RESEARCH ARTICLE

# Comparison of clinical effects of aspherical monofocal and Tecnis ZMB00 multifocal intraocular lenses in patients with age-related cataract

Dan Han, Xinli Ma, Jiayue Gao, Ziwei Xu, Fa Liu

## Abstract

**Objective:** To compare the clinical effects and outcomes in patients implanted with aspheric monofocal and multifocal intraocular lens.

**Method:** This study was conducted from January 2020 to January 2023 at Harbin 242 Hospital in China, using a prospective randomized case-control design. The research subjects were hospitalized patients with age-related cataracts, randomly divided into a control group A receiving single focus intraocular lenses and an intervention group B receiving multi focus intraocular lenses. The visual acuity, visual quality, glasses independence rate, vision related quality of life, and incidence of complications were compared between the two groups. Data analysis was conducted using SPSS 25 software.

**Results:** Of the 100 patients, 50(50%) were in group A; 28(56%) females and 22(44%) males with mean age 63.25±7.59 years. The other 50(50%) patients were in group B; 26(52%) females and 24(48%) males with mean age 62.03±6.74 years ($p>0.05$). Group B patients had higher uncorrected visual acuity at 1 week, 1 month and 3 months post-surgery ($p<0.05$), higher vision-related quality of life at 3 months post-surgery ($p<0.05$), and higher rate of spectacle independence ($p<0.05$) than group A. However, group B had lower modulation transfer function at 30 and 45 cycles per degree, and lower contrast sensitivity function at 3 and 6 cycles per degree than group A ($p<0.05$). The incidence of halo and glare in group B was higher than group A ($p<0.05$).

**Conclusion:** The multifocal intraocular lens outperformed the aspherical monofocal intraocular lens in improving the vision-related quality of life and rate of spectacle independence. However, it had dark vision defects and optical side-effects.

**Key Words:** Cataract, Intraocular lenses, Visual acuity, Treatment outcome.

(JPMA 75: 1229; 2025) **DOI: https://doi.org/10.47391/JPMA.21014**

## Introduction

Age-related cataract is a common cause of visual impairment in the world. Phacoemulsification and intraocular lens (IOL) implantation is an effective method to treat cataract and improve the visual acuity (VA). With a high success rate, this method has been widely used in clinical practice.[1] There are many types of IOLs, each with its own advantages and disadvantages. Different IOLs have different performance levels in improving VA and visual quality (VQ). Monofocal IOLs are commonly used and the degree of the lens can be selected according to the target diopter to correct the patient's vision. However, the spherical monofocal IOLs allow only near or distant vision, with the other vision needed to be corrected by wearing glasses.[2] In order to meet the requirements of improving vision without wearing glasses in the patients undergoing cataract surgery, multifocal IOLs are used. Multifocal IOLs can provide distant, intermediate and near vision, and greatly improve VQ, but they may induce adverse photic phenomena, such as glare and halo.[3] In addition to the design of the lens system, innovation has been achieved in the IOLs, such as aspherical lenses, which reduced glare and improved contrast sensitivity in dim light.[4]

The current study was planned to compare the clinical effects and outcomes in patients implanted with aspheric monofocal and multifocal IOLs.

## Patients and Methods

The prospective, randomised case-control study was conducted at Harbin 242 Hospital in China, China, from January 2020 to January 2023, and comprised inpatients with age-related cataract who were randomised into control group A receiving monofocal IOLs and intervention group B receiving multifocal IOLs. After approval from the ethics review board of Harbin 242 Hospital, sample size was calculated using the formula in reference.[5]

It was assumed that group B and group A will have improved uncorrected near VA (UCNVA) by 0.57 and 0.15,

Department of Ophthalmology, Harbin 242 Hospital, Harbin, China.

**Correspondence:** Fa Liu **Email:** tgy01566@163.com

**ORCID ID:** 0009-0004-9390-3504

**Submission complete:** 15-08-2024 **First Revision received:** 05-11-2024

**Acceptance:** 31-05-2025 **Last Revision received:** 27-05-2025

respectively, with a UCNVA difference of 0.57-0.15=0.42 and an equal standard deviation of 0.30. Alpha (α) was 0.05 (bilateral, $Z\alpha = 1.96$), beta (β) was 0.2 (efficacy 80%; $Z\beta = 0.842$, and δ was the mean difference between the groups. The sample size was enough to cover 20% loss to follow-up.

These patients included men and women aged at least 50 years, diagnosed with monocular cataracts based on slit lamp microscopy, fundus examination, and VQ examination, and have surgical indications such as significant visual impairment, sensitivity to glare, elevated intraocular pressure (IOP) due to anterior chamber flatness and angle stenosis, hyperopia, and presbyopia. After signing the written informed consent form, these patients were randomly assigned through computer sampling and divided into 50 groups using block randomization method. The excluded patients were those with corneal diseases, glaucoma, uveitis, lens dislocation or subluxation, and other eye diseases, patients with a history of previous intraocular and refractive surgeries, patients with severe cardiovascular and cerebrovascular diseases, liver and kidney dysfunction, or cognitive impairment who cannot cooperate with the examination, patients with a history of trauma, high myopia, corneal opacity, and severe dry eye syndrome, as well as patients with serious complications occurring during the surgical process.

Corneal curvature was measured using an automatic refractometer (KR-8900, Topcon, Japan). A corneal topography analyser (Atlas 9000, Carl Zeiss, Germany) was employed to evaluate corneal morphology and measure corneal refractive power. The ocular parameters such as axial length, anterior chamber depth, corneal refractive power, and corneal diameter were estimated by using an IOL optical biometric instrument (Master, Carl Zeiss, Germany). The refractive power of IOL was calculated using the SRK-II formula[6], and the postoperative conventional refractive power was 0-0.25D. Note: SRK-II is a formula for calculating the refractive power of an intraocular lens (IOL), named after the initials of three ophthalmologists: Sanders, Retzlaff, and Kraff. This formula is an improved version of the SRK-I formula developed by them in the 1980s, aimed at more accurately calculating the intraocular lens power of patients with different axial lengths.

Two groups underwent standard phacoemulsification and IOL implantation, respectively. Compound topiramine eye drops (national drug approval number J20180051, TianTian Pharmaceutical (China) Co., Ltd.) were instilled to fully dilate the pupils, and use procaine hydrochloride eye drops (registration number: H20160133, S.A. ALCON-COVREUR) Puurs-Sint-Amands, Belgium before surgery. After surface anaesthesia, a corneal incision was made with a diameter of 2-3 millimeters and a pocket with a diameter of 5-5.5 millimeters. The phacoemulsification probe was inserted through the main incision to emulsify and aspirate the lens. The remaining cortical material was removed from the capsule and an IOL implanted inside the capsule. Note: 5-5.5mm is the size for tearing the capsule.

Group A was implanted with a non spherical single focus IOL (ZA9003, Johnson & Johnson Global Vision), while Group B was implanted with a multifocal IOL (52501TW, Medd Ophtec B.V., Netherlands). After the IOL is implanted in the center of the visual axis, the remaining viscoelastic agent is removed and the corneal incision is closed. After surgery, the patient used tobramycin dexamethasone eye drops (National Medical Products Administration Approval No. H20073641, Hangzhou Guoguang Pharmaceutical Co., Ltd.) and propranolol eye drops (National Medical Products Administration Approval No. H20093827, Shandong Haishan Pharmaceutical Co., Ltd.) China, four times a day for two weeks. Follow up visits to the outpatient department (OPD) were required one week, one month, and three months after surgery. All surgeries were performed by the same surgeon.

Computer optometry was performed at each follow-up visit to examine uncorrected and best-corrected distance (5m), near (33cm), and intermediate (100cm) VA. The uncorrected distance VA (UCDVA), UCNVA and uncorrected intermediate VA (UCIVA) were noted.[3]

Three months after surgery, a visual analyser (KR-1W, Topcon, Japan) was used to analyse the VQ of the whole eye. The modulation transfer function (MTF) values at 15, 30, 45 and 75 cycles per degree (c/d) were measured at the pupil diameter of 5mm. A visual contrast sensitivity tester (CSV-1000E, Vector Vision Company, United States) was used to measure the contrast sensitivity function (CSF) of the surgical eye under dark light conditions 3 months after surgery. The test was carried out with chart brightness 220 lux (lx), distance 3m, and spatial frequency 1.8-24 c/d.

The visual independence rates between groups were compared. Visual acuity related quality of life (VRQoL) was evaluated at baseline and 3 months postoperatively[7]. VRQoL includes 25 items in 4 dimensions: far vision, mobility and light sensitivity, regulatory ability, as well as reading, fine work, and daily life. Each project was rated on a scale of 0-5 points, with a total score range of 0-125 points. The higher the score, the better the quality of life.

The incidence of posterior capsular rupture, corneal incision leakage, and adverse photic phenomena, such as halo, glare and starburst, was recorded for both the groups.

Data was analysed using SPSS 25. Continuous variables with normal distribution were presented as mean± standard deviation. Independent sample t-test was used to compare intergroup differences. Paired sample t-test was used for intragroup differences. Chi-square test was used for intergroup comparison of categorical variables which were expressed as frequencies and percentages. McNemar test was used for intragroup comparisions. P<0.05 was taken as statistically significant.

## Results

All the 100 patients enrolled completed the study and the follow-up, with the response rate being 100%. Of them, 50(50%) were in group A; 28(56%) females and 22(44%) males with mean age 63.25±7.59 years. The other 50(50%) patients were in group B; 26(52%) females and 24(48%) males with mean age 62.03±6.74 years (p>0.05) (Table 1).

UCNVA and UCIVA were higher in group B than group A at 1 week, 1 month and 3 months after the surgery (P<0.05), while the UCDVA difference between the groups at different time points was not significant (p>0.05) (Figure 1).

There was no significant difference with respect to MTF between the groups at 15 c/d (p>0.05). The MTF in group A was higher than that in group B at 30 and 45 c/d (p<0.05) (Figure 2).

The CSF in group A was higher than that in group B at 3 and 6 c/d (p<0.05) (Figure 3).

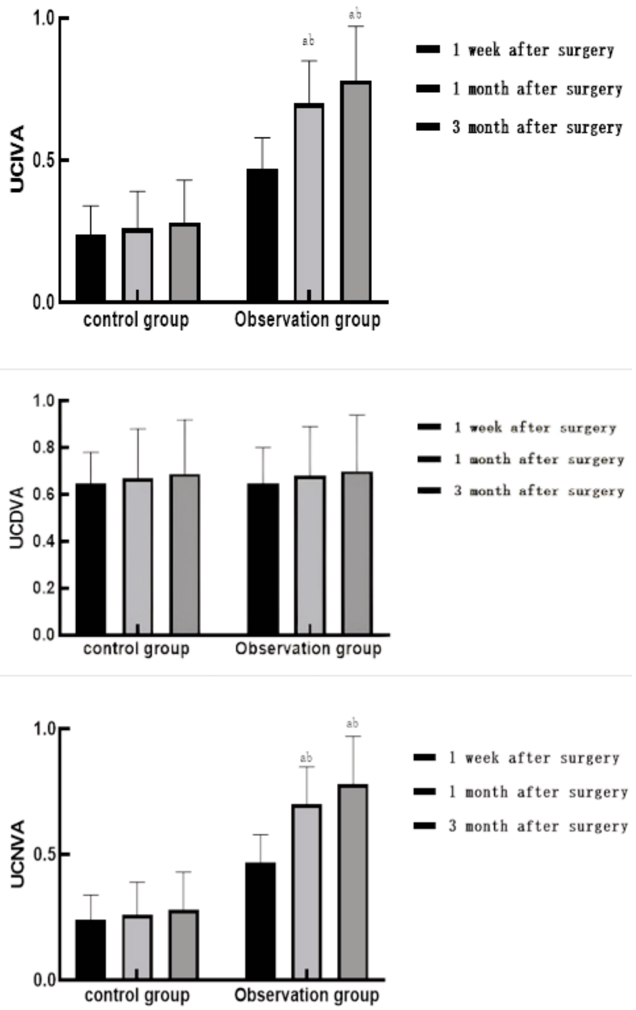


**Figure-1:** Intergroup comparison of visual acuity.
UCDVA: Uncorrected distance visual acuity, UCNVA: Uncorrected near visual acuity, UCIVA: Uncorrected intermediate visual acuity.

**Table-1:** Baseline data.

| Group | n | Age (years) | Male/female | Sides laevo | Sides f. hepatica | Corneal curvature （mm） | Axial length （mm） |
|---|---|---|---|---|---|---|---|
| Group A | 50 | 63.25±7.59 | 22/28 | 18（36.00） | 32（64.00） | 45.32±3.65 | 24.13±1.62 |
| Group B | 50 | 62.03±6.74 | 24/26 | 21（42.00） | 29（58.00） | 44.95±3.07 | 24.08±1.57 |
| *t/x*2 | | 0.850 | 0.161 | 0.378 | 0.549 | 0.157 | |
| P | | 0.398 | 0.688 | 0.539 | 0.585 | 0.876 | |

**Table-2:** Intergroup comparison of rate of spectacle independence and complications.

| Group | Cases | Spectacle independence | Halo | Glare | Starburst | Skimming |
|---|---|---|---|---|---|---|
| Group A | 50 | 10 (20.00) | 0 (0.00) | 1 (2.0) | 0 (0.00) | 1 (2.00) |
| Group B | 50 | 39 (78.00) | 4 (8.00) | 6 (12.00) | 1 (2.00) | 2 (4.00) |
| $\chi^2$ | | 33.654 | - | 4.891 | - | 0.344 |
| P | | 0.000 | 0.041 | 0.027 | 0.315 | 0.558 |

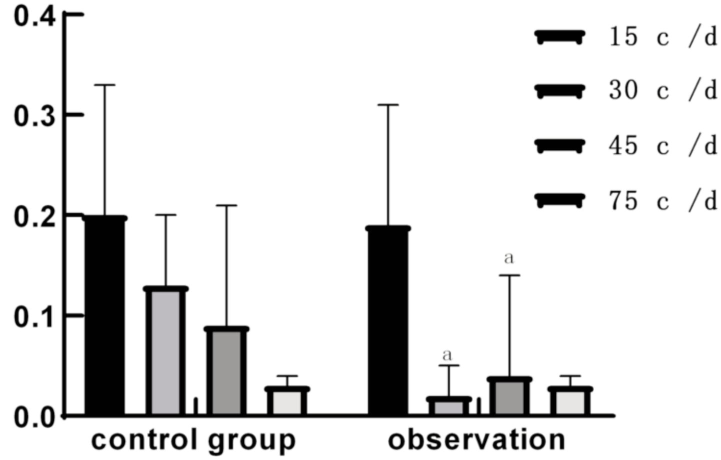


**Figure-2:** Intergroup comparison of modulation transfer function (MTF).

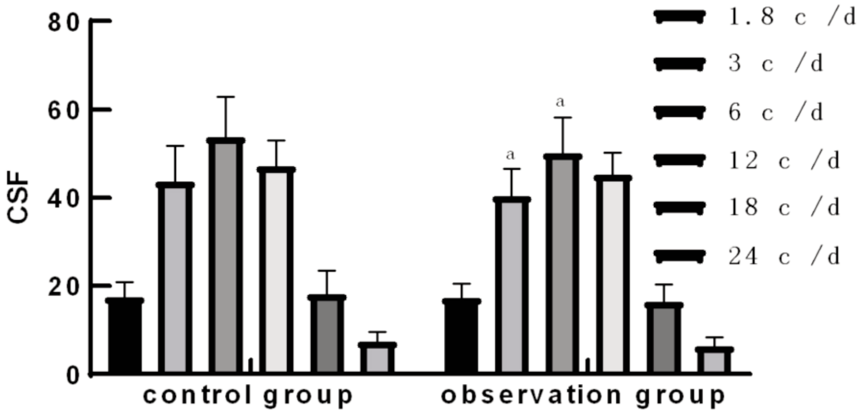


**Figure-3:** Intergroup comparison of contrast sensitivity function (CSF).

VRQoL scores at 3 months post-surgery in group A was 75.19±21.46 minutes compared to 53.02±12.65 minutes pre-surgery. The corresponding values in group B were 95.48±30.28 minutes and 52.77±11.43 minutes ($p<0.05$). The difference is group B at 3 months post-surgery was significantly higher than group A ($p<0.05$).

The rate of spectacle independence in group B was higher than that in group A ($p<0.05$). Neither group showed rupture of posterior capsule or leakage of corneal incision. The incidence of halo and glare in group B were higher than those in group A ($p<0.05$). The incidence of starburst and skimming showed no significant differences between the groups ($p>0.05$) (Table 2).

## Discussion

As age increases, the lens aberration of cataract patients increases, and the imaging quality of the optical system decreases.[8] The traditional single focus artificial intraocular lens cannot solve the problem of spherical aberration due to its spherical design, which affects postoperative VQ.[9] Non spherical single focus intraocular lenses can compensate for the corneal aberration of traditional spherical single focus intraocular lenses, reduce the total aberration of implanted eyes, improve day night vision and postoperative VQ.[10-11] In the current study, UCDVA in the control group improved after treatment. MTF is the spatial equivalent of the frequency response of an imaging system, which reflects the fine ability of a visual object. CSF reflects the ability of the visual system to perceive contrast, such as object boundaries being clear versus blurred, black versus white, and so forth, and is therefore more indicative of visual function than VA.[12] This study showed that the MTF at 30 and 45 c/d was higher in the control group than in the observation group, and the CSF at 3 and 6 c/d was higher than in the observation group, which indicates that aspheric monofocal IOLs have significant advantages in improving night vision and the resolution of the contours and details of objects. There may be several reasons for such an outcome. The optical morphology of aspheric crystals is closer to the physiological properties of natural lenses, especially mimicking the negative spherical aberration properties of young lenses, which counteracts the positive spherical aberration of the cornea and creates a quality of vision that is closer to physiological states.[13] Also, the high-end aspheric crystal used adopts high dispersion coefficient materials and precision manufacturing process, which can reduce chromatic aberration interference and further enhance the clarity and colour reproduction ability of imaging. Besides, the aspherical design eliminates spherical aberration, which makes the light passing through the peripheral and central parts of the crystal focus more consistently, avoiding the problems of night-time glare and halo caused by the peripheral aberration of traditional spherical crystals[14], and making the VQ more stable, especially in dark light environments. Moreover, the peripheral flattening design of the aspheric crystal optics maintains the accuracy of light focussing when the pupil is dilated (e.g., at night) and reduces the blurring or distortion of the image caused by pupil dilation. Finally, the aspheric design reduces light scattering and aberrations and enhances contrast perception under different light conditions.[15]

A multifocal IOL is a good alternative to IOL implantation for cataract patients. It uses an optical design, such as refraction, diffraction or extended depth of focus, to divide light into multiple focal points. In this way, the retina can focus on images at different distances, thus obtaining a complete range of vision. Thus, multifocal IOLs provide additional technical support in cataract surgery. Multifocal IOLs overcome the disadvantages of monofocal IOLs, such as fixed curvature, loss of adjustability, and difficulty in near vision, and complete vision can be reconstructed after surgery. In this study, multifocal IOL implantation was used in the observation group. After surgery, UCNVA, UCIVA, VRQoL and spectacle independence rate of the observation group were higher than those of the control group. The results suggest that multifocal IOLs can improve the vision and QoL of patients with senile cataracts and satisfy their need for spectacle independence.

The multifocal IOL was superior to the monofocal IOL in these aspects. This was because, through the special design of optical zones (such as diffraction ring or refractive zoning), multifocal IOLs distribute the incident light to different focal points, and satisfy the visual needs of multiple distances at the same time, such as far, intermediate and near. Besides, expanding the effective depth of field range through optical zoning and aberration control, diffractive crystals utilise the principle of light wave interference to form multiple overlapping focal points in the retina, covering a wider range of visual distances. Asymmetric refractive crystals (e.g. SBL-3) can optimise intermediate vision by introducing coma to enhance the quality of mid-distance vision. The surface of the crystal can be divided into different functional zones (e.g., distance, intermediate, and near zones), and the light distribution can be dynamically adjusted according to the pupil. Some crystals (e.g., the rotating asymmetric design) can maintain intermediate and near vision in dim light, reduce glare interference, and have low-light adaptability. In addition, the type of lens (e.g. trifocal, bifocal) can be selected and the implantation position adjusted according to the patient's corneal astigmatism, pupil diameter and other parameters to ensure that the optical centre is aligned with the optic axis, thus achieving personalised fit and precise implantation. Note: The asymmetric refractive artificial crystal SBL-3 is a newly designed multifocal IOL.

Wu et al.[16] used multifocal IOL for astigmatism correction and single focal IOL for astigmatism correction to treat cataracts. The results showed that multifocal IOLs provided good near and far vision, and compared to single focal IOLs, multifocal IOLs provided a higher glasses independence rate (91% compared to 18%). It can be seen that multifocal intraocular lenses can systematically improve mid to far vision through physical optical design, optimized biological and neural adaptation mechanisms, which is crucial for improving patients' visual quality of life scores and eyeglass independence rates.[17] Ban et al. [14] compared the use of trifocal intraocular lenses, area refractive non spherical multifocal intraocular lenses, and single focal intraocular lenses for age-related cataracts, and concluded that trifocal intraocular lenses are superior to single focal intraocular lenses in improving vision and VQ.

However, multifocal IOLs cause light splitting due to the increase in focal depth or the projection of multiple foci, resulting in loss of light energy and optical interference due to light redistribution, especially in dark environments where retinal contrast sensitivity is reduced. In the current study, the observation group had lower MTF values than the control group at 30 and 45 c/d, lower CSF values than the control group at 3 and 6 c/d, and a higher incidence of halos and flares than the control group, which suggests that multifocal IOLs have dark vision defects and optical side-effects. Side-effects can seriously affect patients' VQ and satisfaction. The additional diopter of a trifocal IOL may increase the incidence of glare. In some cases, adaptation failure can lead to poor subjective vision and light abnormalities at distance, thus affecting VQ. In severe cases, removal of the multifocal IOL may be required.[18]

The current study has limitations, such as a small sample size, and a short postoperative follow-up. Future studies with larger samples and longer follow-ups are recommended to validate the current findings.

## Conclusion

Both aspherical monofocal and multifocal IOLs achieved good corrected VA. The multifocal IOL outperformed the aspherical monofocal IOL in terms of uncorrected near-to-intermediate VA, meeting the patient’s full vision needs and improving the VRQoL and the rate of spectacle independence. However, there were dark vision defects and optical side-effects. The selection of appropriate IOLs according to the needs of patients is essential in clinical practice.

**Consent for publication:** Written informed consent to publish this information was obtained from the study participants.

**Disclaimer:** None.

**Conflict of Interest:** None.

**Source of Funding:** The Research Project of Heilongjiang Provincial Health and Family Planning Commission, China (No. 2016-267).

**Ethics approval and consent to participate:** The study was approved by the institutional review board and ethics committee of Harbin 242 Hospital and was conducted in accordance with the principles of the Helsinki Declaration. All patients provided written informed consent to use their data for analysis and publication.

## References

1. Jain S, Rajshekar K, Aggarwal A, Chauhan A, Gauba VK. Effects of cataract surgery and intra-ocular lens implantation on visual function and quality of life in age-related cataract patients: a systematic review protocol. Syst Rev. 2019; 8:204. doi: 10.1186/s13643-019-1113-6.
2. Lapp T, Wacker K, Heinz C, Maier P, Eberwein P, Reinhard T. Cataract Surgery-Indications, Techniques, and Intraocular Lens Selection. Dtsch Arztebl Int. 2023; 120:377-86.doi: 10.3238/arztebl.m2023.0028.
3. Wu J, Zhu L. Full range of vision and pseudo accommodation in early stage after multifocal intraocular lens implantation. Rec Adv Ophthalmol. 2017; 37:572-5.
4. Song XD, Hao YS, Li XR, Zhang H, Ye J, Sun YX, et al. Safety and efficacy of A1-UV aspheric intraocular lens implantation over the postoperative 5 years. Zhonghua Yan Ke Za Zhi. 2021; 57:41-7.doi: 10.3760/cma.j.cn112142-20200227-00120.
5. Lv YQ, Feng GS. Common sample size estimation methods in medical research. J Chronic Pathematol. 2016; 17:359-61.
6. Chen WR, Meng QL, Ye HY, Liu YZ. Reading ability and stereoacuity with combined implantation of refractive and diffractive multifocal intraocular lenses. Acta Ophthalmol. 2011; 89:376-81. doi: 10.1111/j.1755-3768.2009.01702.x.
7. Zhenping Z. Crystallography. Guangzhou: Guangdong Science and Technology Press, 2005; pp-80.
8. Chen LL, Chen ZL, Xu GH, Huang BY. Observation of long-term efficacy of phacoemulsification combined with intraocular lens implantation in the treatment of age-related cataract patients with high myopia. Shandong Med J. 2021; 61:93-6.
9. Huo M, Dong YH, Zhang J. The relationship between different SA values and visual quality in patients with age-related cataract after intraocular lens implantation. Anhui Med J. 2021; 42:912-5.
10. Jianquan L, Xiaoli W, Jian Z. Visual acuity and visual quality analysis after regional refractive multifocal and non-spherical single focal IOL implantation. Int J Ophthalmol. 2020; 20: 1714-8.
11. Lian HF, Ma WS, An L, Chen C, Wei QH. Clinical study of the visual quality after implantation of an aspherical intraocular lens ZCB00. China Med Herald. 2017; 14:121-4.
12. Mai SL, Xing JQ, Huang XG. Comparison between the visual functions of age-related cataract patients after implantation of multifocal intraocular lens and extended depth-of-focus intraocular lens. Rec Adv Ophthalmol. 2021; 41:737-40.
13. Cao GL, Liu XM, Fan Z, Ren ZC, Huang YS. Evaluation of optical performance of IOL in vitro by optical bench. Chin J Optom Ophthalmol Vis Sci. 2022; 24:894-901.
14. Ban JF, Li JK, Guo LX. Influence of three kinds of intraocular lens on vision and visual quality of patients with age-related cataract. IES. 2021; 21:106-10.
15. Lee JH, Kong M, Sohn JH, Cho BJ, Choi KY, Lee SM. Analysis of Korean retinal specialists' opinions on implanting diffractive multifocal intraocular lenses in eyes with underlying retinal diseases. J Clin Med. 2022; 11:1836. doi: 10.3390/jcm11071836.
16. Wu Q, Wang CY, Li Y, Tang L. Study on visual quality and patient satisfaction after astigmatic multifocal intraocular lens implantation. IES. 2019; 19:1586-9.
17. Wang JH, Guan HJ, Ji M. Research progress of multifocal intraocular lens. Rec Adv Ophthalmol. 2023; 43:651-5.
18. Al-Shymali O, McAlinden C, Alio Del Barrio JL, Canto-Cerdan M, Alio JL. Patients' dissatisfaction with multifocal intraocular lenses managed by exchange with other multifocal lenses of different optical profiles. Eye Vis. 2022; 9:8. doi: 10.1186/s40662-022-00280-8.

---

**AUTHOR'S CONTRIBUTION:**
**DH:** Concept, design, data acquisition, analysis and interpretation.
**XM & JG**: Drafting and revision.
**ZX:** Final approval.
**FL:** Final approval and agreement to be accountable for all aspects of the work.