Advances in Ophthalmology Practice and Research 3 (2023) 147–152

Contents lists available at ScienceDirect

Advances in Ophthalmology Practice and Research

journal homepage: www.journals.elsevier.com/advances-in-ophthalmology-practice-and-research

Full Length Article

Stereopsis after bilateral implantation of Toric intraocular lenses in high myopic cataract patients with astigmatism

Wei Fan [a,b], Guangbin Zhang [a,b,*]

[a] Eye Institute and Affiliated Xiamen Eye Center of Xiamen University, School of Medicine, Xiamen University, Xiamen, Fujian, China
[b] Fujian Provincial Key Laboratory of Corneal & Ocular Surface Diseases, Xiamen, Fujian, China

ARTICLE INFO

Keywords:
Toric IOL
Stereopsis
High myopia
Cataract
Near visual acuity

ABSTRACT

Purpose: To evaluate near, intermediate, distance visual acuity and stereopsis after bilateral implantation of Toric intraocular lenses (IOLs) in high myopic patients with astigmatism.
Methods: Bilateral Toric or non-Toric IOL implantation (n = 40 eyes each) was performed on high myopic cataract eyes with astigmatism. Best-corrected distance visual acuity (BCDVA), uncorrected intermediate visual acuity (UCIVA), uncorrected near visual acuity (UCNVA), residual refractive astigmatism (RRA), and near, intermediate, and distance stereoacuity were measured postoperatively at 7 days, 1 month, and 3 months.
Results: The three-month postoperative BCDVA, UCIVA, and UCNVA of the Toric group were 0.08 ± 0.07, 0.30 ± 0.11, and 0.23 ± 0.14 LogMAR. All improved over the preoperative assessments ($P < 0.05$). The RRA, UCIVA, and UCNVA were significantly better in the Toric group than the non-Toric group at all follow-up examinations (all $P < 0.05$). At 3 months, the median near and intermediate stereoacuity of the Toric group were 100 (range 40 – 400) and 120 (range 50 – 400) arcsec, which were better than the non-Toric group (both $P < 0.05$). Fine near stereopsis ≥100 arcsec was present in 65% of the Toric patients, and 50% had good intermediate stereopsis of ≥100 arcsec. However among non-Toric patients, only 15% and 5% achieved fine near and intermediate stereopsis. The postoperative BCDVA and best-corrected distance stereoacuity were similar in the two groups ($P > 0.05$).
Conclusions: In bilateral high myopic cataract patients with astigmatism, Toric IOLs not only improved UCIVA, UCNVA, and RRA, but also enhanced near and intermediate stereopsis acuity.

1. Introduction

Previous studies have shown that corneal astigmatism of >1.0 diopter (D) occurs in 40.4% of cataract patients, and ocular residual astigmatism correction with glasses remains relatively inefficient.[1] Toric intraocular lenses (IOLs) are routinely used in cataract patients with astigmatism due to a wide range of corneal irregularities.[2,3] However, cataract patients with high myopia tend to increase the difficulty of Toric IOL because of the length of the long ocular axis, large capsular bag, thick lens, relatively loose capsule, and vitreous liquefaction.[4] Although a long axial length is a risk factor for Toric IOL rotation, emerging studies have indicated high predictability and reliability of Toric IOL in correcting astigmatism compared to limbal relaxing incisions, and no significant difference in the rotation degree was noted between high myopia and low myopia.[5–8]

Cataract patients with high myopia usually prefer a post-surgical target refraction of −3.0 D in both eyes to achieve good binocular vision and a comfortable performance of near-distance tasks without spectacles.[9] Hence, near stereopsis is an important part of binocular vision for high myopia patients after cataract surgery. To our knowledge, the intermediate and near visual acuity and the stereopsis acuity of Toric IOL implantation in bilateral highly myopic cataract patients have not been quantitatively assessed, and associated studies are currently lacking. Thus, the aim of this study was to evaluate the near, intermediate, and distant visual acuity and stereopsis acuity after femtosecond laser-assisted cataract surgery (FLACS) combined with Toric or non-Toric IOL implantation in bilateral highly myopic cataract patients.

2. Methods

In this prospective study, 40 patients diagnosed with bilateral high myopia and senile cataract were selected from all cases that presented for cataract surgery at Xiamen Ophthalmic Center, Affiliate Xiamen

* Corresponding author. Xiamen Ophthalmic Center, Affiliate Xiamen University, No.336 Xiahe Road, Xiamen, 361001, China.
E-mail address: 386975604@qq.com (G. Zhang).

https://doi.org/10.1016/j.aopr.2023.07.001
Received 5 June 2023; Received in revised form 5 July 2023; Accepted 9 July 2023
Available online 10 July 2023

University, China, between January 2020 and February 2021. The enrollment of the patients was non-randomized. Surgical methods and the implantation of Toric or non-Toric IOLs were decided by the participants with full understanding of the potential benefits and risks. All protocols adhered to the tenets of the Declaration of Helsinki, and all patients provided informed consent. Approval was obtained from the ethics committee at the institution (Approval Number: XMYKZX-LW-2018-002).

Based on the selected implantation of Toric or non-Toric IOLs (Tecnis Toric ZCT or Tecnis PCB00; both Johnson & Johnson Vision, Santa Ana, Inc.), 40 patients (80 eyes) were divided into two groups. One of the groups had FLACS combined with Toric IOL implantation (Toric group). The other group had FLACS combined with Tecnis PCB00 IOL implantation (non-Toric group). All patients received bilateral cataract surgery, and the same surgical procedure and IOL were used in both eyes. According to the different personal reading habits and individual choices, postoperative target refractive status was set between −2.0 D and −3.5 D. These settings were fully accepted by the patients after they were explained to them prior to the surgery.

Inclusion criteria were pre-existing bilateral corneal regular astigmatism >1.00 D with confirming results from optical coherence interferometry measurement and corneal topography, long axial length >26 mm, visually significant cataracts interfering with activities of daily living according to the Lens Opacities Classification System III (LOCS III),[10,11] long-term habit of wearing glasses, and pupil dilation of at least 6.0 mm before surgery. Excluded from the study were patients with a history of ocular surgery, corneal opacities, irregular astigmatism, strabismus, active ocular inflammation, uncontrolled glaucoma, pseudoexfoliation syndrome, lens dislocation, optic nerve or retinal disease, or age-related macular degeneration.

2.1. Preoperative and postoperative evaluation

Preoperative ophthalmic examinations included best-corrected distant visual acuity (BCDVA) at 5 m, uncorrected intermediate visual acuity (UCIVA) at 80 cm, uncorrected near visual acuity (UCNVA) at 40 cm, spherical equivalent (SE) measured by phoropter examination (RT-5100, Nidek, Japan), optical coherence interferometry measurement (Lenstar 900 system, Haag-Streit AG, Gartenstadt, Switzerland), and corneal topography (Pentacam, Oculus Optikgeräte GmbH, Wetzlar, Germany). Other pre-operative examinations for cataract surgery, including cataract severity grading based on LOCS III at the slit lamp examination, funduscopy, and corneal endothelioscopy were also routinely performed.

The postoperative primary outcome measures were uncorrected near and intermediate stereoacuity and the best-corrected distant stereoacuity at the 1 and 3-months follow-ups. The secondary outcomes were BCDVA, UCIVA, UCNVA, SE, and residual refractive astigmatism (RRA) at the 7-day and the 1- and 3-months follow-ups.

Stereoacuity at near distance (40 cm) and at intermediate distance (80 cm) was measured using the Titmus stereotest (Stereo Fly Test, Stereo Optical Co., Cook, IL, USA) through polarizing spectacles. Titmus tests provide a measure of stereoacuity by asking the patient to identify the correct target that has stereoscopic depth. The criterion for scoring was the last correct group before two consecutive misses. The Titmus stereotest has disparities ranging from 800 to 40 arcsec. Distant stereoacuity (3 m) was assessed with Binoptometer 4P (Oculus Optikgerate GmbH, Wetzlar, Germany). The measuring method is based on the principle of polarized light, the same as Titmus (range from 600 to 15 arcsec), that has proven to be reliable for measuring stereoacuity.[12] A stereoacuity level of 60 arcsec or better is considered to be good and 100 arcsec is the lowest limit of normal stereoacuity.[13,14] To reduce variability, an experienced ophthalmic technician performed the preoperative and postoperative examinations in an identical manner in all cases, and three measurements for each eye were averaged.

2.2. Surgical technique

All procedures were performed by the same experienced ophthalmologist (G.Z.). Topical or sub-Tenon anesthesia was administered, and adequate dilation was obtained with preoperative mydriatic drops. Surgically induced astigmatism of 0.2 D was assumed in all cases. In the Toric group, the alignment axes of the Toric IOLs were pre-generated using an online calculator (http://www.tecnistoriccalc.com) according to the data from the optical coherence interferometry measurements. The horizontal axis was marked preoperatively at the corneal limbus with a marker pen while the patient was sitting upright with the head straight on the chin rest of a slit lamp. The Toric IOL target axis was marked intraoperatively using a marker ring.

FLACS was performed in all cases through a LENSAR femtosecond laser platform (LENSAR LLC, Orlando, FL, USA). The procedure included a 5.5-mm diameter capsulotomy with pupil centration and a concentric cylinder and chop (sextants cut) pattern for lens fragmentation. After all laser procedures, each patient was transported to a day-surgery operating room where a conventional phacoemulsification cataract surgery was performed. A 2.2mm temporal clear corneal incision as per standard technique was made with an active-fluidics torsional phacoemulsification machine (Centurion Vision System, Alcon Laboratories, Inc.). An IOL (Tecnis ZCT or PCB00) was then placed in the capsular bag. In the Toric group, the IOL was rotated clockwise to the target axis according to preoperative manual marking on the corneal limbus.

After the surgery, all patients received the same treatment consisting of a combination of levofloxacin (Cravit) and dexamethasone (Tobradex) eyedrops, four times a day during the first week. The drops were slowly tapered over the next 3 weeks.

2.3. Sample size

The calculation of sample size was based on the important visual outcome: uncorrected near visual acuity. In previous study, Shin et al. reported that patients with corneal astigmatism received cataract surgery and has nearly −3.0 D myopic refraction as the target power, the uncorrected near visual acuity of eyes implanted with Tecnis Toric ZCT IOL was 0.26 ± 0.33 logMAR and Tecnis ZCB00 IOL was 0.48 ± 0.32 logMAR.[15] To find a clinically significant difference between the two groups in our study, we used PASS 15.0.5 software to calculate the sample size based on the available data. The results showed that at least 36 samples were required in each group, the total number of at least 72 samples needed to be included in this study (alpha = 0.05 and power = 0.8).

2.4. Statistical analysis

Data analysis was performed using SPSS statistical software (version 25.0, IBM Corp.). Descriptive values are given as means ± standard deviations. All data were tested for distribution normality using the Kolmogorov-Smirnoff test. For data with a normal distribution, independent *t*-tests were used to compare differences between the two groups, and paired *t*-tests were used for comparison of the pre- and postoperative data. For data with a non-normal distribution (stereopsis acuity), Mann-Whitney *U* tests were used to compare postoperative differences between the groups. Chi-squared tests were used to compare categorical data. *P*-values less than 0.05 were considered statistically significant.

3. Results

3.1. Preoperative data

The Toric group included 40 eyes (20 patients, 7 men and 13 women) and the age was 58.2 ± 8.0 years (range: 48–74 years). The non-Toric group included 40 eyes (20 patients, 12 men and 8 women), and the age was 59.1 ± 7.4 years (range: 44–75 years). Demographic and

preoperative biometric parameters were evaluated for both groups (Table 1). There were no significant differences in the age, cataract grade (LOCS III), axial length, preoperative BCDVA, UCIVA, UCNVA, SE, or corneal astigmatism between two groups ($P > 0.05$, Table 1).

3.2. Postoperative data

The post-operative BCDVA (Fig. 1A) and UCIVA (Fig. 1B) of the Toric group were 0.08 ± 0.07 logarithm of the minimum angle of resolution (logMAR) and 0.30 ± 0.11 logMAR at 3 months, respectively. For the non-Toric group, the post-operative BCDVA (Fig. 1D) and UCIVA (Fig. 1E) were 0.09 ± 0.09 logMAR and 0.46 ± 0.09 logMAR at 3 months, respectively. Both were significantly improved over the preoperative assessments ($P < 0.05$). For the UCNVA, the 3-months postoperative value of the Toric group was 0.23 ± 0.14 logMAR, which was significantly lower than at preoperative value (Fig. 1C, $P < 0.05$). However for the non-Toric group, the postoperative UCNVAs at all follow-up visits were not significantly different from preoperative values (all $P > 0.05$, Fig. 1F).

There were no significant differences in the postoperative BCDVA between two groups ($P > 0.05$, Table 2). The UCIVA and UCNVA were significantly better in the Toric group than the non-Toric group at all follow-up examinations (all $P < 0.05$, Table 2). At the third postoperative month, the RRA in the Toric group, 0.44 ± 0.24 D, was lower than in non-Toric group, 1.49 ± 0.55 D ($P < 0.05$). For the SE, at three months after IOL implantation, the value of the Toric group, −2.99 ± 0.70, was not different from the non-Toric group, −2.93 ± 0.56 ($P > 0.05$, Table 2).

For both groups, the stereoacuity values at 1 and 3 months after IOL insertion were similar to one another (Table 3). At three months, the median near stereoacuity of the Toric group, 100 (range 40 – 400) arcsec, was less than in the non-Toric group, 300 (range 50 – 800) arcsec ($P < 0.001$, Table 3). At the same time, the intermediate stereoacuity of the Toric group, 120 (range 50 – 400) arcsec, was also less than in the non-Toric group, 400 (range 80 – 800) arcsec ($P < 0.05$). However, there was no significant difference in the best-corrected distant stereoacuity between two groups ($P > 0.05$, Table 3, Fig. 2).

At the third postoperative month, the near distance (40 cm) fine stereopsis of 100 arcsec or better was achieved by 13 of 20 (65%) patients in Toric group and 3 of 20 (15%) patients in non-Toric group. At the intermediate distance (80 cm), fine stereopsis of 100 arcsec or better was achieved by 10 of 20 (50%) patients in Toric group and 1 of 20 (5%) patients in non-Toric group.

Table 1
Patient demographics and preoperative data in the Toric and non-Toric groups.

Parameter	Group		*P* value
	Toric	Non-Toric	
Eyes (n)	40	40	–
Age (years)	58.2 ± 8.0	59.1 ± 7.4	0.583[a]
Sex (n)			0.113[b]
Male	7	12	
Female	13	8	
Cataract grade (LOCS III)			
Nuclear opalescence	3.7 ± 1.0	3.8 ± 0.9	0.723[a]
Nuclear color	3.7 ± 0.9	3.8 ± 0.8	0.678[a]
Axial length (mm)	27.62 ± 1.31	27.69 ± 1.19	0.788[a]
BCDVA (logMAR)	0.50 ± 0.24	0.48 ± 0.23	0.767[a]
UCIVA (logMAR)	0.69 ± 0.17	0.67 ± 0.16	0.634[a]
UCNVA (logMAR)	0.39 ± 0.13	0.40 ± 0.11	0.849[a]
SE (D)	−11.93 ± 3.23	−11.72 ± 2.96	0.812[a]
Corneal astigmatism (D)	2.18 ± 0.63	2.00 ± 0.55	0.201[a]

Abbreviations: LOCS III, Lens Opacities Classification System III; BCDVA, best-corrected distance visual acuity; UCIVA, uncorrected intermediate visual acuity; UCNVA, uncorrected near visual acuity; logMAR, log minimum angle of resolution; SE, spherical equivalent; D, diopter.
Notes:
[a] Independent *t*-test.
[b] Chi-square test.

In the Toric group, the mean absolute rotation of the Toric IOL at the third postoperative month was 4.08 ± 2.25°, and the Toric IOL rotation of 32 eyes (80%) was no more than 5°.

4. Discussion

The incidence of highly myopic eyes has been increasing, especially in Asian nations.[16] High myopia is also a powerful risk factor for cataract formation.[17] For patients with high myopia after cataract surgery, we strive to establish a low level of myopia to maintain adequate near and middle vision without the use of spectacles. In our study, according to the different personal reading habits of our patients, we set a post-implantation target of about −2.0 D to −3.5 D bilateral myopia in both groups to achieve a clear near and middle vision that was likely to ensure high spectacle independence. Hence, the postoperative uncorrected near and intermediate stereoacuity, UCNVA and UCIVA, were very important for bilateral high myopia cataract patients with astigmatism. We believe that this is the first controlled, prospective, comparative study to examine the outcomes of near, middle, and distant visual acuity and stereopsis in patients with high myopia and corneal astigmatism who received a Toric or non-Toric IOLs through femtosecond laser-assisted cataract surgery.

In a previous study, many of the cataract patients with high myopia also had astigmatism, and treatment with Toric IOLs was effective.[18] However, certain experts do not suggest the implantation of Toric IOLs to correct astigmatism in cataract patients with high myopia because the long axial length is a risk factor for Toric IOL rotation.[19] In our series, compared with preoperative vision, the BCDVA, UCIVA, and UCNVA were significantly improved in patients with Toric IOL implantation after FLACS. The results indicate that Toric IOLs could improve visual outcomes in high myopic patients with corneal astigmatism. In contrast, although the BCDVA and UCIVA of the non-Toric group was significantly decreased from the preoperative state, the postoperative UCNVA did not improve significantly. Furthermore, the UCIVA and UCNVA were significantly better in the Toric group than the non-Toric group. This indicates that Toric IOLs allow high myopia patients with corneal astigmatism to achieve spectacle freedom for intermediate and near vision. At the third postoperative month, the RRA in the Toric group was significantly reduced compared with the non-Toric group. Thus the changes in the postoperative UCIVA and UCNVA could be attributed to the changes in the RRA.

Stereopsis is important in enabling precise sensing of position and distance, and it is the most demanding quality of binocularity. Reduced stereopsis may cause symptoms of discomfort, such as eyestrain and diplopia.[20] Astigmatism is an important factor relevant to stereoacuity in patients with pseudophakia.[21] For cataract patients, surgery is the best solution to optical correction, as an IOL after cataract extraction can restore stereopsis.[14] Many studies have suggested that patients can restore normal stereopsis after multifocal IOL implantation.[20,22] However, it is not an optimal inclusion criteria for high myopic patients with astigmatism and stereopsis has been largely overlooked in the field of high myopic eyes. The near and intermediate distance Titmus stereopsis is based on a vectographic technique and uses polarized glasses to induce retinal disparity. Disparity varies between 40 and 800 arcsec in nine steps for the Titmus test. There is no possibility of examining stereopsis in patients with cataracts; thus, in the current study, we investigated only postoperative stereopsis. Hence, the median uncorrected near and intermediate distance stereoacuity of the Toric group were, respectively, 100 and 120 arcsec at 3 months postoperatively, which were significantly better than the non-Toric group. However, there was no significant difference in the best-corrected distant stereoacuity between two groups. It is likely that Toric IOL implantation helps improve near and intermediate distance stereoscopic vision in bilateral high myopic cataract patients with astigmatism.

There are many studies on the relationship between visual acuity and stereopsis.[23] Donzis reported that when binocular Snellen visual acuity

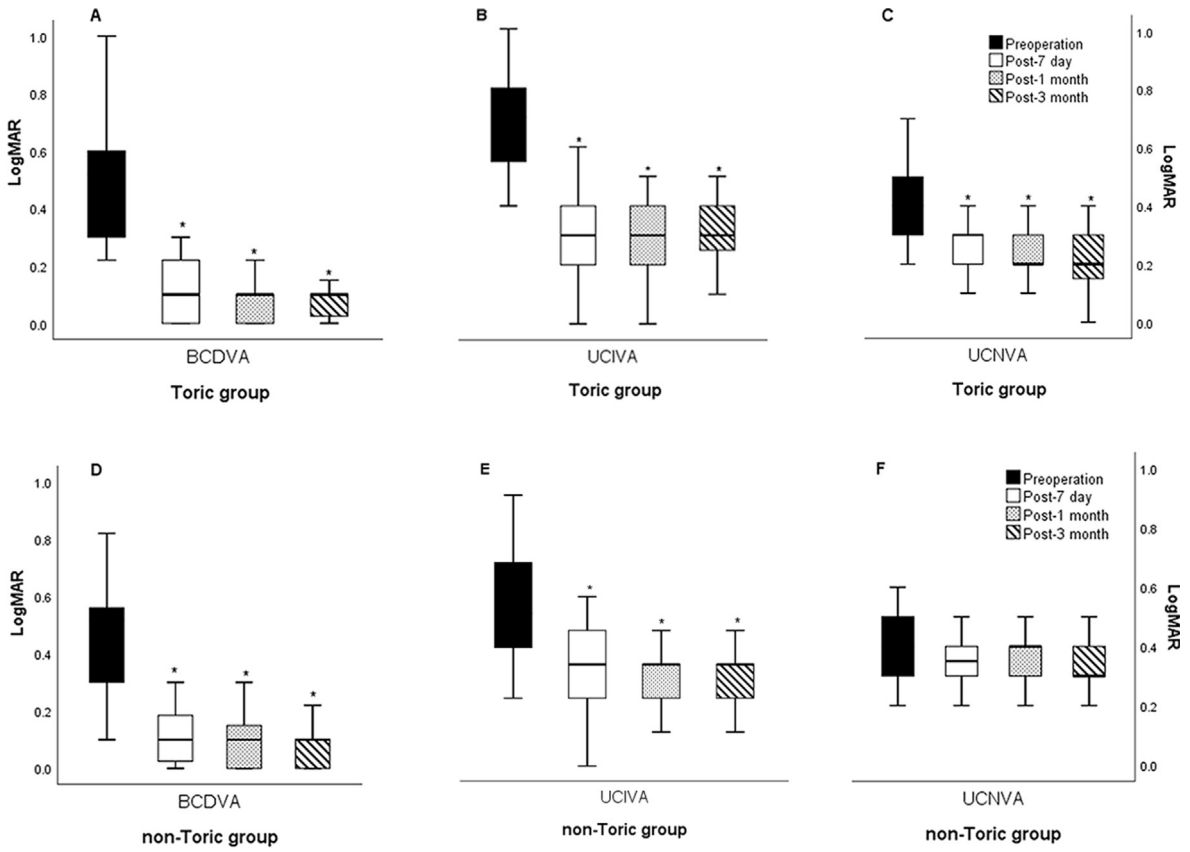

Fig. 1. Comparison of BCDVA, UCIVA, and UCNVA before and after surgery in the Toric and non-Toric groups
BCDVA, best-corrected distance visual acuity; UCIVA, uncorrected intermediate visual acuity; UCNVA, uncorrected near visual acuity; LogMAR, log minimum angle of resolution; *, $P < 0.05$.

Table 2
Postoperative data in the Toric and non-Toric groups.

Parameter/Group	After surgery		
	7 days	1 month	3 months
BCDVA (logMAR)			
Toric	0.10 ± 0.10	0.09 ± 0.09	0.08 ± 0.07
Non-Toric	0.11 ± 0.09	0.09 ± 0.08	0.09 ± 0.09
P value	0.490	0.860	0.914
UCIVA (logMAR)			
Toric	0.29 ± 0.15	0.31 ± 0.12	0.30 ± 0.11
Non-Toric	0.47 ± 0.12	0.47 ± 0.11	0.46 ± 0.09
P value	< 0.001*	< 0.001*	< 0.001*
UCNVA (logMAR)			
Toric	0.24 ± 0.11	0.22 ± 0.09	0.23 ± 0.14
Non-Toric	0.36 ± 0.11	0.36 ± 0.10	0.35 ± 0.09
P value	< 0.001*	< 0.001*	< 0.001*
RRA (D)			
Toric	0.48 ± 0.33	0.46 ± 0.31	0.44 ± 0.24
Non-Toric	1.46 ± 0.69	1.48 ± 0.55	1.49 ± 0.55
P value	< 0.001*	< 0.001*	< 0.001*
SE (D)			
Toric	−2.40 ± 0.57	−2.93 ± 0.70	−2.99 ± 0.70
Non-Toric	−2.49 ± 0.49	−2.91 ± 0.56	−2.93 ± 0.56
P value	0.405	0.895	0.662

Values are presented as means ± standard deviations. Abbreviations: BCDVA, best-corrected distance visual acuity; logMAR, log minimum angle of resolution; UCIVA, uncorrected intermediate visual acuity; UCNVA, uncorrected near visual acuity; RRA, residual refractive astigmatism; D, diopter; SE, spherical equivalent. *, $P < 0.001$.

Table 3
Postoperative stereoacuity in the Toric and non-Toric groups.

Stereoacuity (arcsec)	Toric group	Non-Toric group	*P*
Near stereoacuity			
1 month postop	90 (52.5, 140)	300 (155, 800)	< 0.001*
Range	40 – 400	60 – 800	
3 months postop	100 (50, 185)	300 (140, 800)	< 0.001*
Range	40 – 400	50 – 800	
Intermediate stereoacuity			
1 month postop	120 (65, 200)	400 (155, 800)	0.002*
Range	50 – 800	60 – 800	
3 months postop	120 (65, 200)	400 (155, 800)	0.001*
Range	50 – 400	80 – 800	
Best-corrected distance stereoacuity			
1 month postop	100 (60, 200)	90 (60, 175)	0.793
Range	30 – 400	30 – 400	
3 months postop	100 (60, 200)	90 (60, 175)	0.793
Range	30 – 400	30 – 400	

Values are presented as medians (25% quartile, 75% quartile). *, $P < 0.05$.

varies in normal subjects from 20/20 to 20/200, stereopsis changes proportionally.[24] Moreover, the presence of strabismus is a contributing factor to good visual acuity and stereoscopic vision.[21] In the present study, we excluded all of the patients with postoperative strabismus. We found that fine near and intermediate distance stereopsis of 100 arcsec or better were higher in the Toric group at 3 months after IOL insertion. This also indicates that Toric IOL implantation resulted in improved near and intermediate distance stereopsis and visual acuity, which suggests the possibility of a higher rate of post-surgical spectacle independence for the patients. This can profoundly improve the postoperative quality of life and satisfaction of patients with high myopic astigmatism.

A limitation of this study was that we calculated the visual outcomes without taking into consideration the uncorrected distant visual acuity, best-corrected intermediate visual acuity, and best-corrected near visual acuity. Regarding the living habits of patients with high myopia, for far

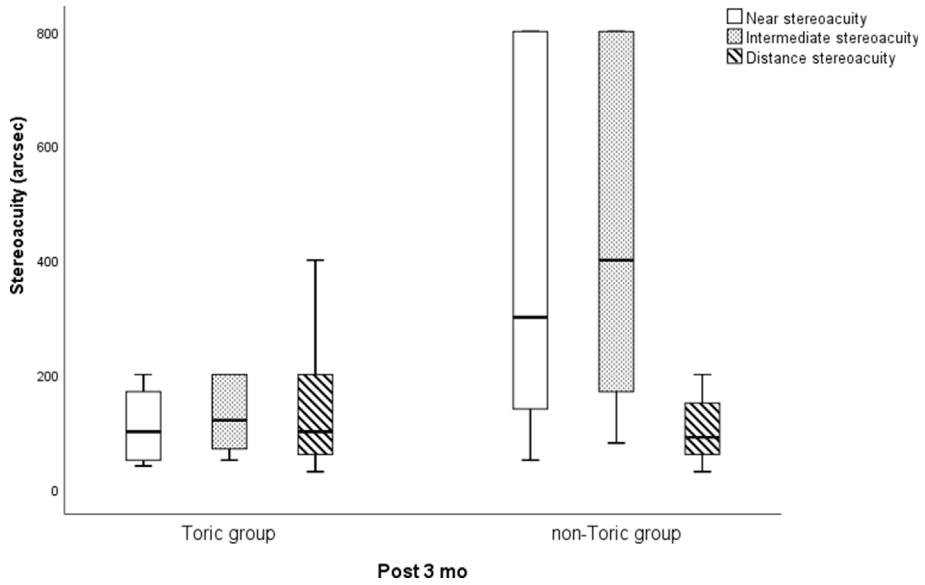

Fig. 2. Near, intermediate, and distance stereoacuity at 3 months postoperatively in the Toric and non-Toric groups.

vision they continue the postoperative use of low myopia-correcting glasses, and for middle and near vision, no glasses are generally required. Thus, it was not necessary to measure these values in this clinical study. A second limitation was that clinical Titmus stereopsis only estimates local stereoacuity between steps (from 40 to 800 arcsec in nine steps) without establishing a stereoscopic threshold. Perhaps a continuous measure of stereoacuity with high accuracy, like the Howard-Dolman apparatus, would have shown greater differences in the measured parameters between the Toric and non-Toric groups. These limitations might have somewhat weakened the statistical power of our study. Nevertheless, this first report provides insights into the differences in the postoperative near, middle, distant visual acuity and stereopsis acuity of cataract patients with high myopia and corneal astigmatism who had FLACS combined with Toric or non-Toric IOLs implantation.

In conclusion, Toric IOL implantation resulted in improvement in visual outcomes and provided good near and intermediate distance stereopsis acuity in high myopia patients with astigmatism. This suggests that Toric IOLs are effective not only for correction of astigmatism but also for improving visual function in bilateral high myopic cataract patients with astigmatism.

5. Conclusions

Toric IOL rotation is significantly influenced by axial length, making Toric IOL implantation in eyes with high myopia a challenge. For bilateral high myopia cataract patients with astigmatism, FLACS combined with Toric IOL implantation resulted in better UCMVA, UCNVA, and near and intermediate distance stereopsis acuity than did non-Toric IOL implantation. Toric IOL patients also had a lower RRA and a higher rate of spectacle independence than did non-Toric IOL patients.

Study approval

The authors confirm that any aspect of the work covered in this manuscript that involved human patients or animals was conducted with the ethical approval of all relevant bodies and the study was performed in accordance with the Declaration of Helsinki, and the protocol was approved by Eye Institute and Affiliated Xiamen Eye Center of Xiamen University (Approval Number: XMYKZX-LW-2018-002).

Author contributions

WF: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation, Visualization, Investigation, Writing-Reviewing and Editing; GZ: Supervision, Software, Validation. All authors reviewed the results and approved the final version of the manuscript.

Funding

This article was financed by the Fujian Youth Health Science and Technology Program (2019-2-60).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

IOLs	Intraocular Lenses
BCDVA	Best-corrected Distance Visual Acuity
UCIVA	Uncorrected Intermediate Visual Acuity
UCNVA	Uncorrected Near Visual Acuity
RRA	Residual Refractive Astigmatism
FLACS	Femtosecond Laser-assisted Cataract Surgery
LOCS III	Lens Opacities Classification System III
SE	Spherical Equivalent
logMAR	Logarithm of the minimum angle of resolution

References

1. Khan MI, Muhtaseb M. Prevalence of corneal astigmatism in patients having routine cataract surgery at a teaching hospital in the United Kingdom. *J Cataract Refract Surg*. 2011;37:1751–1755. https://doi.org/10.1016/j.jcrs.2011.04.026.
2. Allard K, Zetterberg M. Toric IOL implantation in a patient with keratoconus and previous penetrating keratoplasty: a case report and review of literature. *BMC Ophthalmol*. 2018;18:215. https://doi.org/10.1186/s12886-018-0895-y.
3. Sun XY, Vicary D, Montgomery P, et al. Toric intraocular lenses for correcting astigmatism in 130 eyes. *Ophthalmology*. 2000;107:1776–1781. https://doi.org/10.1016/s0161-6420(00)00266-9. discussion 81-2.

4. Khan MI, Ch'ng SW, Muhtaseb M. The use of toric intraocular lens to correct astigmatism at the time of cataract surgery. *Oman J Ophthalmol*. 2015;8:38–43. https://doi.org/10.4103/0974-620X.149865.
5. Zhu X, He W, Zhang K, Lu Y. Factors influencing 1-year rotational stability of AcrySof Toric intraocular lenses. *Br J Ophthalmol*. 2016;100:263–268. https://doi.org/10.1136/bjophthalmol-2015-306656.
6. Guo T, Gao P, Fang L, et al. Efficacy of Toric intraocular lens implantation in eyes with high myopia: a prospective, case-controlled observational study. *Exp Ther Med*. 2018;15(6):5288–5294. https://doi.org/10.3892/etm.2018.6102.
7. Dick HB, Buchner SE. [Toric phakic intraocular lenses]. *Ophthalmologe*. 2007; 104(12):1032–1040. https://doi.org/10.1007/s00347-007-1657-z.
8. Edrington TB. A literature review: the impact of rotational stabilization methods on toric soft contact lens performance. *Contact Lens Anterior Eye*. 2011;34(3):104–110. https://doi.org/10.1016/j.clae.2011.02.001.
9. Chong EW, Mehta JS. High myopia and cataract surgery. *Curr Opin Ophthalmol*. 2016; 27:45–50. https://doi.org/10.1097/ICU.0000000000000217.
10. Chylack Jr LT, Wolfe JK, Singer DM, et al. The lens opacities classification system III. The longitudinal study of cataract study group. *Arch Ophthalmol*. 1993;111:831–836. https://doi.org/10.1001/archopht.1993.01090060119035.
11. Bencic G, Zoric-Geber M, Saric D, et al. Clinical importance of the lens opacities classification system III (LOCS III) in phacoemulsification. *Coll Antropol*. 2005; 29(Suppl 1):91–94.
12. Bai Z, Nie D, Zhang J, et al. Visual function assessment of posterior-chamber phakic implantable collamer lenses with a central port. *Ann Transl Med*. 2022;10:194. https://doi.org/10.21037/atm-22-107.
13. Fawcett SL. An evaluation of the agreement between contour-based circles and random dot-based near stereoacuity tests. *J AAPOS*. 2005;9:572–578. https://doi.org/10.1016/j.jaapos.2005.06.006.
14. Hayashi K, Hayashi H. Stereopsis in bilaterally pseudophakic patients. *J Cataract Refract Surg*. 2004;30:1466–1470. https://doi.org/10.1016/j.jcrs.2003.12.030.
15. Shin DY, Hwang HS, Kim HS, et al. Clinical differences between toric intraocular lens (IOL) and monofocal intraocular lens (IOL) implantation when myopia is determined as target refraction. *BMC Ophthalmol*. 2021;21(1):203. https://doi.org/10.1186/s12886-021-01966-8.
16. Wang TJ, Chiang TH, Wang TH, et al. Changes of the ocular refraction among freshmen in National Taiwan University between 1988 and 2005. *Eye (Lond)*. 2009; 23:1168–1169. https://doi.org/10.1038/eye.2008.184.
17. Praveen MR, Shah GD, Vasavada AR, et al. A study to explore the risk factors for the early onset of cataract in India. *Eye (Lond)*. 2010;24:686–694. https://doi.org/10.1038/eye.2009.137.
18. Mencucci R, Favuzza E, Guerra F, et al. Clinical outcomes and rotational stability of a 4-haptic toric intraocular lens in myopic eyes. *J Cataract Refract Surg*. 2014;40: 1479–1487. https://doi.org/10.1016/j.jcrs.2013.12.024.
19. Shah GD, Praveen MR, Vasavada AR, et al. Rotational stability of a toric intraocular lens: influence of axial length and alignment in the capsular bag. *J Cataract Refract Surg*. 2012;38:54–59. https://doi.org/10.1016/j.jcrs.2011.08.028.
20. Ferrer-Blasco T, Madrid-Costa D, Garcia-Lazaro S, et al. Stereopsis in bilaterally multifocal pseudophakic patients. *Graefes Arch Clin Exp Ophthalmol*. 2011;249: 245–251. https://doi.org/10.1007/s00417-010-1558-8.
21. Lee SJ, Kim WS. Factors influencing stereoacuity levels after surgery to correct unilateral developmental cataracts in children. *Int J Ophthalmol*. 2013;6:331–336. https://doi.org/10.3980/j.issn.2222-3959.2013.03.14.
22. Ferrer-Blasco T, Montes-Mico R, Cervino A, et al. Stereoacuity after refractive lens exchange with AcrySof ReSTOR intraocular lens implantation. *J Refract Surg*. 2009; 25(11):1000–1004. https://doi.org/10.3928/1081597X-20091016-05.
23. Lee SY, Isenberg SJ. The relationship between stereopsis and visual acuity after occlusion therapy for amblyopia. *Ophthalmology*. 2003;110:2088. https://doi.org/10.1016/S0161-6420(03)00865-0, 1092.
24. Donzis PB, Rappazzo JA, Burde RM, et al. Effect of binocular variations of Snellen's visual acuity on Titmus stereoacuity. *Arch Ophthalmol*. 1983;101:930–932. https://doi.org/10.1001/archopht.1983.01040010930016.