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Visual effects of trifocal intraocular lens implantation in cataract patients with different refractive states

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Abstract

Aims To compare the visual effect and subjective satisfaction of cataract patients with different refractive states after trifocal intraocular lens (IOL) implantation.

Methods This retrospective study describes 134 eyes of 86 patients that were implanted with trifocal IOL (TFNT00). Patients were allocated into three groups according to their preoperative axial length (AL): A group (AL ≤ 24 mm), B group (24 mm < AL < 26 mm), and C group (AL ≥ 26 mm). Postoperative visual acuity, defocus curve, visual quality and subjective satisfaction were collected and compared, and the postoperative follow-up time was at least 3 months (3 months to 3 years).

Results The uncorrected intermediate visual acuity (UIVA) and uncorrected near visual acuity (UNVA) of A group was significantly better than B group ($P=0.008$ and $P=0.016$). The UNVA of C group was significantly better than B group ($P=0.047$). The defocus curve showed that the visual acuity of three groups from 40 cm to 5 m was better than 0.16 (LogMAR). The near vision satisfaction of B group was significantly lower than A group and C group ($P<0.001$ and $P=0.004$).

Conclusions For cataract patients with different refractive states, trifocal IOL implantation can provide good visual and refractive outcomes. For cataract patients with low and moderate myopia, the UIVA and UNVA were worse, and the subjective satisfaction of near vision was also worse than the hyperopia and emmetropia and the high myopia.

Keywords Trifocal intraocular lens, Cataract, Refractive status, Visual quality, Satisfaction

Introduction

With the development of trifocal intraocular lens (IOL) technology, modern cataract surgery has developed from simple operation to cover the eyesight to refractive cataract surgery with the goal of improving "functional vision", and patients have put forward higher requirements for postoperative visual quality and life quality. The design of multifocal intraocular lens (MIOL) overcomes the defect that the traditional monofocal IOL has no accommodation, which leads to the difficulty of postoperative near vision, and MIOL can reconstruct the whole postoperative vision of patients, improve the rates

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of spectacle independence, and improve the postoperative life quality of cataract patients.

PanOptix trifocal intraocular lens (TFNT00) provides an intermediate focal point at 60 cm and a near focal point at 40 cm, which can provide patients with clear vision from distance to near. It has been widely used in clinical and achieved good results [1–4]. Previous studies have shown that for patients with hyperopia, emmetropia or myopia, the trifocal intraocular lens can provide satisfactory vision and refractive results [5–10]. For high myopia patients with different axial lengths, the trifocal intraocular lens can also provide good visual effects [11, 12]. However, there are few studies on the comparison of visual effects after implantation of trifocal intraocular lens in cataract patients with different refractive states.

We performed a retrospective study of 86 patients (134 eyes) who underwent cataract phacoemulsification combined with TFNT00 implantation in our hospital, and compared the postoperative visual effects and satisfaction of cataract patients with different refractive states, in order to provide references for clinical diagnosis and treatment.

Methods

Patients

The inclusion criteria were cataract patients aged ≥ 18 years and underwent cataract phacoemulsification combined with trifocal intraocular lens (TFNT00) implantation. The exclusion criteria included previous corneal refractive surgery, endothelial keratopathy, glaucoma, amblyopia, retinal diseases and serious systemic diseases.

A total of 86 patients (134 eyes) were available for analysis who underwent cataract phacoemulsification combined with trifocal intraocular lens (TFNT00) implantation in the Army Specialty Medical Center (Daping Hospital) from August 2020 to December 2023. According to preoperative axial length (AL), the patients were divided into 3 groups: A group (AL ≤ 24 mm), B group (24 mm < AL < 26 mm), and C group (AL ≥ 26 mm). This study process complies with the requirements of the Declaration of Helsinki and was approved by the Ethics Committee of the Army Specialty Medical Center [Medical Research Review (2024) No. 50]. All patients gave informed consent.

Preoperative examinations

All patients underwent a thorough preoperative evaluation before surgery, including the examination of uncorrected and corrected visual acuity, intraocular pressure (IOP), slit-lamp examination, manifest refraction, corneal endothelial cell examination, ocular B-ultrasound, macular OCT, corneal topography (Pentacam HR), biometric evaluation (IOLMaster 700) and a fundus examination. Visual acuity was recorded in the form of logarithm of the minimum angle of resolution (logMAR). The axial length of the eye was measured by the IOLMaster700. The IOL power required was calculated with the Barrett Universal II formula. The preoperative correction type of all the patients were wearing glasses.

Surgical procedure

Surgery was performed by the experienced surgeon using topical anesthesia. For patients with preoperative corneal astigmatism of less than 0.50 D, an incision at 135∘ and an incision at 45∘ were used. For the other patients with higher corneal astigmatism, the incision was located at the steep meridian. Femtosecond corneal incisions were applied with the LenSx femtosecond laser system. After the continuous curvilinear capsulorhexis with a 5.5–6.0 mm diameter, the phacoemulsification were performed. After cataract removal by phacoemulsification, the anterior chamber was filled with the ophthalmic viscosurgical device, and then the trifocal IOL (TFNT00) was implanted in the capsular bag. The ophthalmic viscosurgical device was thoroughly removed before the incision was hydrated.

Postoperative follow-up

After sugery, the uncorrected distance visual acuity (UDVA) (5 m), the uncorrected intermediate visual acuity (UIVA) (60 cm), the uncorrected near visual acuity (UNVA) (40 cm), IOP, slit-lamp examination, manifest refraction, defocus curve, QQAS, OPD-ScanIII were examined. In addition, patients need to complete a questionnaire to assess their subjective satisfaction. The postoperative follow-up time was at least 3 months (3 months to 3 years).

The defocus curve was measured by using lenses including + 1.0D, + 0.5D, 0.0D, -0.5D, -1.0D, -1.5D, -2.0D, -2.5D, -3.0D, -3.5D and − 4.0D to measure and record visual acuity.

The main indicators for assessing objective visual quality include: objective scatter index (OSI), modulation transfer function cutoff frequency (MTF cut off), sterr ratio (SR), predicted visual acuity (PVA) in 100%, 20% and 9% contrast ratio, that is OV100%, OV20%, OV9% in the QQAS and high order aberration, coma aberration, trefoil aberration and spherical aberration in the OPD-ScanIII.

The main indicator to evaluate subjective visual quality is a questionnaire, referring to the Visual Function Index Scale (VF-14) questionnaire developed by the National Eye Institute of the United States. Patients were asked about three aspects in the form of questionnaires and scores: (1) the rates of spectacle independence (whether they used spectacles for near vision, intermediate vision or far vision; (2) the occurrence of postoperative photic phenomena (halo, glare and starburst) and the degree

Table 1 Patient characteristics

Parameter	A group ($n=51$)	B group ($n=38$)	C group ($n=45$)	*P* value
Sex (male/female)	14/37	13/25	20/25	0.218
Age (years)	60.1 ± 11.3[b, c]	55.1 ± 13.0[a, c]	51.5 ± 9.3[a, b]	< 0.001*
SE (D)	-0.29 ± 1.94[b, c]	-5.57 ± 3.57[a, c]	-9.83 ± 3.54[a, b]	< 0.001*
BCVA (logMAR)	0.38 ± 0.53	0.40 ± 0.25	0.37 ± 0.27	0.456
AL (mm)	23.11 ± 0.56[b, c]	25.13 ± 0.55[a, c]	27.48 ± 1.06[a, b]	< 0.001*
Endothelial cell density (cells/mm2)	2568.8 ± 193.6	2570.7 ± 175.4	2490.8 ± 275.9	0.133
IOL power (D)	21.89 ± 1.39[b, c]	15.61 ± 2.85[a, c]	10.43 ± 2.69[a, b]	< 0.001*
Target SE (D)	-0.22 ± 0.18	-0.25 ± 0.18	-0.26 ± 0.18	0.382

[a]$P < 0.05$ vs. the A group; [b]$P < 0.05$ vs. the B group; [c]$P < 0.05$ vs. the C group

*$P < 0.05$ among three groups

Table 2 Postoperative refraction and visual acuity

Parameter	A group	B group	C group	*P* value
SE (D)	-0.07 ± 0.35	-0.14 ± 0.31	-0.13 ± 0.30	0.402
BCVA (logMAR)	0.08 ± 0.08	0.08 ± 0.07	0.06 ± 0.06	0.468
UDVA (logMAR)	0.08 ± 0.11	0.08 ± 0.10	0.05 ± 0.09	0.126
UIVA (logMAR)	0.07 ± 0.11[b]	0.13 ± 0.12[a]	0.08 ± 0.09	0.025*
UNVA (logMAR)	0.10 ± 0.10[b]	0.16 ± 0.12[a, c]	0.11 ± 0.10[b]	0.039*

[a]$P < 0.05$ vs. the A group; [b]$P < 0.05$ vs. the B group; [c]$P < 0.05$ vs. the C group

*$P < 0.05$ among three groups

of impact on life (no, mild, moderate and severe); (3) Patients' satisfaction for far vision (watching TV, seeing signs, recognizing acquaintances, reading large fonts), intermediate vision (cooking, computer work, seeing stairs and kerbs clearly), and near vision (reading books and newspapers, reading small fonts, filling out forms, sewing): from "0 completely dissatisfied" to "10 very satisfied".

Statistical analysis

All statistical analyses were performed with SPSS software (version 27.0). For preoperative and postoperative examination results, Kolmogorov-Smirnov test was used to verify the normal distribution. Since most samples were not normally distributed, non-parametric statistical methods were used. KruskalWallis H test was used to compare the data among three groups, and Mann-Whitney U test was used to compare data between the two groups. Categorical variables were compared using chi-square tests. The results were recorded as means and standard deviations (mean ± SD), and $P < 0.05$ was considered statistically significant.

Results

Patient characteristics

The mean age of 86 patients (134 eyes) was 55.8 ± 11.7 years, and 66.3% were female. 51 eyes were in the A group, 38 eyes were in the B group, and 45 eyes were in the C group. Table 1 shows the preoperative characteristics of the three groups. There were statistically significant differences in age, preoperative spherical equivalent (SE), AL and IOL power (all $P < 0.001$). No significant difference was found in sex ratio, best corrected visual acuity (BCVA), endothelial cell density and target SE (all $P > 0.05$).

Refraction and visual acuity

Table 2 shows the postoperative refraction and visual acuity of the three groups. There was no significant difference in the postoperative SE, BCVA and UDVA (all $P > 0.05$). While the UIVA in the A group was significantly better than that in the B group ($P = 0.008$). Compared to the postoperative UNVA in the B group was significantly worse than that in the other two groups ($P = 0.016$ and $P = 0.047$).

Defocus curves

The defocus curves of the three groups are shown in Fig. 1. The visual acuity of the three groups from 40 cm to 5 m was all better than 0.16 (LogMAR).

Objective visual quality

The postoperative objective visual quality of the three groups were shown in Table 3. There was no significant difference in QQAS parameters and high-order aberrations among the three groups (all $P > 0.05$).

Subjective visual quality

The rates of spectacle independence at distance and intermediate among the three groups were all 100%, and the rates of spectacle independence at near in the three group were 94%, 92%, 98%. The incidence of halo in the three group were 20%, 11%, 13%, which had no influence on life, the incidence of glare were 8%, 16%, 13%, which had mild influence on life in one patient of the B group and the incidence of starburst were 0%, 8%, 16%, which had no influence on life.

The subjective satisfaction survey of the three groups was shown in Table 4. The near vision satisfaction of the B group was significantly lower than the A group and the C group ($P < 0.001$ and $P = 0.004$). There was no significant difference in the far vision satisfaction and

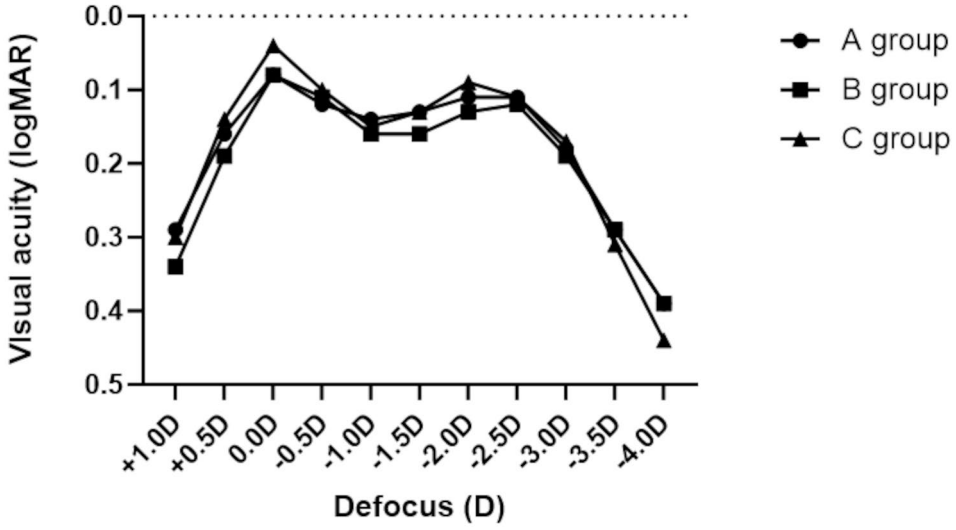

Fig. 1 The defocus curves of the three groups

Table 3 Postoperative objective visual quality

Parameter	A group	B group	C group	*P* value
OSI	2.10 ± 0.94	2.38 ± 1.08	2.62 ± 1.49	0.277
MTF off	24.61 ± 9.60	27.04 ± 11.17	25.97 ± 11.94	0.670
SR	0.12 ± 0.03	0.13 ± 0.04	0.13 ± 0.07	0.683
PVA 100%	0.82 ± 0.32	0.91 ± 0.37	0.87 ± 0.40	0.602
PVA 20%	0.52 ± 0.21	0.60 ± 0.29	0.58 ± 0.33	0.644
PVA 9%	0.27 ± 0.10	0.31 ± 0.12	0.29 ± 0.21	0.229
Higher-order aberration (μm)	0.60 ± 0.90	0.67 ± 0.78	0.67 ± 0.41	0.176
Coma aberration (μm)	0.21 ± 0.44	0.24 ± 0.52	0.22 ± 0.24	0.353
Trefoil aberration (μm)	0.46 ± 0.53	0.41 ± 0.26	0.47 ± 0.30	0.525
Spherical aberration (μm)	0.11 ± 0.21	0.17 ± 0.50	0.11 ± 0.16	0.454

Table 4 Postoperative subjective satisfaction

Parameter	A group	B group	C group	*P* value
Far vision satisfaction	9.0 ± 1.3	9.1 ± 1.0	9.3 ± 0.9	0.680
Intermediate vision satisfaction	9.1 ± 1.3	9.6 ± 0.8	9.5 ± 0.8	0.125
Near vision satisfaction	8.4 ± 1.7[b]	7.3 ± 1.7[a, c]	8.3 ± 1.2[b]	0.001[*]

[a] $P < 0.05$ vs. the A group; [b] $P < 0.05$ vs. the B group; [c] $P < 0.05$ vs. the C group

[*] $P < 0.05$ among three groups

intermediate vision satisfaction among the three groups (all $P > 0.05$).

Discussion

As cataract patients have higher and higher requirements for postoperative visual quality, spectacle independence and satisfaction, trifocal IOL has been widely used because of its good visual effect [13–16]. However, few study has compared the visual effects and satisfaction of cataract patients with different refractive states after trifocal IOL implantation.

Because cataract can increase the myopic diopters, the AL is an important index to evaluate the preoperative refractive status of cataract patients. The AL of the high myopia patients is ≥ 26 mm, and previous studies have taken the AL > 24 mm as the standard of myopia [17, 18], so we choose 24 mm and 26 mm as the grouping criteria.

Our study found that the postoperative UIVA in the cataract patients with hyperopia and emmetropia was significantly better than that the low and moderate myopia. And the postoperative UNVA in the low and moderate myopia was significantly worse than that in the other two groups. The results are similar to the study of Tong S et al. [19]. They found that the uncorrected near visual acuity in the long AL group (AL more than 25.5 mm) was higher, but in their questionnaire, patients in the long AL group showed a relatively lower spectacle independence at near distance and had difficulties in near activities,

mental health and role in daily life. It was a little different from our results. In our subjective satisfaction survey, the near vision satisfaction of the low and moderate myopia was significantly lower than the other groups. The results are similar to the study of Jiaqi M et al. [11]. They found the higher near vision satisfaction in the high myopia patients, and they explain that the experience of getting rid of heavy glasses that had been worn for a long time offset the highly myopic patients concern about slight "side effects" of the trifocal IOLs.

We think that it was probably due to patients' preoperative habit of using eyes. Myopic patients adjust to a shorter reading distance and have clear near vision before surgery, but feel uncomfortable after surgery because they don't adapt to the 40 cm near focal point provided by the trifocal IOL. However, patients with high myopia may not have expectations as high as those with low to moderate myopia, due to they wear the heavy glasses before surgery, the postoperative subjective satisfaction was higher. Hyperopia and emmetropia patients may need to change reading glasses frequently because of the advanced presbyopia and feel difficult to see near before surgery. After implanting the trifocal IOL, they can see far and near easily without glasses, so their satisfaction were also higher.

There were some limitations in this study. First, this was a single-centre retrospective study, drawing data from a sole source. Second, only one type of trifocal IOL was investigated in this study. Other IOL may have a different outcome. Third, there is a statistically significant age difference among the three groups, and the effect of age don't be excluded.

Conclusion

In conclusion, for cataract patients with different refractive states, trifocal IOL implantation can provide good visual and refractive outcomes. For cataract patients with low and moderate myopia, the UIVA and UNVA were worse, and the subjective satisfaction of near vision was also worse than the hyperopia and emmetropia and the high myopia. A prospective multicentre study with a large sample size which can add the hyperopia patients (AL < 22 mm) and exclude the effect of age is warranted to further validate the results of the current study.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-03963-7.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions
Study design (JZ, XZ, YH, JY); Data collection (JZ, XZ); Data analysis and interpretation (JZ, XZ, YH, JY); drafting and revision of the manuscript (JZ, XZ, YH, JY); supervision (YH, JY). All authors read and approved the final manuscript.

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Data availability
Data is provided within the supplementary information files.

Declarations

Ethical approval
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the Army Specialty Medical Center [Medical Research Review (2024) No. 50].

Informed consent
Informed consent was obtained from all individual participants included in the study.

Competing interests
The authors declare no competing interests.

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