptix trifocal IOL implantation in patients with different axial lengths. Note: ***P < 0.001; **P < 0.01; *P < 0.05; MTF: modulation transfer function; SR: strehl ratio; tHOA: total high order aberration; iHOA: internal HOA.

Our findings indicate that postoperative higher-order aberrations, including intraocular higher-order aberrations, coma, and trefoil, were reduced compared to preoperative levels. Notably, the PanOptix trifocal IOL exhibited lower high-order aberrations post-surgery compared to the bifocal IOL. The generation of intraocular phase differences in cataract-affected eyes is primarily due to lens opacity. Thus, we hypothesize that the intraocular high-order phase differences significantly decrease post-surgery due to the removal of the turbid lens. The overall eye phase difference, which includes the intraocular component, also shows a reduction post-surgery. These conclusions, while promising, require confirmation through further large-scale case studies to validate the findings comprehensively.

Carneros-Llorente et al. [19] noted that trifocal IOLs provide better intermediate vision compared to bifocal IOLs without compromising near and far vision, corroborating the findings of this study.

Abnormal optical symptoms can significantly reduce patient satisfaction following cataract surgery, making the assessment of visual quality crucial. Post-surgical changes in corneal and intraocular aberrations, particularly coma, are often linked to the eccentricity and tilt of the intraocular lens. This issue is prevalent when the anterior capsule is not centered, continuous, and annular, potentially causing blurring, ghosting, and phenomena such as astigmatism and comet tails that interfere with vision [20].

SR and MTF-cutoff are critical metrics used to evaluate the loss of imaging contrast and sharpness, eliminating the influence of subjective factors such as low-order aberrations and neural responses. These metrics objectively reflect the optical imaging quality of the eye and quantitatively measure human visual quality under the best-corrected visual acuity [21]. According to Kora et al. [22], AL correlates with the severity of cataract lesions. Longer axial lengths are associated with more severe fundus lesions and poorer visual quality, often compounded by other ocular conditions such as retinal choroidal atrophy, leading to suboptimal surgical outcomes. Conversely, shorter AL, which indicate a smaller eyeball size, are linked to more severe macular dysplasia of the optic papilla, resulting in diminished visual function after surgery.

In this study, the SR and MTF cutoff values for the two patient groups with different AL were significantly higher at T1 compared to T0. The improvements in these indices were more pronounced in the observation group than in the control group. These results demonstrate that the PanOptix trifocal IOL not only significantly enhances uncorrected visual acuity but also objectively improves visual quality indicators such as contrast and sharpness. The PanOptix trifocal IOL effectively reduces total aberrations without introducing excessive high-order aberrations. Compared to bifocal IOLs, it offers superior improvements in imaging contrast and sharpness, thereby enhancing overall visual quality.

The defocus curve is a crucial metric for assessing overall visual acuity, illustrating how visual acuity varies under different defocus conditions (analogous to varying viewing distances). In this study, the defocus curve obtained at T1 revealed a bimodal distribution in the observation group, with peaks at 0 D and -2.5 D. The transition between +0.5 D and -3.0 D was smooth, achieving a visual acuity level exceeding 0.73. Conversely, the peak visual acuity for the control group ranged from 0 to -1 D, with the curve from -0.5 D to -3.0 D demonstrating a declining trend. Consistently, the visual acuity in the observation group surpassed that of the control group, indicating superior full-range vision with the PanOptix trifocal IOL. This IOL effectively addresses common deficiencies in middle and near vision while maintaining excellent far vision, attributed to its design incorporating +3.33 D for near and +1.66 D for intermediate additional focal lengths. Further analysis focused on the subjective visual quality, showing that postoperative visual quality scores were significantly higher than preoperative scores. This improvement underscores the PanOptix trifocal IOL's efficacy in enhancing patients' visual experiences across various distances.

While slight IOL tilt does not typically affect visual acuity, it may negatively influence the optical performance of eyes implanted with aspheric IOLs, astigmatism-corrected IOLs, and multifocal IOLs [23]. Lawu et al. [24] posited that the eccentricity and tilt of the IOL increase higher-order aberrations such as coma, which can induce astigmatism and defocus. Although astigmatism and defocus are correctable with glasses, non-correctable aberrations like coma can degrade visual quality. This study corroborated these findings, showing a positive correlation between the tilt of the PanOptix trifocal IOL and coma, consistent with results by Taketani et al. [25]. Additionally, Turuwhenua [26] observed that IOL decentration could exacerbate Coma, with the direction of IOL tilt influencing the increase or decrease in Coma. These studies collectively highlight that IOL eccentricity and tilt impact higher-order aberrations, particularly affecting coma.

This study has limitations due to its small sample size, potentially introducing bias in the statistical analysis. Future research should include expanded sample size and randomized controlled trials to enhance reliability and validity. Comparisons with optical performance post-implantation of different types of IOLs were not conducted in this study and represent a direction for future research.

In summary, implanting PanOptix trifocal IOL effectively enhances visual quality in patients with cataracts of varying AL, offering excellent subjective and objective visual outcomes and full-range vision. These benefits affirm its clinical value and justify wider adoption.

Disclosure of conflict of interest

None.

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