• Clinical Research •

Visual and accommodative outcomes after femtosecond LASIK with and without monovision in patients over 40 years

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Abstract

● **AIM:** To evaluate changes in visual acuity and accommodation function following femtosecond laser-assisted *in situ* keratomileusis (FS-LASIK) combined with monovision in patients aged over 40y.

● **METHODS:** This prospective, non-randomized cohort study included patients who were divided into an FS-LASIK binocular group (full correction) and an FS-LASIK monovision group. The binocular group consisted of Group 1 (15 patients) with simple myopia and Group 2 (12 patients) with myopia and presbyopia. The monovision group (Group 3) included 13 patients with myopia and presbyopia. Parameters assessed included the uncorrected distance visual acuity (UCVA), the uncorrected near visual acuity (UNVA), contrast sensitivity (CS), binocular cross-cylinder (BCC), accommodative amplitude (AMP), positive relative accommodation (PRA), negative relative accommodation (NRA), and accommodative facility (AF). Patient satisfaction was evaluated at 3mo postoperatively.

● **RESULTS:** A total of 40 patients (80 eyes) were enrolled (mean age 43.63±3.666y; 12 males). At 3mo after FS-LASIK, UCVA improved significantly in all patients (P<0.001), while UNVA remained comparable to preoperative levels (P>0.05). BCC in Group 3 decreased by 0.30±0.43 compared to preoperative levels, showing a statistically significant difference (P=0.037). The AMP in Group 3 showed an increasing trend with greater improvement in the nondominant eye than in the dominant eye (P>0.05). Patient satisfaction was high in all groups.

● **CONCLUSION:** FS-LASIK combined with monovision is an effective treatment for patients aged over 40y with myopia and presbyopia, which not only improves visual acuity but also achieves high patient satisfaction and improves postoperative BCC.

● **KEYWORDS:** refractive surgery; FS-LASIK; presbyopia; monovision; vision acuity; accommodation function

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INTRODUCTION

As global life expectancy continues to rise, an increasing number of individuals maintain high expectations for quality of life as they age[1-2]. Although laser-assisted *in situ* keratomileusis (LASIK) surgery was historically performed on younger populations (18–30 years of age), advancements in laser technology and improved quality of life have expanded its application to patients aged 40y and older, including a growing proportion with presbyopia[3]. In this age group, the gradual decline of lens accommodation function often leads to difficulties with near vision, and concurrent myopia and presbyopia cannot be fully corrected simultaneously in both eyes after LASIK surgery[4-5]. Consequently, how to appropriately manage age-related accommodation deficiency while correcting myopia has emerged as a critical clinical challenge.

Currently, presbyopia correction methods include wearing spectacles, corneal contact lenses, and surgical treatments[6]. Surgical treatments include the following three types[5]: 1) Monovision: it includes monovision LASIK and mono-focal intraocular lens (IOL) implantation in a monovision design[7]. 2) Multifocal modality: it includes multifocal corneal ablation and multifocal IOL implantation[8]. 3) Scleral modification: it mainly refers to scleral expansion bands and laser-assisted presbyopia reversal[9]. The scleral modification approach is based on Schachar's theory. However, the mechanism of action remains under investigation and has not been applied clinically[10].

Among these, monovision has emerged as an effective surgical approach for correcting myopia accompanied by presbyopia. Monovision LASIK, in particular, has become a mainstay of refractive surgery for presbyopia due to its simplicity and efficacy[11]. This technique typically involves complementary corrections in both eyes: one eye (usually the dominant eye) is fully corrected for clear distance vision, while the other eye (usually the nondominant eye) retains a residual myopic degree to facilitate near vision[12]. This strategy satisfies patients' requirements for both distance and near vision while enabling spectacle independence.

However, studies report that monovision may affect binocular vision, stereopsis, and contrast sensitivity in some patients[5,13]. Patients with presbyopia often have high surgical expectations, prioritizing not only good postoperative distance and near vision but also overall visual comfort[14-15]. Notably, refractive surgery induces sudden changes in the refractive state, potentially disrupting the balance of binocular visual function. For myopic patients over 40 years of age undergoing corneal refractive surgery, the demands on accommodation differ significantly from those of younger individuals. Therefore, greater attention must be paid to postoperative changes in accommodation function to ensure visual comfort. Despite this, limited research exists on postoperative accommodation changes following femtosecond laser-assisted *in situ* keratomileusis (FS-LASIK) in this age group.

Therefore, we conducted a prospective study to comprehensively assess the changes in vision and accommodation after FS-LASIK with monovision in patients over 40 years old with myopia and presbyopia, in terms of several indices such as uncorrected distance visual acuity (UCVA), uncorrected near visual acuity (UNVA), accommodation response, accommodative amplitude (AMP), positive relative accommodation (PRA) and negative relative accommodation (NRA), accommodative facility (AF), and contrast sensitivity (CS).

PARTICIPANTS AND METHODS

Ethical Approval This prospective cohort study included 40 consecutive patients who were undergoing FS-LASIK at Tianjin Medical University Eye Hospital from Dec. 2020 to Dec. 2023. The study was approved by the Chinese Clinical Trial Registry (registration number: ChiCTR2100049534; date of registration: 2021/01/26) and followed the principles of the Declaration of Helsinki (Ethics approval number: 2019KY-13, 2020KY-24). All participants signed an informed consent form for the use of clinical data for analysis and publication.

The inclusion criteria were as follows : 1) age≥40y; 2) refractive status stable for over 2y; 3) cessation of soft corneal contact lenses for more than 1wk; discontinuation of rigid gas permeable contact lenses for ≥2wk; 4) spherical refractive error ≥-12.00 D and astigmatism ≥-6.00 D; 5) basic lens transparency. The exclusion criteria were as follows: 1) spherical refractive error <-12.00 D; astigmatism <-6.00 D; 2) systemic connective tissue diseases and autoimmune diseases; 3) suspected keratoconus, diagnosed keratoconus, or other types of corneal dilatation including pellucid marginal degeneration, Terrien's marginal degeneration, and postoperative corneal ectasia; 4) active inflammation or infection of the eye or its adnexa; 5) postoperative corneal stromal bed thickness less than 250 μm; 6) have severe dry eye, uncontrolled glaucoma, cataracts affecting vision, severe ocular appendage lesions such as eyelid defects, deformities, *etc*; 7) failure to attend regular follow-up visits.

Prior to subject enrollment, a prospective sample size estimation was conducted. Based on published studies on refractive surgery, the mean difference and standard deviation of postoperative uncorrected visual acuity were derived. With α=0.05, statistical power 1−β=0.80, and an estimated 10% dropout rate, the minimum required sample size was calculated as 36 cases. A total of 40 participants were finally recruited, which met the statistical sample size requirement. This study adopted a single-blind design. Examiners were masked to group allocation (full binocular correction group *vs* monovision design group). Statisticians were also blinded to grouping and baseline information during statistical analysis to minimize subjective assessment bias.

Preoperative Ophthalmic Examination All participants underwent a comprehensive ophthalmic examination before the FS-LASIK surgery. Follow-up evaluations were conducted at 1wk, 1, and 3mo postoperatively. General ophthalmic examinations included refraction, UCVA, UNVA, dominant eye, intraocular pressure (IOP), slit-lamp microscopy, and CS. Addition for presbyopia (ADD) was determined using a phoropter (Topcon, Japan); the initial ADD value was set based on the half-amplitude of accommodation rule and adjusted binocularly with positive lenses until clear and comfortable vision was achieved. The final ADD was confirmed using the NRA and PRA balancing method [Final ADD=Initial ADD+(NRA+PRA)/2], ensuring the absolute values of NRA and PRA were close (ideal difference ≤0.25 D). IOP was measured *via* non-contact tonometry, and anterior segment structures were evaluated using slit-lamp biomicroscopy. Ocular dominance was determined using the hole-in-the-card method. CS was assessed under photopic and mesopic conditions using the CSV-1000E (Vector Vision). Accommodation function assessment included accommodation response using the binocular cross-cylinder (BCC) method, AMP, PRA, NRA, and AF. As primary outcome measures, the binocular accommodation response was examined using the BCC method with full refractive correction. The visual target was positioned 40 cm in front of the patient, and a ±0.50 D cross-cylinder was added in front of the examined eye. And spherical lenses were adjusted until the horizontal and vertical lines were reported equally clear. As another of the primary outcome measures, with full refractive correction, AMP was measured monocularly using the push-up method, the target was moved from 40 cm at approximately 2 cm/s to the point of persistent blur, and AMP was recorded as the reciprocal of the distance at this position. For relative accommodation, positive spherical lenses were simultaneously added in front of both eyes until visual target became blurred, and the amount of positive spherical lenses added at the time of final clarity was recorded as the NRA. Similarly, negative spherical lenses were added simultaneously in front of both eyes until the scale became blurred, and the amount of negative spherical lenses added was recorded as PRA. For AF, it was assessed as the number of complete cycles (one cycle=viewing through +2.00 and -2.00 D) completed within one minute using a ±2.00 D flipper lens on a 20/30 target at 40 cm. All measurements were assessed following standardized clinical protocols. Each parameter was tested twice, and the mean value was adopted for statistical analysis. Consistent examination equipment and constant ambient illumination were maintained throughout the trial. Finally, patient satisfaction was assessed using a satisfaction questionnaire at 3 mo postoperatively.

Surgical Technique The surgery was conducted by the same experienced ophthalmologist specializing in corneal refractive surgery. The operated eye was anesthetized using 0.4% oxybuprocaine hydrochloride eye drops, the eyelid was opened with a lid opener, and a negative pressure suction ring was placed at the center of the cornea to stabilize the eye. An 8.5 mm diameter hinged corneal flap was dissected using the Intralase FS femtosecond laser system (USA), while the Amaris 1050RS excimer laser system (Schwind, Germany) ablated the stromal bed. Following the ablation, the flap was rinsed and repositioned using a balanced salt solution.

Monovision Program Design For the dominant eye, the refractive error was fully corrected, and for the nondominant eye, the refractive target was set to induce mild myopia, ranging from -0.50 to -1.50 D, based on the patient's age and specific visual requirements. The correction for the nondominant eye was determined through the following steps: 1) For a reading test distance of 40 cm and an accommodation demands of 2.5 D, an experimental near addition was calculated by reserving half the AMP. 2) Calculate the average of NRA and PRA and add it to the experimental near addition to obtain the exact near addition. 3) Adjust the exact near addition based on the patient's actual reading distance and the most commonly used visual standard sizes, until clear and comfortable vision was achieved.

Statistical Analysis This study defined BCC and AMP as the primary outcome measures, and other parameters as secondary outcome measures. All data were analyzed using SPSS Statistics for Windows (version 25.0., IBM Corp., USA). The normality of the data was assessed by the Shapiro-Wilk test. Data were presented as mean±standard deviation (SD). For normally distributed data, the independent samples *t*-test and one-way analysis of variance (ANOVA) analysis with LSD adjustment were used. Given the relatively small sample size of this study, the Bonferroni method was deemed unsuitable for analyzing data such as BCC and AMP. Therefore, the LSD method was selected for multiple comparisons correction. The Wilcoxon Mann-Whitney *U* test and Kruskal-Wallis *H* test were performed on non-normally distributed data. For the primary outcome measures (BCC, AMP) and secondary measures (UCVA, UVNA, NRA, PRA), a within-group paired analysis was primarily conducted using preoperative and postoperative data from the same subjects. This self-controlled design inherently eliminates confounding biases arising from baseline imbalances in age and preoperative spherical equivalent between groups or other factors; therefore, analysis of covariance (ANCOVA) was not employed for assessing within-group changes. All P value <0.05 was considered statistically significant.

RESULTS

A total of 40 people (80 eyes) were enrolled and divided into the FS-LASIK binocular group or FS-LASIK monovision group based on patient preference. The FS-LASIK binocular group (full correction of both eyes) comprised 27 patients (54 eyes), categorized as follows: 15 patients (30 eyes) with simple myopia (Group 1), 12 patients (24 eyes) with myopia and presbyopia (Group 2), and 13 patients (26 eyes) undergoing FS-LASIK combined with monovision (Group 3). The mean additional power (ADD) was 1.10±0.53 D in Group 2 and 0.93±0.33 D in Group 3, with no statistically significant difference between the two groups (P=0.332). Age differences among the three groups were statistically significant (P=0.004); however, Group 2 and 3 did not differ significantly in age (P=0.471), though both were older than Group 1 (P<0.05). No statistically significant differences were observed in spherical refractive error, cylindrical refractive error, or manifest refraction spherical equivalent (MRSE) across the three groups (P>0.05). Table 1 summarizes the clinical characteristics of the patients.

Visual Acuity Figure 1 depicts the UCVA of patients preoperatively and at 3mo postoperatively, demonstrating a

Table 1 Clinical characteristics of patients who used FS-LASIK binocular and FS-LASIK monovision

Parameters	Myopia (n=30) Group 1	Myopia with presbyopia (n=24) Group 2	FS-LASIK monovision (n=26) Group 3	P
ADD		1.10±0.53	0.93±0.33	0.332[a]
Age (y)	41.27±1.44	44.50±4.32	45.43±3.57	0.004[b]
Gender, n (%)				
Male	3 (20)	4 (33.3)	5 (38.5)	
Female	12 (80)	8 (66.7)	8 (61.5)	
Spherical refractive error (D)	-4.89±1.36	-4.70±2.05	-4.80±2.61	0.940[b]
Cylindrical refractive error (D)	-0.55±0.42	-0.84±0.75	-0.65±0.71	0.232[b]
MRSE (D)	-5.17±1.37	-5.12±2.02	-4.02±3.16	0.118[b]

[a]*t*-test; [b]One-way ANOVA analysis with LSD adjustment. FS-LASIK: Femtosecond laser-assisted *in situ* keratomileusis; ADD: Additional power; MRSE: Manifest refraction spherical equivalent.

significant improvement in UCVA in all patients postoperatively (all P<0.001; Figure 1A). Table 2 summarizes the changes in visual acuity at 3mo postoperatively. At the three-months follow-up, the mean UCVA improvement was 0.99±0.17 in the dominant eye and 0.81±0.29 in the nondominant eye for Group 3, with distance visual acuity marginally better in the dominant eye than in the nondominant eye (P=0.062). Postoperative near visual acuity at 3mo remained comparable to preoperative levels across all patient groups, with no statistically significant difference (P>0.05; Figure 1B). At the three months follow-up after surgery, in Group 3, UNVA was modestly better in the nondominant eye than in the dominant eye, with a mean improvement of 0.10±0.12 in the nondominant eye versus 0.02±0.17 in the dominant eye; the difference was not statistically significant (P=0.164).

Table 2 Changes in visual acuity before and after FS-LASIK surgery

Parameters	ΔUCVA	ΔUNVA
Group 1		
OD	1.20±0.21	-0.08±0.16
OS	1.10±0.20	-0.05±0.12
Group 2		
OD	1.08±0.14	0.01±0.31
OS	1.02±0.41	0.00±0.23
Group 3		
Dominant eye	0.99±0.17	0.02±0.17
Nondominant eye	0.81±0.29	0.10±0.12
P	0.062	0.164

Values are presented as mean±standard deviation. FS-LASIK: Femtosecond laser-assisted *in situ* keratomileusis; UCVA: Uncorrected distance visual acuity; UNVA: Uncorrected near visual acuity; ΔUCVA: UCVA at 3mo postoperatively−UCVA preoperatively; ΔUNVA: UNVA at 3mo postoperatively−UNVA preoperatively; OD: Right eye; OS: Left eye. The *t*-test was used to compare differences between dominant eye and nondominant eye.

Contrast Sensitivity Figures 2 and 3 depict the preoperative and 3mo postoperative CS results. In Group 3, CS at most spatial frequencies was generally higher in the dominant eye compared to the nondominant eye; however, no statistically significant difference was observed (P>0.05). At all spatial frequencies, no statistically significant differences were identified between Group 1 and Group 2.

Accommodation Function Consistent with the predefined statistical plan, only intra-group pre-post comparisons were conducted for BCC and AMP in the primary result presentation, without inter-group statistical comparison across three groups.

Figure 4 depicts the results of the patients' accommodation function after surgery, and Table 3 depicts the accommodation parameters at different time points after surgery. At 3mo postoperatively, there was no statistically significant difference in BCC of Group 1 and Group 2 compared with preoperative (P=0.719, P=0.438), while the BCC of Group 3 decreased by 0.30±0.43 compared with preoperative, which was statistically significant (P=0.037; Figure 4B).

At 3mo postoperatively, the AMP in Group 3 showed a trend of increase compared with the preoperative period, with the increase in the nondominant eye being higher than that in the dominant eye (P>0.05), and the increase in both eyes was greater than that in Group 1 and Group 2 (Figure 4C).

For NRA and PRA, there was no statistically significant difference at 3mo postoperatively compared with preoperatively in all three groups (P>0.05). In Group 3, PRA decreased at 1wk postoperatively and returned to preoperative levels by 3mo postoperatively, being significantly higher at 3mo than at 1wk postoperatively (P=0.042; Figure 4E). In Group 1, PRA decreased significantly at 1wk postoperatively (P=0.016), was higher at 3mo postoperatively than at 1wk postoperatively (P=0.028), and returned to preoperative levels.

Measurements of AF both preoperatively and postoperatively yielded a result of 0 cycles/min. None of the subjects were able to successfully clear the accommodative stimulus of the minus (-2.00 D) lens.

Patient Satisfaction Questionnaire Table 4 presents the patient satisfaction scores after FS-LASIK at 3mo postoperatively. At this time point, all three groups exhibited

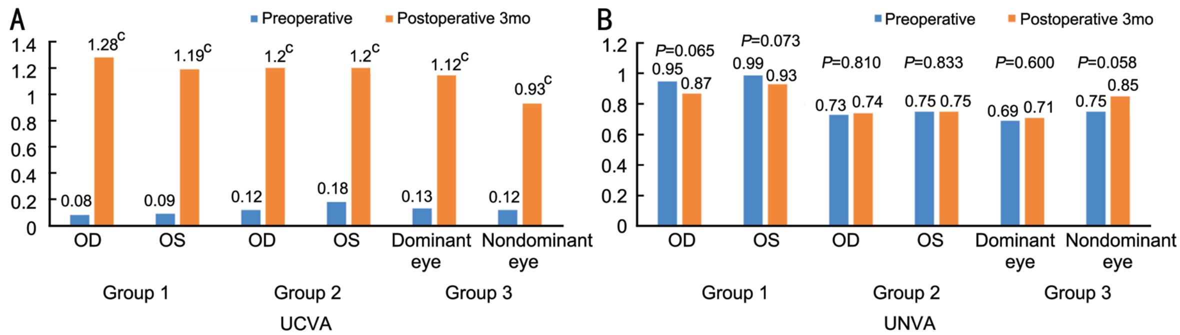

Figure 1 Visual acuity in patients after FS-LASIK preoperatively and at 3mo postoperatively A: Histogram of preoperative and postoperative uncorrected distance visual acuity (UCVA); B: Histogram of preoperative and postoperative uncorrected near visual acuity (UNVA). UCVA and UNVA are non-normally distributed data. The Wilcoxon Mann-Whitney *U* test was used to compare differences between preoperative and postoperative 3mo. [c]P<0.001. OD: Right eye; OS: Left eye; FS-LASIK: Femtosecond laser-assisted *in situ* keratomileusis.

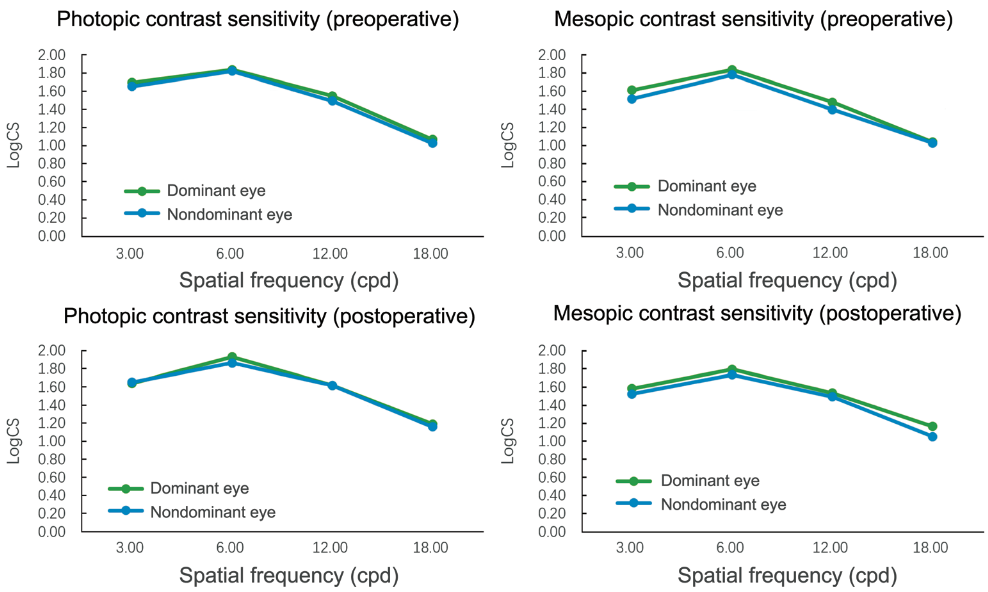

Figure 2 Preoperative and postoperative contrast sensitivity (CS) in Group 3 at different spatial frequencies.

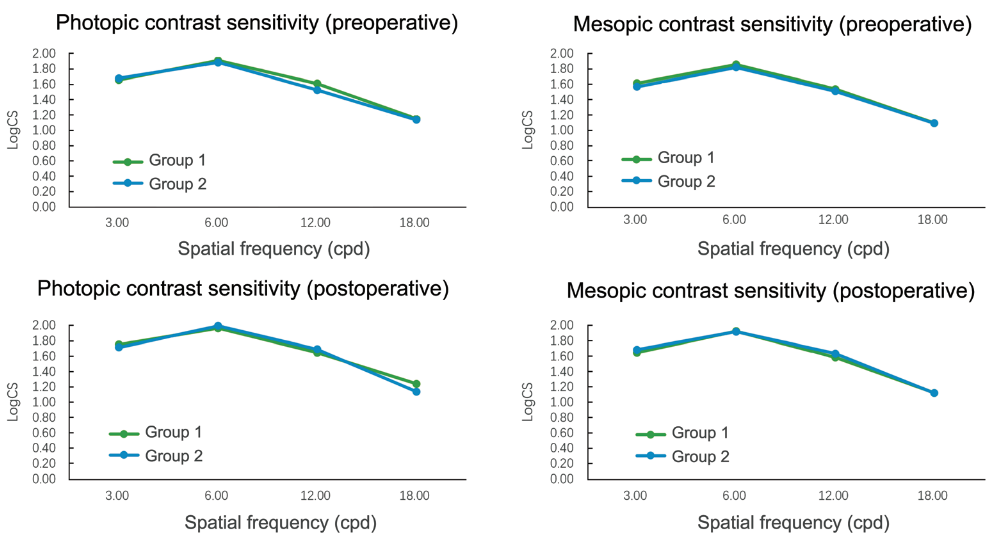

Figure 3 Preoperative and postoperative contrast sensitivity (CS) in Group 1 and Group 2 at different spatial frequencies.

high levels of satisfaction (Group 1: 9.40±0.632, Group 2: 9.67±0.651, Group 3: 9.62±0.650). In Group 2, 8.33% (1/12) of patients reported occasional discomfort with close work after surgery, and 25% (3/12) required reading glasses for near vision; however, these conditions were communicated preoperatively and accepted by the patients. Only 15.38% (2/13) of patients in Group 3 experienced discomfort in close work and none required reading glasses postoperatively.

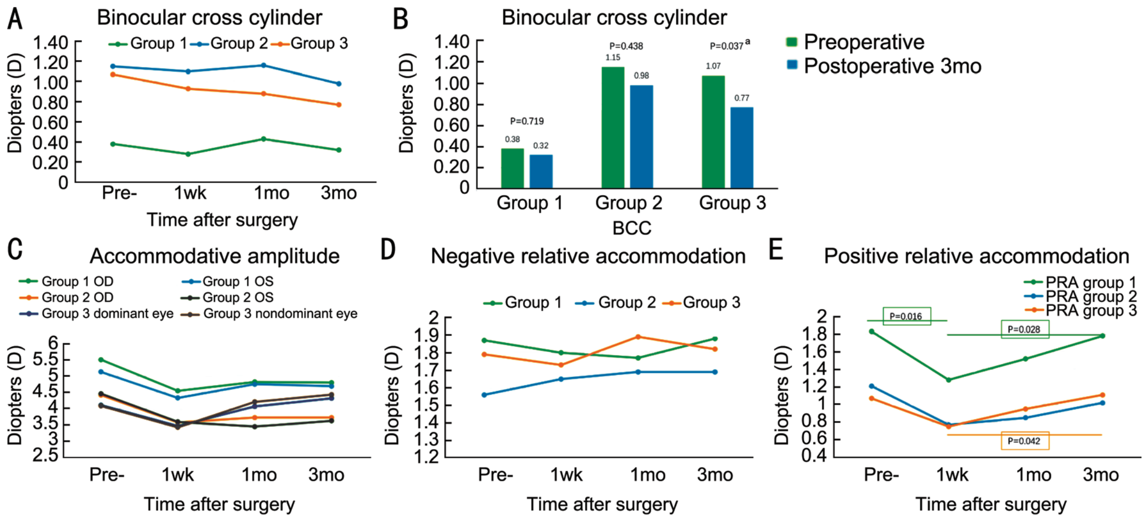

Figure 4 Preoperative and postoperative accommodation function A: Preoperative and postoperative accommodation response measured using the binocular cross cylinder (BCC) method; B: Histogram of preoperative and 3mo postoperative accommodation response; C: Preoperative and postoperative accommodative amplitude measured using push-up method; D: Preoperative and postoperative negative relative accommodation (NRA); E: Absolute value of preoperative and postoperative positive relative accommodation (PRA). The independent samples *t*-test was used to compare differences between preoperative and postoperative 3mo. [a]Statistically significant; OD: Right eye; OS: Left eye.

Table 3 Preoperative and postoperative accommodation function

Parameters	Preoperative	Postoperative 1wk	Postoperative 1mo	Postoperative 3mo	*F*	*P*
BCC (D)						
Group 1	0.38±0.45	0.28±0.28	0.43±0.41	0.32±0.55	0.363	0.780
Group 2	1.15±0.47	1.10±0.57	1.16±0.46	0.98±0.56	0.302	0.824
Group 3	1.07±0.39	0.93±0.33	0.88±0.41	0.77±0.35	1.627	0.194
NRA (D)						
Group 1	1.87±0.47	1.80±0.56	1.77±0.64	1.88±0.48	0.154	0.927
Group 2	1.56±0.75	1.65±0.60	1.69±0.43	1.69±0.65	0.108	0.955
Group 3	1.79±0.51	1.73±0.47	1.89±0.44	1.82±0.59	0.249	0.862
PRA (D)						
Group 1	-1.83±0.77	-1.28±0.55[a]	-1.52±0.50	-1.78±0.571[a]	2.652	0.057
Group 2	-1.21±1.30	-0.77±0.56	-0.85±0.49	-1.02±0.79	0.624	0.603
Group 3	-1.07±0.58	-0.75±0.47	-0.95±0.34	-1.11±0.381[a]	1.776	0.163
AMP (D)						
Group 1^{OD}	5.50±1.98	4.55±1.32	4.82±2.08	4.80±1.34	0.847	0.474
Group 1OS	5.13±1.82	4.33±0.93	4.75±2.04	4.69±1.32	0.844	0.481
Group 2^{OD}	4.42±2.31	3.58±1.42	3.73±1.10	3.73±1.36	0.647	0.589
Group 2OS	4.46±2.35	3.60±1.43	3.45±0.96	3.63±1.60	0.900	0.449
Group 3 (dominant eye)	4.11±1.03	3.47±0.94	4.07±1.43	4.32±1.46	1.229	0.308
Group 3 (nondominant eye)	4.09±1.00	3.43±0.99	4.21±1.45	4.43±1.92	1.329	0.275

Data presented as mean±standard deviation. BCC: Binocular cross cylinder; NRA: Negative relative accommodation; PRA: Positive relative accommodation; AMP: Accommodative amplitude; Group^{OD}: The right eye of group; Group^{OS}: The left eye of group. *P* values for comparisons before and after surgery of accommodation parameters were calculated by one-way ANOVA with LSD adjustment. [a]Statistically significant.

DISCUSSION

FS-LASIK with monovision is a surgical procedure designed for myopic patients with presbyopia. This technique reshapes the corneas of both eyes using an excimer laser, fully correcting the dominant eye for distance vision while retaining a controlled degree of myopia in the nondominant eye for near vision. This approach aims to provide clear vision at both near and far distances, making it particularly suitable for middle-aged and elderly individuals experiencing presbyopia[16].

Previous studies have shown that refractive surgery not only significantly improves visual acuity, but may also significantly affect binocular accommodation function compared to traditional spectacle correction. However, limited research has investigated accommodation function changes

Table 4 The satisfaction scores of the patients after FS-LASIK treatment

Groups	Mean±SD	Postoperative discomfort in close work	Postoperative near vision requires reading glasses
Group 1	9.40±0.632	6.67% (1/15)	0
Group 2	9.67±0.651	8.33% (1/12)	25% (3/12)
Group 3	9.62±0.650	15.38% (2/13)	0

FS-LASIK: Femtosecond laser-assisted *in situ* keratomileusis; SD: Standard deviation.

after monovision in individuals over 40 years of age. To comprehensively investigate the postoperative changes in visual acuity and accommodation function in this population, this study systematically evaluated both subjective and objective outcomes. Subjective assessment was conducted using a patient satisfaction questionnaire, while objective assessment included measurements of distance and near visual acuity, CS, and accommodation function parameters such as BCC, AMP, PRA, NRA, and AF. BCC, NRA, and PRA are indicators representing binocular accommodative function, while AMP is an indicator of monocular accommodative function.

The main goal of refractive surgery is to improve UCVA, and previous studies have shown that FS-LASIK is safe and effective in patients over 40 years old, with no significant correlation between age and surgical efficacy or safety[17-18]. In this study, all patients achieved satisfactory distance visual acuity postoperatively. Except for Group 3 (nondominant eyes), which exhibited a UCVA of 0.93±0.24 at 3mo postoperatively, the remaining groups achieved a UCVA of 1.00 or better, consistent with the finding of Leray *et al*[19].

For presbyopia patients over 40 years old, achieving clear near visual acuity is as critical as improving distance vision. Studies on monovision induced by corneal refractive surgery have demonstrated superior near visual acuity in monovision groups[20]. In this study, postoperative UNVA analysis revealed the following: Group 1 exhibited ΔUNVA values of -0.08±0.16 (right eye) and -0.05±0.12 (left eye); Group 2 showed ΔUNVA values of 0.01±0.31 (right eye) and 0.00±0.23 (left eye); and Group 3 demonstrated ΔUNVA values of 0.02±0.17 (dominant eye) and 0.10±0.12 (nondominant eye). These results suggest that patients over 40 years old, owing to their naturally declining accommodation function, exhibit a slight decline or no significant fluctuation in near vision after full myopia correction, whereas monovision design improves near vision. These findings are consistent with the results of previous studies, further demonstrating that monovision can provide better near work ability for patients over 40 years old with myopia accompanying presbyopia while preserving distance visual function.

CS, defined as the ability to perceive the shape and clear outlines of small objects, and to differentiate visual targets in different spatial brightness levels and spatial frequencies, is a comprehensive representation of visual function and a critical subjective indicator of functional vision[20-21]. In this study, no statistically significant decrease in CS was observed at 3mo postoperatively compared to preoperative values across all spatial frequencies in any patient group (P>0.05). In Group 3, monocular CS at 3mo postoperatively was generally higher in the dominant eye than in the nondominant eye at most spatial frequencies (P>0.05), consistent with the findings of Zhang *et al*[22]. This discrepancy may be attributed to the mild myopic refractive state of the nondominant eye[23]. These results suggest that FS-LASIK not only enhances distance vision but also preserves CS across all spatial frequencies, further supporting the safety of FS-LASIK combined with monovision for myopic presbyopic patients aged over 40y. Whether this observation holds clinical or functional significance warrants further investigation.

The accommodation response refers to the accommodative reaction of the eye when a certain accommodative stimulus is given, with a normal range of +0.25 to +0.75 D of accommodation lag in non-presbyopic eyes. In this study, Group 3 demonstrated significant improvement in accommodation response, with the accommodation lag decreasing from 1.07±0.39 D preoperatively to 0.77±0.35 D at 3mo postoperatively (P=0.037), suggesting that the monovision design effectively reduced accommodation lag in patients with myopia accompanying presbyopia. In this study, a statistically significant BCC improvement of 0.30 D was observed postoperatively in Group 3. However, according to the consensus from previously published studies, changes in BCC magnitude are typically associated with noticeable clinical symptoms and alterations in visual function only when they exceed 0.50 D. Therefore, the slight reduction in BCC observed in our study merely suggests a subtle, favorable shift in the state of binocular accommodative balance. Its actual value regarding daily visual experience and long-term clinical prognosis remains unclear. Future studies with larger sample sizes, extended follow-up periods, and the inclusion of more composite endpoints (both subjective and objective visual function metrics) are needed to further validate the true clinical and physiological significance of this minor change. Notably, AMP declined in all patients at 1wk postoperatively but gradually recovered to preoperative level at 3mo postoperatively. Similarly, PRA exhibited a transient decline followed by recovery to baseline at 3mo, consistent with findings by Zhou *et al*[24]. It is worth noting that Group 3 showed a unique recovery trend. AMP increased from 4.11±1.03 D preoperatively to 4.32±1.46 D (ΔAMP=0.21±1.69) at 3mo postoperatively in dominant eyes, and from 4.09±1.00 to 4.43±1.92 D (ΔAMP=0.34±2.14) in nondominant eyes. As in Group 1 and Group 2, no statistically significant differences in AMP were observed between preoperative and postoperative values in Group 3, this numerical trend suggests that the monovision design influenced AMP to a certain extent; however, studies with larger sample sizes are needed to validate this observation. This finding is consistent with Zhang *et al*[22], who reported enhanced binocular accommodation amplitude and PRA after Q-guided optimized monovision combined with FS-LASIK in presbyopic patients with low-to-moderate myopia (P<0.001). Similarly, Zhang *et al*[25] concluded that monovision corrects low-to-moderate myopia, reduces presbyopic symptoms, and increases accommodation amplitude. These findings support the potential of FS-LASIK with monovision to improve accommodation in presbyopic patients with low-to-moderate myopia. In contrast, Zhang *et al*[26] observed no significant changes in AMP or PRA at 3mo postoperatively in highly myopic patients (mean age: 42.58±3.06y; spherical equivalent<-6.00 D), though NRA increased significantly (P<0.001), potentially linked to enhanced fusional convergence post-surgery. This suggests that differences in patients' preoperative refractive error may influence postoperative changes in accommodation. Although the change in AMP did not reach statistical significance, the observed increasing trend may be related to the following mechanisms: Regarding neuroadaptation, the monovision design may prompt the visual cortex to readjust the integration of binocular inputs, thereby improving visual processing efficiency[27]. In terms of visual training, patients may actively engage in visual tasks postoperatively to adapt to their new visual state. Furthermore, it is necessary to consider the inherent subjectivity and measurement errors associated with AMP assessment, as the push-up method has limited repeatability. In summary, this trend warrants further exploration in future studies.

In this study, we found that the patients' postoperative AMP and NRA exhibited an initial decline followed by gradual recovery to preoperative levels by 3mo postoperatively. This transient reduction in accommodation may be attributed to several factors: 1) Refractive state changes. Surgery changes the refractive state of the eye. Preoperatively, myopic patients required minimal accommodation for near vision. Postoperative reductions in corneal curvature increased accommodative demands for near tasks[28]. 2) Vertex distance disappearance. Due to the disappearance of the vertex distance existence, the vergence of near objects to the cornea is different from that for near vision when wearing spectacles, resulting in heightened accommodation demands postoperatively for near vision. This mismatch between increased demands and insufficient self-accommodation may contribute to early postoperative accommodative dysfunction[29]. 3) Monovision adaptation. During early monovision adaptation, patients' visual systems undergo reprogramming, often causing transient visual discomfort. Over time, the patient's visual system usually adapts to the change, and accommodation returns to preoperative levels.

This recovery pattern contrasts with findings by Xu *et al*[30], who reported that young patients (18–35y) had significantly higher AF than preoperative levels as early as 1mo after FS-LASIK, with accommodation parameters returning to or exceeding preoperative levels by 1mo. This discrepancy suggests that the magnitude of change in accommodation function after refractive surgery in patients over 40 years old may not be as pronounced as in younger patients, and the recovery period may be longer than in younger patients[31]. These differences suggest that age may be an important factor influencing the ability to recover accommodation function after surgery. In addition, changes in accommodation function are also closely related to patients' preoperative refractive status, ocular physiological characteristics, and postoperative recovery. Studies have shown[32] that the recovery of postoperative accommodation depends not only on surgical technique but also on individual differences. These findings underscore the importance of comprehensive preoperative assessments to optimize postoperative outcomes.

This study found that AF was zero for all patients both preoperatively and postoperatively (failure to clear the minus lenses). This stands in marked contrast to the findings of Alrasheed *et al*[33], who reported that using a ±2.00 D flipper, young individuals achieved a mean monocular AF of 8.22±3.19 cycles/min and a binocular AF of 7.29±2.99 cycles/min. This result is closely related to the patients' age (41–45y, entering or in the early stages of presbyopia) and their physiologically reduced AMP and PRA. We observed that the PRA values of many patients were lower than -2.00 D, meaning they struggled to overcome the accommodative demand induced by the -2.00 D minus lenses used in the standard AF test[34]. Therefore, the ±2.00 D flipper test, which is designed for young non-presbyopic individuals, may exceed the remaining accommodative limits of the presbyopic patients in this study. This resulted in uniformly zero AF values without discernible differences, and thus no further analysis was performed. To more accurately assess accommodative function in the presbyopic population, future studies are advised to adjust the AF measurement protocol, such as using ±1.00 or ±1.50 D flippers or adjusting the target distance.

The results of the patient satisfaction questionnaire correlated well with the objective assessment of accommodation function, with good overall satisfaction on average at 3mo postoperatively, consistent with most studies[35-36]. By analyzing specific vision symptoms, the results of this study showed that Group 3 significantly reduced their dependence on presbyopia glasses, and most of them were able to switch between distance and near vision more smoothly to achieve the monovision goal of observing things at a distance while the nondominant eye remained clear at near distance. 25% (3/12) of Group 2 needed to wear presbyopic glasses when viewing near, but this was communicated preoperatively, understood and accepted by the patients, and did not have a serious impact on subjective satisfaction.

Compared with previous studies, there are some differences in the results of this study, which may stem from the following factors: regarding patient age differences, previous studies mostly focused on presbyopic patients aged 45–50y, while this study included early presbyopic patients aged 40–45y. Younger patients may have better neuroplasticity and adaptability; regarding surgical protocols, this study adopted FS-LASIK combined with personalized monovision design. Differences in laser surgical methods may affect postoperative visual quality and the adaptation process. This study conducted evaluations at 3mo postoperatively, while some studies performed assessments at 6mo or 1y, which may affect the judgment of long-term adaptation effects. This study used various accommodative function assessment methods, and different studies may have methodological differences when measuring parameters such as AMP and BCC, affecting the comparability of results[37].

In addition, this study has several shortcomings: First, the relatively small sample size and uneven distribution among groups, combined with the non-randomized grouping based on patient preference, may have introduced selection bias and resulted in imbalanced baseline characteristics. Although univariate analysis was employed as the primary statistical method to assess pre- and post-operative changes in patients undergoing FS-LASIK combined with monovision, the lack of multivariate analysis to control for potential confounders constitutes a limitation. Furthermore, limited by the sample size, sufficient subgroup analysis regarding the varying degrees of under-correction reserved for the non-dominant eye (-0.50 to -1.50 D) could not be performed, thereby restricting statistical power and the precision of the evaluations. Second, there are limitations regarding the evaluation metrics and follow-up duration. This study lacked an assessment of stereopsis and failed to investigate the dose-response relationship between the degree of under-correction and postoperative adaptation parameters. Additionally, the 3-month follow-up period was insufficient to evaluate the long-term stability of neuroadaptation, trends in accommodative function, and the persistence of visual fatigue. Finally, the study population was restricted to patients with low to moderate myopia and did not include individuals with high myopia or younger age groups. Future studies should address these limitations by employing larger sample sizes, randomized grouping, extended follow-up periods (6–12mo), and multivariate statistical models to further validate these findings and optimize personalized monovision treatment strategies.

Despite several inherent limitations of this study, the findings are credible and reproducible. We preliminarily explored the alterations in visual acuity and accommodative function following FS-LASIK surgery in myopic presbyopic patients aged over 40y. In conclusion, FS-LASIK combined with monovision is an effective treatment for patients aged over 40y with myopia and presbyopia, which not only improves postoperative distant and near visual acuity but also achieves high patient satisfaction and improves postoperative BCC.

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