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Comparison of visual outcomes in patients with cataracts and high myopia after implantation of a zonal refractive multifocal or diffractive bifocal intraocular lens

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This study compares the optical quality of zonal refractive multifocal and diffractive bifocal intraocular lenses (IOLs) and visual outcomes after implantation in 93 patients(93 eyes) with cataracts and high myopia. A retrospective analysis was conducted to measure visual acuity at far, intermediate, and near distances, defocus curves, wavefront aberrations, modulation transfer function (MTF), a Quality of Vision questionnaire (QoV) and visual quality self-evaluation were examined at 3 months. The results demonstrated the ZMB group showed better uncorrected near visual acuity ($P < 0.01$), and the MF15 group showed better uncorrected intermediate visual acuity ($P < 0.001$). The ZMB group provided better MTF than the MF15 group ($P < 0.01$) but demonstrated a worse QoV score, especially for the severity of glare, halo, and starburst ($P < 0.05$). The satisfaction score and spectacle independence rate in the ZMB group were higher than in the MF15 group ($P < 0.01$). LS-313MF15 and TecnisZMB00 offered excellent visual restoration, stable distance visual acuity, and good subjective visual function.

Keywords Zonal refractive multifocal, Diffractive bifocal intraocular lenses, High-order aberration, Visual quality, High myopia

Cataracts and high myopia are the major causes of blindness worldwide. The proportion of cataract patients with high myopia is as high as 12.6%, and its incidence increases annually[1]. With the rapid development of refractive cataract surgery for patients with cataracts and high myopia, implantation of multifocal intraocular lenses (MIOLs) can effectively correct ametropia[2]. MIOLs offer excellent visual restoration and visual acuity after surgery, helping patients remove their lenses and improve satisfaction. The Lentis Comfort LS-313 MF15 and Tecnis ZMB00 are examples of intraocular lenses that have gained widespread use in clinical settings.

Studies with similar scope in this setting have been scrutinized[3]. This study aims to analyze and compare the visual acuity, visual quality, and overall satisfaction in patients with cataracts and high myopia 3 months after implantation of MIOL (either LS-313MF15 or TecnisZMB00). Furthermore, this study will evaluate the visual characteristics of the two types of IOLs. We aim to offer guidance for formulating personalized treatment plans for clinical work.

Results

Preoperative parameters

In this retrospective study, ninety-three eyes (93 patients) were included. MF15 IOL (50 eyes, 50 patients) was implanted in those who required intermediate vision and ZMB IOL (43 eyes, 43 patients) in those who required near vision. There were no statistically significant differences in age, UDVA, and other preoperative variables such as AL, IOP, corneal endothelial count, and presence of corneal astigmatism between the two groups ($P > 0.05$). (Table 1).

Visual acuity

The UDVA of the two groups improved significantly 3 months after the operation. There was no significant difference in UDVA and BDVA between the MF15 and ZMB groups ($P > 0.05$). The UIVA of the MF15 group

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Preoperative parameter	MF15	ZMB	*P*-value
No. of eyes (patients)	50 (50)	43 (43)	
Age (y)	66.52 ± 7.03	68.19 ± 8.28	0.296
Sex (n)			0.598
Male	24	23	
Female	26	20	
AL (mm)	27.48 ± 1.19	27.60 ± 1.30	0.658
IOP (mmHg)	16.92 ± 2.49	16.88 ± 2.38	0.943
Corneal endothelial cell density (/mm^2)	2795.44 ± 295.84	2813.70 ± 304.07	0.779
UDVA (log MAR)	1.222 ± 0.61	1.10 ± 0.54	0.424
Astigmatic (D)	0.52 ± 0.26	0.44 ± 0.24	0.154

Table 1. Comparison of general data between the two groups before surgery. Values presented as mean ± SD. AL = Axial length; IOP = Intraocular pressure; UDVA = Uncorrected distance visual acuity.

Parameters	MF15	ZMB	*p*-value
UDVA (log MAR)	0.12 ± 0.20	0.10 ± 0.22	0.670
UIVA (log MAR)	0.19 ± 0.16	0.38 ± 0.24	< 0.001***
UNVA (log MAR)	0.32 ± 0.15	0.21 ± 0.21	0.003**
BDVA (log MAR)	0.08 ± 0.08	0.10 ± 0.11	0.798
SA (μm)	0.032 ± 0.021	−0.001 ± 0.033	< 0.001***
Coma (μm)	0.074 ± 0.050	0.060 ± 0.048	0.112
tHos (μm)	0.208 ± 0.110	0.190 ± 0.108	0.355
QoV score	17.34 ± 5.17	20.42 ± 6.26	0.011*
Satisfaction	7.10 ± 1.56	8.05 ± 1.36	0.002**
Spectacles independence	38 (76%)	42 (97.7%)	0.002**

Table 2. Comparison of the results between the two groups 3 months after operation. Values presented as mean ± SD. UDVA = Uncorrected distance visual acuity; UIVA = Uncorrected intermediate visual acuity; UNVA = Uncorrected near visual acuity; BDVA = Best-corrected distance visual acuity; SA = spherical aberrations; tHos = total high-order aberrations; QoV = Quality of vision score. *$P < 0.05$,**$P < 0.01$,***$P < 0.001$.

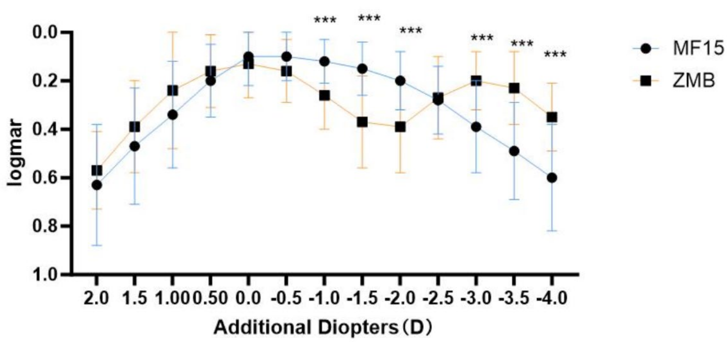

Fig. 1. Defocus curve of two groups 3 months after operation (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

was better than that of the ZMB group ($P < 0.001$), and the UNVA of the ZMB group was better than that of the MF15 group ($P < 0.01$; Table 2).

Defocus curve

Figure 1 shows the monocular defocus curves of the two groups at 3 months post-surgery. The curve on the span of − 0.50D to − 2.50D in the MF15 group decreased slowly, and the visual acuity showed a plateau with a high peak, which was better than that in the ZMB group ($P_{-1.00D}$<0.001, $P_{-1.50D}$<0.001, and $P_{-2.00D}$<0.001). The defocus curve of the ZMB group had a bimodal shape with peaks at 0.0D and − 3.00D. The span of the − 3.00D–-4.00D group was better than that of the LS-313MF15 group ($P < 0.001$).

Objective visual quality /wavefront aberration and the MTF

As shown in Table 2, the spherical aberration in the MF15 group was higher than that in the ZMB group ($P < 0.001$). However, no significant difference was observed in the coma or total high-order aberrations ($P > 0.05$).

The MTF in the ZMB group, as shown in Fig. 2, was significantly higher than that in the MF15 group at each spatial frequency ($P < 0.01$).

Quality of vision questionnaire and visual quality self-evaluation

Details on the QoV score, postoperative satisfaction scores, and spectacle independence are presented in Table 2. The QoV score in the ZMB group was significantly higher than in the MF15 group ($P < 0.05$). The glare, halo, and starburst severity in the ZMB group was significantly higher than in the MF15 group ($P < 0.05$; Fig. 3). The postoperative satisfaction scores were high in both groups and significantly better in the ZMB group ($P < 0.01$). The spectacle independence of the ZMB group was significantly higher than that of the MF15 group ($P < 0.01$).

Discussion

Cataract surgery has evolved into an era of refractive surgery, with the extensive clinical adoption of MIOL leading to improvements in far, intermediate, and near visual acuity[4,5]. Patients with cataracts and high myopia have a higher demand for near-visual acuity post-surgery, and due to prolonged spectacle use, they have a stronger desire to eliminate dependency on spectacles[6]. However, these patients often have anatomical abnormalities such as a deep anterior chamber, loose capsule, and elongated axial length of the eye[7], necessitating a cautious approach in selecting MIOL. With the advancements in science and technology, some studies have reported[8,9] improved visual quality in patients with cataracts and high myopia following MIOL implantation. Nonetheless, postoperative glare, halos, and decreased contrast sensitivity persist as challenges.

There is a close relationship between high myopia and cataracts, with cataracts occurring earlier and progressing rapidly in patients with high myopia. Highly myopic eyeballs are often associated with various pathological changes such as thinning and flattening of the cornea, a deep anterior chamber, a large lens capsule, relaxation of the suspensory ligament, posterior scleral staphyloma, and other highly myopic fundus lesions. These unfavorable factors restrict the use of MIOL in patients with cataracts and high myopia. However, the 2023 Recommendation for Presbyopia-Correcting Intraocular Lenses indicates that patients with myopia who do not have obvious fundus lesions and express a strong desire to eliminate the need for lenses can choose multifocal IOL implantation with full awareness of associated risks[10]. Patients with cataract and high myopia have long axial length, and their conditions are more complicated than normal cataract patients, so the choice of IOLs should be more careful. This article can provide a better personalized treatment plan for these patients.

This study compared and analyzed visual acuity and visual quality 3 months after implantation of refractive MIOL (LS-313MF15) or diffractive MIOL (TecnisZMB00) in patients with cataracts and high myopia and reported the characteristics of visual quality in both groups.

Some studies have shown that[3,11–14] both the refractive and diffractive MIOLs can yield good UDVA, with MF15 additionally providing good intermediate vision. The ZMB, on the other hand, can provide good near vision. Our study showed that the UDVA of MF15 and ZMB were satisfactory. Also, the uncorrected near visual acuity of the ZMB group was better than that of the MF15 group, consistent with the results of previous studies.

The defocus curve indicates real vision under different defocus conditions, providing insight into the overall vision[15,16]. In our analysis, the defocus curve showed that both groups exhibited good uncorrected distant visual acuity in the range of + 1.0D to − 0.5D. The intermediate visual acuity of the MF15 group was significantly better than that of the ZMB00 group in the range of − 0.5D to − 2.0D, while the uncorrected near visual acuity of the

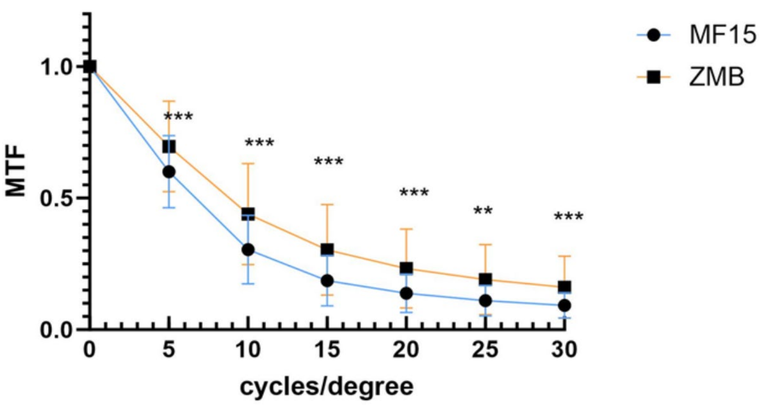

Fig. 2. MTF of the two groups at each spatial frequency 3 months after operation (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

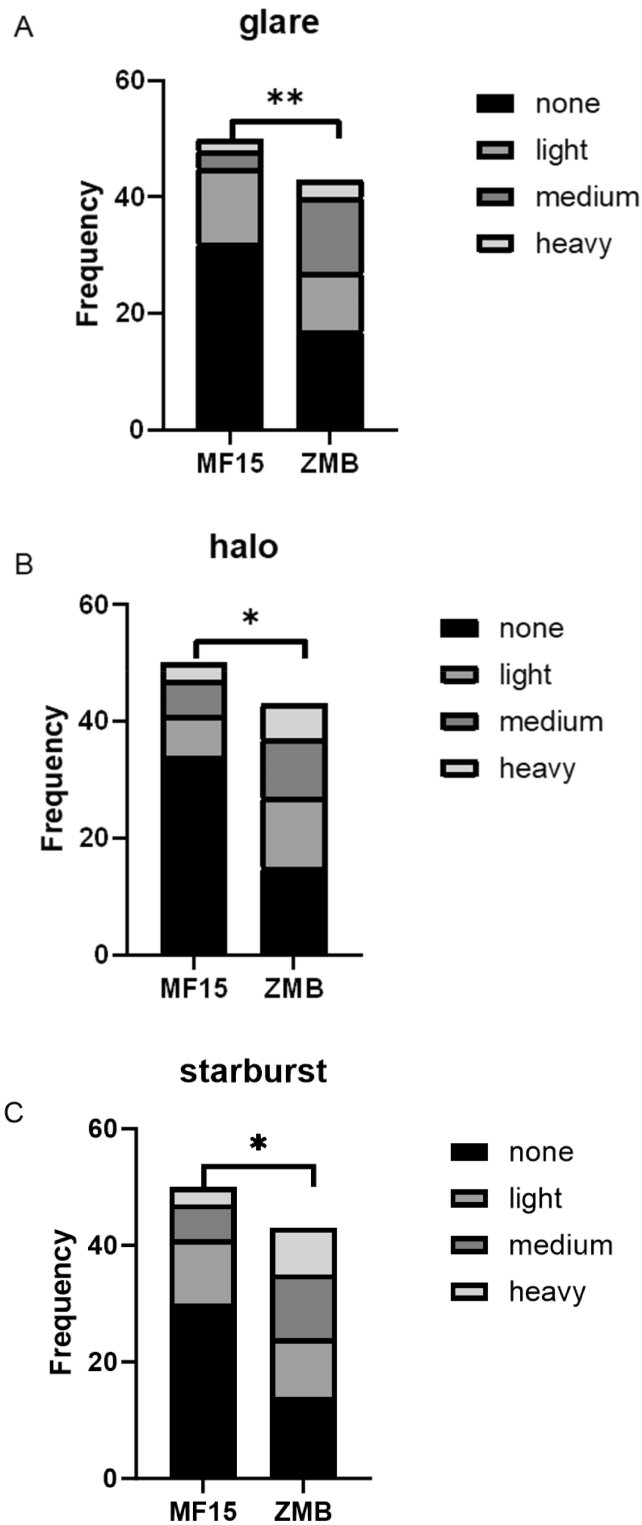

Fig. 3. Bars showing the proportion of severity of glare (**A**), halo (**B**), and starburst (**C**) in the QoV questionnaire 3 months after operation in both groups (*$P < 0.05$, **$P < 0.01$).

ZMB group was significantly better than that of the MF15 group at − 3.0D to − 3.5D. Compared to ZMB, the defocus curve of MF15 has more visual continuity. Patients in the ZMB group reported significantly better near vision, eliminating the need to wear glasses at close range post-operation. Patient satisfaction was high among those in the ZMB group, consistent with findings from previous studies[17,18].

MTF can quantify the objective visual quality and is a dynamic expression of contrast sensitivity[19]. This suggests the capacity of the optical system to translate minute intricacies (spatial frequencies) from the object to its corresponding image. The MTF constitutes the optical element within the CS function. Higher MTF values correspond to better postoperative visual quality. Some studies have shown[17]that refractive IOLs, in comparison to diffractive IOLs, offer better contrast sensitivity. However, aberrations may reduce its retinal imaging quality and decrease the contrast sensitivity of refractive IOLs. Our study demonstrated that the ZMB exhibited higher MTF values across all spatial frequencies than the MF15, indicating superior objective visual quality. This improvement is attributed to the − 0.27 aberration reduction technology, the elongated focal point from the echelette design and the high Abbe number of hydrophobic acrylic achromatic technology incorporated into ZMB based on the Tecnis platform[20]. This ultimately enhances contrast sensitivity and improves retinal imaging quality.However, Charles et al. found that in the range of 6–18 cycles/degree, contrast sensitivity is not only influenced by optical quality, but neural sensitivity is also critical[21]. This will constitute the primary area of investigation in a study that is scheduled to commence at a subsequent time.

High-order aberrations include spherical, coma, and trefoil aberrations. The aberrations that reduce the imaging quality are mainly spherical aberrations and coma. Vega et al. found that common adverse optical interference phenomena after MIOL implantation, such as glare and halo, are linked to aberrations[22]. This study showed that when the pupil diameter was < 5 mm, there was no significant difference in total high-order aberration and coma between the two groups. However, the spherical aberration in the ZMB group was significantly lower than that in the MF15 group, which was related to using the − 0.27 anti-spherical aberration technique by ZMB on the Tecnis platform.

The QoV is an adjusted questionnaire[23] that uses the most intuitive pictures to illustrate potential visual phenomena that patients may experience. Some studies have shown that compared with monofocal IOL, multifocal IOLs have a higher probability of adverse optical interference phenomena such as halo and glare[24]. Lee et al. observed that patients tended to achieve spectacle independence at a high rate after multifocal IOL implantation; however, this was at the expense of an increased amount of glare and halo post-surgery[25]. This study found higher levels of patient satisfaction and spectacle independence in both groups post-surgery. Patients' self-evaluation of visual quality revealed that ZMB had better visual quality, but the incidence of glare and halo was higher. In contrast, the incidence of glare and halo in MF15 was lower, possibly due to differences in the underlying principles of refractive and diffractive MIOLs[26]. The upper part of MF15 is divided into the far-sighted area, and the lower part is divided into a near-sighted area with a smooth transition region, resulting in a lower occurrence of optical interference at night, unlike ZMB, which is characterized by 29 concentric diffraction rings[3]. Our findings demonstrated a significantly higher spectacle independence rate and near vision satisfaction in the ZMB group than in the MF15 group. The ZMB IOL is more beneficial for improving near vision in patients with cataract and myopia, while the ZMB could provide near vision at 40 cm.

The prevalence of patients with cataracts and high myopia has gradually increased, and choosing a suitable MIOL for these patients is an urgent issue. This study shows that ZMB and MF15 can provide good uncorrected distant visual acuity and visual quality in such patients. However, the ZMB can provide better uncorrected near visual acuity and improve postoperative spectacle independence and satisfaction. MF15 excels in intermediate visual acuity but is insufficient for near visual acuity in patients with high myopia. Although poor optical interference was mild in patients implanted with MF15 IOL, postoperative spectacle independence and patient satisfaction were slightly lower when compared to those implanted with ZMB. The limitation of this study is that we did not consider the visual quality analysis under the pupil of 3 mm in daily state.

Conclusion

In conclusion, for patients with cataracts and high myopia, although the ZMB or MF15IOL was selected based on the need for vision at varying distances, the ZMB group exhibited higher satisfaction due to their preoperative habit of reading at close range and superior uncorrected near vision compared to their uncorrected distance vision.It is also driven by the dependence on spectacles before surgery and a superior preoperative near vision. Therefore, the diffraction TecnisZMB00 IOL was preferred for this patient group. However, the LS-313MF15IOL has a wider range of refraction, from − 10D to + 34D, providing an alternative for patients with a higher degree of refraction in high myopia. Clinicians should tailor treatment plans to meet each patient's needs and eye conditions to achieve accurate treatment with refractive cataract surgery. Future studies should conduct comparative effectiveness studies to evaluate the long-term outcomes, patient satisfaction, and quality of life for individuals with cataracts and high myopia who undergo refractive surgery with different IOL options.

Methods

Ethical approval

This retrospective study was approved by the Institutional Review Board of The Second Hospital in Jilin University, Changchun, China. All the patients provided written informed consent to participate in this study. The study received the approval of the local ethics committee (2024-045).

Study sbjects

Patients underwent uneventful cataract surgery with the implantation of a Tecnis ZMB (Johnson & Johnson Surgical Vision, Inc., Santa Ana, CA, USA) or a LS-313 MF15 (Teleon Surgical BV, Spankeren, Netherlands) IOL. The surgeries took place from June 2020 to January 2023 at our hospital.

The Lentis Comfort LS-313 MF15 is a foldable, rotationally asymmetric, refractive MIOL composed of a hydrophilic acrylic material and a hydrophobic surface[27]. The double-light mirror inspires the design principle of the MF15. The upper part represents the hyperopic area, the lower part is the + 1.50D additional myopic area, and the light energy loss in the narrow wedge transition zone in the middle is only 5%. This design provides the

IOL with good distant and intermediate vision and a certain level of close vision while simultaneously reducing postoperative optical interference.

The Tecnis ZMB00 is a foldable posterior surface diffractive multifocal intraocular lens. It uses a hydrophobic acrylic material with a high Abbe number to minimize chromatic aberration and increase contrast sensitivity by 12%. The Tecnis ZMB00 adopts a -0.27 anti-spherical aberration design on the Tecnis platform, which makes the total spherical aberration close to 0. It has an all-optical rear surface diffraction design that includes 29 concentric diffraction rings, a central ring diameter of 1 mm, and a near addition of + 4.0D. The IOL can provide patients with 31 cm near vision, addressing the specific near vision needs of Asians[28].

Inclusion criteria were as follows: (1) age 50–80 years; (2) 26 mm ≤ axial length (AL ≤ 30 mm (IOLMaster700 biological measurement); (3) no obvious abnormality in the fundus based on Optical Coherence Tomography (OCT) findings; (4) no other eye diseases including glaucoma, uveitis, endophthalmitis. (5) corneal astigmatism ≤ 1.0D; (6) alpha angle < 0.5 mm, and Kappa angle < 0.3 mm[29]; (7) a reservation degree between − 0.25D and − 0.75D.

The exclusion criteria were as follows: (1) Presence of intraoperative complications; (2) History of severe diabetes, hypertension, or other systemic diseases; and (3) Posterior capsule opacification or any ocular comorbidity. All patients underwent a comprehensive preoperative ophthalmological examination that included measurement of uncorrected distance visual acuity (UDVA, 5 m), intraocular pressure (IOP), and biological parameters (IOL Master 700). Investigations such as corneal endothelial count and morphology, slit-lamp examination, corneal topography (OPD-ScanIII, NIDEK), tear break-up time, and OCT were also done preoperatively.

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Surgical procedure

The same surgeon operated on all patients. Before each operation, the operative eyes were fully anesthetized using 0.4 ml:2 mg procaine hydrochloride. A 2.2 mm main corneal incision, 0.8 mm side-port corneal incision, and 5.5 mm diameter circular continuous capsulorhexis were performed. Lens extraction was accomplished using a standard phacoemulsification technique. The IOL was implanted into the capsule bag. Both theZMB and MF15 IOLs were centered. No complications occurred during the operations.

Outcome and assessment

Three months after surgery, patients were re-examined using UDVA at 5 m, intermediate visual acuity (UIVA, 80 cm), near visual acuity (UNVA, 40 cm), defocus curve, ocular wavefront aberrations (including total high-order aberration, spherical aberration, and coma), modulation transfer function (MTF), QoV and a postoperative visual quality satisfaction score. The specific inspection for each method is detailed below.

Slit lamp examination

Three months after the operation, the reactivity of the conjunctiva, cornea, anterior chamber, and pupil were observed using a slit-lamp microscope (TOPCON Company, Japan), and the tilt, eccentricity, or dislocation of the IOL and opacity of the posterior capsule were observed after mydriasis with tropicamide eye drops.

Visual acuity

Uncorrected visual acuity was measured using a standard logarithmic visual acuity chart[30] in an environment of equal luminance at far (5 m), intermediate (80 cm), and near (40 cm) distances. Corrected visual acuity was measured at a far distance. Values from the standardized logarithm of the minimum angle of resolution visual acuity chart (logMAR) were also derived.

Defocus curve

The + 2.0D to − 4.0D spherical lens degree was added to the patient's operated eye using comprehensive optometry, and the additional spherical lens degree was gradually decreased at an interval of 0.5D. The monocular visual acuity was recorded under each spherical lens.

High-order aberrations and MTF

An iTrace visual quality analyzer (Tracy Technologies, United States) was used to measure total high-order aberrations (tHOs), spherical aberrations (SA), coma, and MTF values at a pupil diameter of 5 mm.

Quality of vision questionnaire and visual quality self-evaluation

The QoV questionnaire evaluated the patients' subjective visual quality and postoperative visual quality satisfaction. The questionnaire evaluated the frequency, severity, and annoyance of 10 optical phenomena, such as glare, halo, and starburst by showing patients standard photos. Each item was scored, ranging from zero to three. The higher the score, the more serious the optical interference and the lower the subjective visual quality. Simultaneously, patients were evaluated using a visual quality satisfaction rating. The score ranges from 1 to 10. The higher the score, the more satisfaction the patients have.

Statistical analysis

Statistical Packages for Social Sciences (SPSS) version 26.0 (IBM Corp.) was used for data analysis. The Shapiro–Wilk test was used to test for normality of data distribution. A tailed independent sample t-test was used for quantitative data, and a chi-square test was used for qualitative data. An alpha value of less than 0.05 was considered statistically significant.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions
The project was created by Hui Zhang. Xinyue Yang and Zhuoya Li created the figures and wrote the manuscript drafts with assistance from Fuqiang Li and He Zou.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
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