

Three-year Clinical Outcomes of Aspheric Micro-monovision LASIK for Correction of Presbyopia and Myopic Astigmatism

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Research article

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Abstract

Background: To investigate the long-term safety and efficacy of aspheric micro-monovision LASIK for the correction of presbyopia and myopic astigmatism.

Methods: In total, 114 eyes of 57 patients with a mean age of 48 ± 4.05 years (range: 43 to 62 years) who were undergoing aspheric micro-monovision LASIK treatment were enrolled. Visual acuity, manifest refraction, amplitude of accommodation, contrast sensitivity, entire eye aberrations and patients' subjective ratings were evaluated from 1 day to 3 years postoperatively.

Results: None of the eyes showed a spherical equivalent change of over 0.75 D between 3 months and 3 years, while 95% of the eyes were within ± 0.50 D of the target correction of the spherical equivalent. The percentage of patients showing monocular uncorrected distance visual acuity $\geq 20/20$ was 95%, and all eyes achieved a visual acuity of 20/25 or better. The percentage of patients showing binocular uncorrected near visual acuity $\geq J2$ was 93%, and all patients achieved a visual acuity of J4 or better. Ninety-one percent of the patients had an uncorrected visual acuity of 20/20 in both eyes and J2 or better binocular visual acuity. Six of 108 eyes (6%) lost 1 line, and no eyes lost 2 lines of corrected distance visual acuity. The overall satisfaction score for surgery was 93 ± 6 .

Conclusions: Aspheric micro-monovision LASIK using the Carl Zeiss Meditec MEL 80 Platform was an efficacious option for older myopic patients with presbyopia. Three-year postoperative outcomes in the Chinese population indicated improvements in uncorrected binocular vision at far and near distances with high satisfaction.

Trial registration: The registration number is ChiCTR-IPC-15005842, and the date of registration is January 16, 2015.

Background

Presbyopia is a universal disorder in people older than 40 years [1]. Restoration of the loss of accommodation and achieving complete spectacle independence in presbyopic patients remain a challenge for refractive surgeons [2]. In fact, monovision, which can be achieved by intraocular lenses (IOLs), contact lenses, or laser ablation, continues to be the regular and effective choice for presbyopia correction [3-5]. However, it is difficult for some patients to adapt to anisometropia induced by monovision, and the myopic target chosen for nondominant eyes in traditional monovision strategy empirically depends on the age of the patients [6].

The visual benefits of higher-order aberrations (HOAs) induced in the case of presbyopia have long been recognized. The induction of specific HOAs may expand the depth of focus (DOF), increase the measured amplitude of accommodation and improve functional near vision [7-10]. LASIK with a nonlinear aspheric ablation profile and micro-monovision, which can increase the spherical aberration in both eyes, was proposed in 2009; this treatment is also known as laser blended vision (LBV) [11]. This aspheric ablation

profile is calculated using the CRS-master platform (Carl Zeiss Meditec, Jena, Germany), and the final treatment profile output depends on the preoperative refractive diopter, customized aspheric aberration that is induced, and functional age, which depends on the patient's residual accommodation rather than real age. While this approach targets an exactly plano surface in the dominant eye as in traditional monovision, it targets slight myopia with an ideal target of -1.50 D for the nondominant eye in most cases.

Dr. Dan Z. Reinstein detailed the efficacy, safety, and predictability of LBV in several studies [11, 12, 13]. The 3-month outcomes in a Chinese population indicated that it was a safe and well-tolerated method for simultaneous correction of myopia and presbyopia with a measurable increase in accommodative amplitude [14]. In 2015, the 3-year postoperative visual outcomes and patient satisfaction after LBV were evaluated retrospectively [15]. However, no prospective study has assessed long-term outcomes in an age-stratified population. Therefore, this study aimed to evaluate the long-term safety and efficacy of LBV in the treatment of myopic astigmatism and presbyopia using the MEL80 and CRS-Master platform (Carl Zeiss Meditec, Jena, Germany).

Methods

This study was a non-comparative case series and was approved by the Medical Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-Sen University, People's Republic of China. The study followed the tenets of the Declaration of Helsinki. A total of 57 patients undergoing LBV treatment were enrolled. All patients provided informed consent before surgery. The mean age of the 57 patients (22 male and 35 female) was 48 ± 4.05 years (range: 43 to 62 years). Patients in this study had a mean preoperative spherical equivalent of -5.59 ± 1.85 D (range: -1.25 to -11.10 D), cylinder of -0.62 ± 0.43 D (range: -2.25 to 0.00 D), and spectacle near addition of 1.75 ± 0.26 D (range: 0.75 to 2.50 D). Patients were enrolled in this study if they were presbyopic, had a corrected distance visual acuity (CDVA) of 20/25 or better in both eyes, were medically suitable for LASIK, and could tolerate at least -0.75 D anisometropia during the tolerance test. Patients with systemic illness and those with clinically relevant lens opacity, previous ocular surgery, or abnormal binocular vision were excluded from the study.

Baseline data included measurements of monocular and binocular uncorrected distance visual acuity (UDVA), uncorrected near visual acuity (UNVA), corrected distance visual acuity (CDVA), corrected near visual acuity (CNVA), distance corrected near visual acuity (DCNVA), manifest refraction, cycloplegic refraction, presbyopic addition, and assessments using slit-lamp examination, dilated fundus examination, amplitude of accommodation, corneal topography (Pentacam, Oculus Optikgerate, Wetzlar, Germany), contrast sensitivity (CSV-1000, Vector Vision, USA), entire eye aberrations (iTrace, Tracey Technologies Corp. Houston, USA), ocular wavefront analyzer (WASCA wavefront analyzer, Carl Zeiss Meditec, Jena, Germany), and subjective rating questionnaires. Ocular dominance was determined using the "hole test"[12]. The patient's tolerance was measured by simulating the intended postoperative refraction using a phoropter, and the patient's acceptance was confirmed after wearing the trial frame, which simulated the intended postoperative refraction, for at least 5 minutes. The subjective

questionnaire included 6 items covering satisfaction with (1) near vision, (2) distance vision, (3) intermediate vision, (4) night vision, (5) dependence on glasses, and (6) overall satisfaction with the correction. Each scale ranged from 0 to 100, where 0 indicated not at all satisfied and 100 indicated completely satisfied. Near acuity was measured under the same lighting conditions in one optometry room using the Sloan Letter Near Vision Card-729000 (GOOD-LITE[®], IL, USA), which was designed such that the card was 40 cm away from the patient's eye when a bead on a 40-cm cord was placed at the patient's lateral canthus. The minus-lens–stimulated measurement was used to measure the amplitude of accommodation in patients, as described in a previous study [16].

All aspherical ablation treatments were prepared using the CRS-Master software platform (Carl Zeiss Meditec, Jena, Germany). The sphere and cylinder values entered into the laser were based on the manifest refraction without any nomogram adjustment. A target of -1.50 D was used for most nondominant eyes but was manually adjusted according to the patient's tolerance of anisometropia. Figure 1 shows a scatterplot indicating the distribution of the intended spherical equivalent refraction in the near eye plotted against the patient's age.

The same surgeon (Q.L.) performed all operations using the VisuMax femtosecond laser and MEL 80 excimer laser (both Carl Zeiss Meditec AG, Jena, Germany). Surgical parameters were as follows: 1) 100- μ m-thick flap; 2) mean optical zone, 6.32 ± 0.24 mm (range: 6.00 to 7.00 mm); 3) mean transition zone, 2.2 ± 0.12 mm (range: 1.30 to 2.30 mm); and 4) total ablation zone, 6.89 ± 0.17 mm (range, 6.50 to 8.30 mm).

At 3 years after surgery, 54 patients (108 eyes, 95%) were still available for follow-up, and all of them completed 3 years of follow-up. Three patients were classified as lost to follow-up and excluded from the analysis. Postoperative follow-up examinations included an assessment of manifest refraction, monocular and binocular UDVA, UNVA, CDVA, DCNVA, and CNVA. Manifest refraction and visual acuity measurements were performed at 1 day, 1 week, 1 month, 3 months, 6 months, 1 year, and 3 years postoperatively. Contrast sensitivity was assessed at 6 months, 1 year and 3 years postoperatively. Subjective questionnaires, aberration measurements and minus-lens–stimulated accommodative amplitudes were assessed at the last visit.

Data were recorded in an Excel software database (2013, Microsoft Corp.). SPSS version 16.0 (SPSS, Inc., Chicago, IL) was used for statistical analysis. For normally distributed data, Student's paired t tests were used. For non-normally distributed data, Friedman tests were performed. Correlations between changes in UNVA, changes in clinical measures in accommodation and changes in each of the higher order aberrations were assessed by linear regression analysis. A P value less than .05 was considered statistically significant.

Results

The baseline characteristics are summarized in Table 1. Postoperative visual acuity and refractive outcomes are shown in Table 2.

Postoperatively, the distributions of monocular and binocular UDVA and UNVA are presented in Figure 2. At 3 years postoperatively, in the dominant eyes, UDVA was 20/20 or better in 75% of patients, and 75% of the dominant eyes achieved a UNVA of J5 or better. In the nondominant eyes, UDVA was at least 20/40 in 95% of patients, and 90% of the nondominant eyes achieved a UNVA of J2 or better. Binocular near visual acuity was at least J4 in all patients. All eyes achieved a CDVA of 0.0 logMAR (20/20) or better postoperatively. Moreover, 91% of the patients achieved a UDVA of 20/20 or better and simultaneously achieved a UNVA of J2 or better. The distributions of monocular and binocular UDVA and UNVA at 1 year after treatment are presented in an additional file [see Additional file 1]

Changes in the lines of CDVA at all follow-up visits are shown in Figure 3. No eyes lost 2 lines of CDVA after treatment. At 3 years postoperatively, 6 of 108 (6%) eyes lost one line of corrected distance visual acuity, and no eyes lost 2 lines. Figure 4 shows the contrast sensitivity (CS) at spatial frequencies (SFs) of 3, 6, 12 and 18 cycles per degree (cpd) under photopic, mesopic and mesopic with glare lighting conditions. Compared on the logarithmic scale, the changes in binocular contrast sensitivity from the preoperative values in all test conditions were not significantly different at any frequency ($P > .05$).

Refractive outcomes are presented in Figure 5. None of the eyes showed a spherical equivalent change of over 0.75 D between 3 months and 3 years. At 3 years postoperatively, the mean spherical equivalent values in distance and near eyes were -0.05 ± 0.23 D (range: -1.00 to 0.75 D) and -1.34 ± 1.67 D (range: -0.75 to -2.75 D), respectively (Table 2). Ninety-five percent of the eyes were within 0.50 D of the target refraction, and all of the eyes were within 1.00 D. Ninety-four percent (51 out of 54) of distance eyes were within 0.5 D of emmetropia, while 96% (52 out of 54) of near eyes were within 0.5 D of the micro-monovision target (-1.50 D), and all eyes were within 0.5 D of the target astigmatism refraction. The preoperative and postoperative aberrations are shown in Table 3. Postoperatively, corneal total higher order aberrations (HOAs) and spherical aberrations (SA) increased significantly. There were no statistically significant differences in coma ($P=0.76$), secondary astigmatism ($P=0.74$) or trefoil aberrations ($P=0.85$) before and after surgery. A correlation between change in lines of UNVA and change in corneal aberrations was found by linear regression analysis (Figure 6). A significant positive correlation was detected with HOAs ($r = 0.943$, $P = 0.000$) and spherical aberrations ($r = 0.979$, $P = 0.000$) but not with coma, second astigmatism or trefoil aberrations.

The accommodative amplitude increased from 4.42 ± 1.26 D (range: 0 to 4.5 D) to 4.91 ± 1.43 D (range: 0.50 to 4.75 D) ($P < .05$). In different age groups, the accommodation amplitude increased after surgery. However, only patients older than 46 years showed a significant increase in amplitude ($P < .05$) (Table 4). A correlation between change in accommodative amplitude and change in entire eye aberrations was also found by linear regression analysis (Figure 6). A significant positive correlation was detected with HOAs ($r = 0.937$, $P = 0.000$) and spherical aberrations ($r=0.941$, $P = 0.000$) but not with coma, secondary astigmatism or trefoil aberrations.

Table 5 shows the subjective rating after LBV. The mean satisfaction score was 93 ± 6 (range: 80 to 100). The satisfaction scores for both near vision, intermediate vision and distance vision improved significantly after surgery. After 3 years, 94% of the patients achieved completely “glasses-off” status. No patient used spectacles for distance vision, even while driving at night.

Discussion

This consecutive case series analyzed the long-term safety and efficacy of presbyopic treatment using LBV. After 3 years, a loss of one line in the corrected distance visual acuity after surgery was observed in only 6% (6 out of 108) of the eyes, and no patients lost 2 lines in this study. Considering the nomogram of near addition in traditional LASIK-induced monovision, the age of the patient was not a consideration when choosing the target refraction for the nondominant eye [12, 14]. In the current study, the mean attempted and achieved spherical equivalent in the near eye was -1.51 ± 0.29 and -1.34 ± 1.67 D, respectively. In earlier studies, the mean refraction of the near eyes was -1.31 D at 3 months and -1.3 D at 1 year [12, 14]. The micro-monovision myopic target of the nondominant eyes was stable during the 3-year follow-up.

Using this aspheric micro-monovision LASIK for presbyopia correction, the nondominant eye was targeted for slight myopia with a target of -1.50 D in most cases. In the current study, no patients reported difficulty in adaptation during the 3-year follow-up period. However, the efficacy of near vision could be a concern due to the decrease in anisometropia. At the 3-year follow-up, 93% (50 out of 54) of patients achieved 0.1 logRAD or better binocular uncorrected near visual acuity. The satisfaction questionnaire scores improved significantly after surgery. Near visual acuity, including UNVA and DCNVA, and the amplitude of accommodation improved significantly after surgery, which showed that presbyopia symptoms were relieved. Refractive surgeons and optical scientists found that corneal laser ablation can change the HOAs of eyes and improve presbyopia symptoms, which are mainly achieved by induced spherical aberrations to increase the depth of focus [7, 8, 17]. Studies by Jorge L. Alió et al are probably the first to have shown the link between HOAs and preservation of near acuity after excimer laser ablation [9, 10]. Using LBV, the postoperative HOAs and SA in our study both increased compared to the prior levels. Although HOAs may degrade the quality of vision, controlled induced spherical aberrations in the case of presbyopia may have a beneficial effect [7]. Some studies have tried to find the balance of expanding the depth of focus while attempting to preserve visual quality [7, 8]. Despite the induced spherical aberrations, a compromise in night vision could not be found after 3 years of surgery in this study. The changes in binocular contrast sensitivity from the preoperative values in all test conditions were not significantly different at any frequency. In Dan’s study and our previous study, LBV improved presbyopia symptoms and increased the measured amplitude of accommodation [12, 14]. However, they did not give the relationship between changes in HOAs and the measured amplitude of accommodation. LBV combined a nonlinear aspheric ablation profile and micro-monovision. The increased amplitude of accommodation is partly due to changes in spherical aberrations instead of micro-monovision only. The positive correlations between induced spherical aberrations and the postoperative measured amplitude of accommodation and near vision seem to support this finding. More importantly, the accommodation

amplitude increased after LBV in different age groups. The significantly increased pseudo-accommodation was useful [18], especially in patients who are older than 46 years of age and experiencing severe presbyopia. These results indicated that this nonlinear aspheric ablation profile induced HOAs, especially spherical aberrations, and manipulating the HOAs of the eyes improved the measured amplitude of accommodation and, as a result, also alleviated presbyopia symptoms.

After three years, the visual acuity and refraction results were stable. The results of this study match those reported by other studies that used LBV and presbyLASIK [12, 14, 15, 19, 20]. The excellent results with respect to visual acuity could be due to moderate myopia with low astigmatism in most eyes. However, these study outcomes confirmed that LBV was safe and effective for presbyopia correction.

The limitation of this study was that the average age of patients in this study was 48 years, with a mean spectacle near addition of 1.75 D (range: 0.75 to 2.50 D). This is generally regarded as low to moderate presbyopia. The study lacked a significantly older population. Nevertheless, patients under 50 years of age formed the majority of patients willing to undergo LBV. The study population did not contain a sufficient number of older patients with refractive errors and clear lenses devoid of cataracts. Analyzing the long-term efficacy and safety of LBV in presbyopic treatments for older patients could have more clinical value. Similar to earlier studies on LBV, this study did not have a control group. However, the pupil diameter gradually decreases with age, and the aspherical ablation design with negative spherical aberrations would induce myopic refraction during accommodation miosis [8]. Both of these effects were beneficial for improving presbyopia symptoms. However, a patient with emmetropic refraction and a significant positive ocular spherical aberration, e.g., after regular myopic LASIK treatment or small incision lenticule extraction (SMILE) treatment, could show a fluctuating refraction depending on the pupil diameter. In other words, the disappearance of the SA upon pupil contraction would cause a hyperopic shift in the refractive state of the eye and require compensatory accommodation (accommodative lag). This would further alleviate the presbyopia symptoms.

Conclusion

In conclusion, to our knowledge, this is the first 3-year long-term prospective study to analyze the efficacy and safety of LBV LASIK for the correction of presbyopia and myopic astigmatism using the Carl Zeiss Meditec MEL 80 Platform. This protocol was safe and effective for the long-term treatment of presbyopia and myopic astigmatism. Three-year postoperative outcomes in the Chinese population indicated improvements in uncorrected binocular vision at far and near distances with high satisfaction. Careful patient selection and information gathering were necessary.

Abbreviations

LBV: laser blended vision; LASIK: laser-assisted in situ keratomileusis; CDVA: corrected distance visual acuity; UDVA: uncorrected distance visual acuity; UNVA: uncorrected near visual acuity; LogMAR: log

minimum angle resolution; LogRAD: log reading acuity determination of the reading equivalent of logMAR; HOAs: higher-order aberrations; DOF: depth of focus

Declarations

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-Sen University, People's Republic of China. The study followed the tenets of the Declaration of Helsinki. Written informed consent was obtained from all subjects after the aims and nature of the study were explained to the participants.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LF drafted the manuscript and performed the literature review. ZT participated in information gathering and editing. LQ conceived the idea and supervised the writing of this paper. All authors read and approved the final manuscript.

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Tables

Table 1. Summary of the Preoperative findings

Preoperative	Monocular Eyes	Binocular Patients
No.	114	57
Age(years)	-	48 ± 4.05 (43 to 62)
Gender ratio(M:F)	-	0.63(22:35)
UDVA(LogMAR)	1.06±0.57(1 to 2)	1.02±0.48(1 to 2)
CDVA(LogMAR)	-0.05±0.07(-0.18 to 0.10)	-0.08±0.04(-0.20 to 0.10)
UNVA(LogRAD)	0.75±0.32(0.4 to 1.0)	0.62±0.43(0.3 to 1.0)
DCNVA(LogRAD)	0.80±0.34(0.5 to 2.0)	0.75±0.32(0.5 to 2.0)
CNVA(LogRAD)	0.07±0.08(0.0 to 0.2)	0.00±0.05(-0.1 to 0.18)
Spherical equivalent(D)	-5.59 ±1.85 D(-1.25 to -11.10)	-
Astigmatism(D)	-0.62 ±0.43 D (-2.25 to 0.00)	-
Spectacle near addition(D)	1.75±0.26 (0.75–2.50)	-
Target SE refraction (D)		
Dominant eye	Plano	-
Non-Dominant eye	-1.51 ± 0.29(-0.75 to -2.25)	-
Optical zone(mm)	6.32±0.24(6.00 to 7.00)	-
Total ablation zone(mm)	6.89±0.17(6.50 to 8.30)	-

All values are presented as mean ± standard deviation (range); UDVA=Uncorrected Distance Visual Acuity; CDVA: Corrected Distance Visual Acuity; UNVA=Uncorrected Near Visual Acuity; DCNVA=Distance Corrected Near Visual Acuity, represents distance corrected without spectacle near addition; CNVA=Corrected Near Visual Acuity, represents distance corrected with spectacle near addition for best near visual acuity; D=Diopter

Table2.Summary of the postoperative data after treatment

3 Year Postoperative	Monocular Eyes	Binocular Patients
No.	108	54
UDVA(LogMAR)		0.00±0.07(-0.18 to 0.00)
Dominant eyes	0.00±0.05(-0.18 to 0.10)	-
Non-dominant eyes	0.27±0.13(0.18 to 0.60)	-
CDVA(LogMAR)		-0.05±0.05(-0.18 to 0.00)
Dominant eyes	0.00±0.14(-0.18 to 0.00)	-
Non-dominant eyes	0.00±0.12(-0.18 to 0.00)	-
UNVA(LogRAD)		0.07±0.04(0.00 to 0.40)
Dominant eyes	0.43±0.18(0.20 to 0.50)	-
Non-dominant eyes	0.08±0.14(0.00 to 0.50)	-
DCNVA(LogRAD)		0.20±0.25(0.01 to 0.40)
Dominant eyes	0.32±0.18(0.18 to 0.40)	-
Non-dominant eyes	0.21±0.11(0.18 to 0.40)	-
CNVA(LogRAD)		0.08±0.14(-0.18 to 0.10)
Dominant eyes	0.08±0.04(-0.10 to 0.10)	-
Non-dominant eyes	0.08±0.09(-0.10 to 0.10)	-
Spherical equivalent(D)		-
Dominant eyes	-0.05±0.23(-1.00 to 0.75)	-
Non-dominant eyes	-1.34±1.67(-0.75 to -2.75)	-
Astigmatism(D)		-
Dominant eyes	-0.18±0.15(-0.75 to 0.00)	-
Non-dominant eyes	-0.27±0.12(-1.00 to 0.25)	-

All values are presented as mean ± standard deviation (range); UDVA=Uncorrected Distance Visual Acuity; CDVA: Corrected Distance Visual Acuity; UNVA=Uncorrected Near Visual Acuity; DCNVA=Distance Corrected Near Visual Acuity, represents distance corrected without spectacle near addition; CNVA=Corrected Near Visual Acuity, represents distance corrected with spectacle near addition for best near visual acuity; D=Diopter

Table 3.Zernike coefficients of preoperative and postoperative aberrations in iTrace (analyzed diameter=5mm)

	Pre-operation	Post-operation	*P
Ocular			
tHOA	0.249 ± 0.047	0.334 ± 0.037	0.000
SA	0.105 ± 0.032	0.200 ± 0.041	0.000
Coma	0.091 ± 0.047	0.098 ± 0.028	0.37
Second Astigmatism	0.035 ± 0.014	0.041 ± 0.014	0.82
Trefoil	0.082 ± 0.051	0.092 ± 0.038	0.36
Conea			
tHOA	0.169 ± 0.051	0.255 ± 0.046	0.000
SA	0.035 ± 0.026	0.132 ± 0.056	0.000
Coma	0.084 ± 0.035	0.091 ± 0.054	0.76
Second Astigmatism	0.035 ± 0.029	0.041 ± 0.031	0.74
Trefoil	0.083 ± 0.048	0.079 ± 0.041	0.85
Internal			
tHOA	0.127 ± 0.044	0.129 ± 0.033	0.73
SA	0.026 ± 0.041	0.028 ± 0.028	0.91
Coma	0.076 ± 0.040	0.076 ± 0.032	0.78
Second Astigmatism	0.042 ± 0.031	0.045 ± 0.025	0.93
Trefoil	0.071 ± 0.026	0.064 ± 0.006	0.95

All values are presented as mean ± standard deviation; tHOA=total higher order aberration, SA=spherical aberration; *P value less than 0.05 was considered statistically significant using paired student's t tests.

Table4. Minus-lens–stimulated accommodative amplitude

Groups(Age,Y)	Preoperative (D)	Postoperative (D)	P*value
Pre-op	Pre-op	Post-3y	
41-45(n=22)	4.26±0.27(2.75 to 4.50)	4.59±0.30(3.75 to 4.50)	0.32
46-50(n=27)	3.50±0.16(0.75 to 3.75)	4.33±0.20(0.75 to 4.75)	0.01
>50(n=5)	1.79±0.97(0 to 2.00)	2.50±0.85(0.50 to 3.00)	0.00
Total(n=54)	4.42±1.26(0 to 4.50)	4.91±1.43(0.50 to 4.75)	0.02

All values are presented as mean ± standard deviation (range); Y=Years old; D=Diopters*P value less than 0.05 was considered statistically significant using paired student's t tests.

Table5: Postoperative Patient Satisfaction Scores

Scale	Preoperative	Postoperative	P*
Near vision	44±20(0 to 50)	90±5(80 to 100)	0.00
Distance vision	49±17(0 to 50)	90±3(80 to 100)	0.00
Intermediate vision	65±14(0 to 80)	91±6(80 to 100)	0.06
Night vision	80±5(60 to 100)	87±6(70 to 100)	0.32
Dependence on glasses	0	94±6(80 to 100)	0.00
Satisfaction with correction	37±14(0 to 50)	93±6(80 to 100)	0.00

Questionnaire included scales ranging from 0 to 100, where 0 indicated not at all satisfied and 100 indicated completely satisfied. *P value less than 0.05 was considered statistically significant using paired student's t tests; All values are presented as mean ± standard deviation (range)

Figures

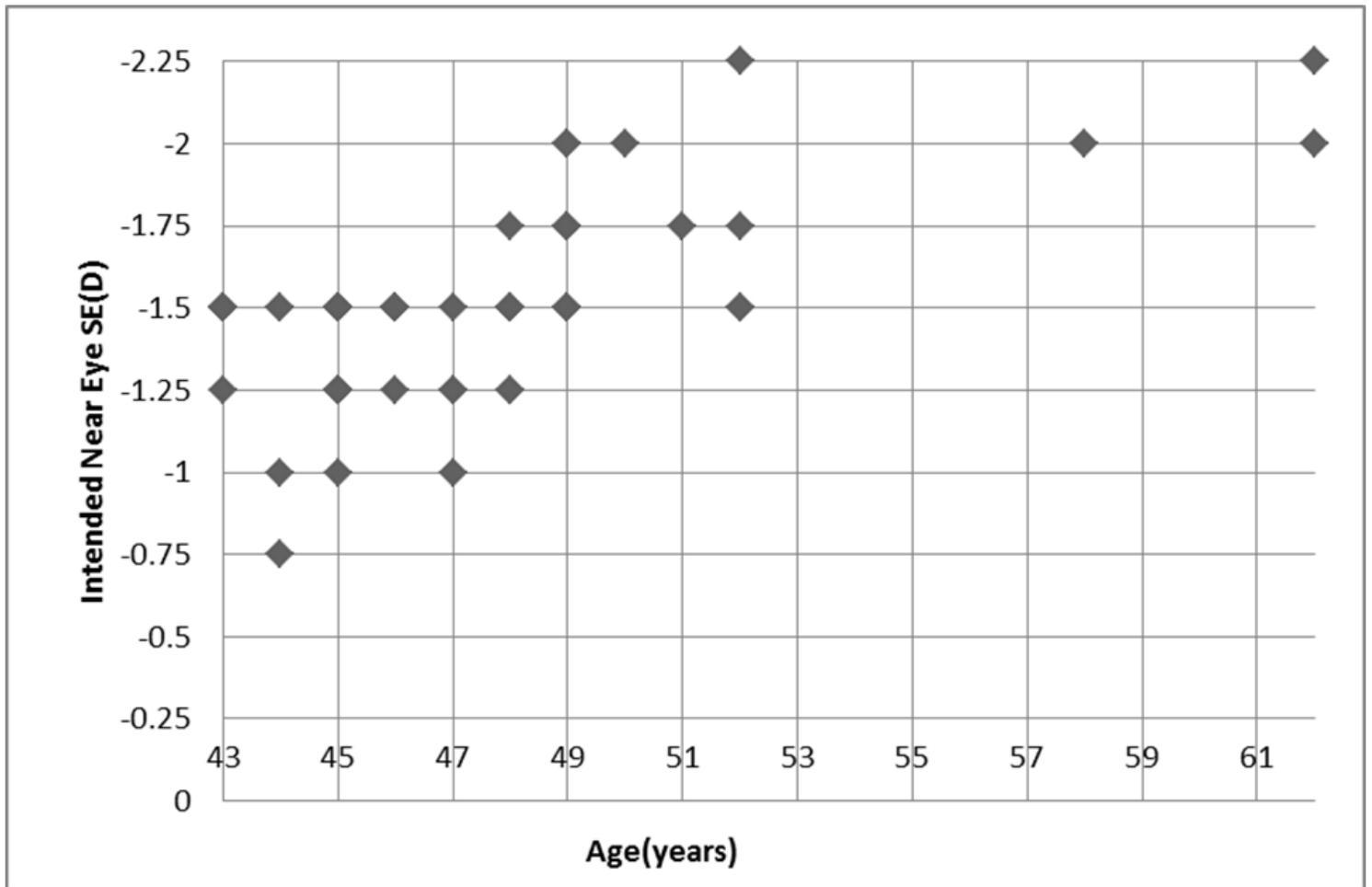


Figure 1

The scatterplot shows the distribution of intended spherical equivalent (SE) refraction in the near eye plotted against the patient's age. D: Diopter

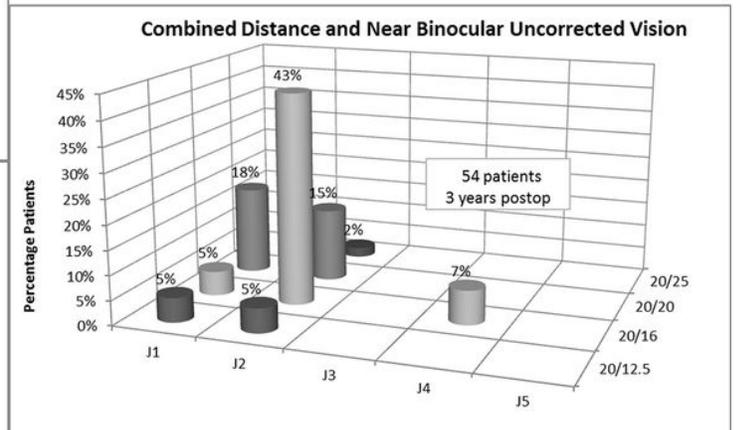
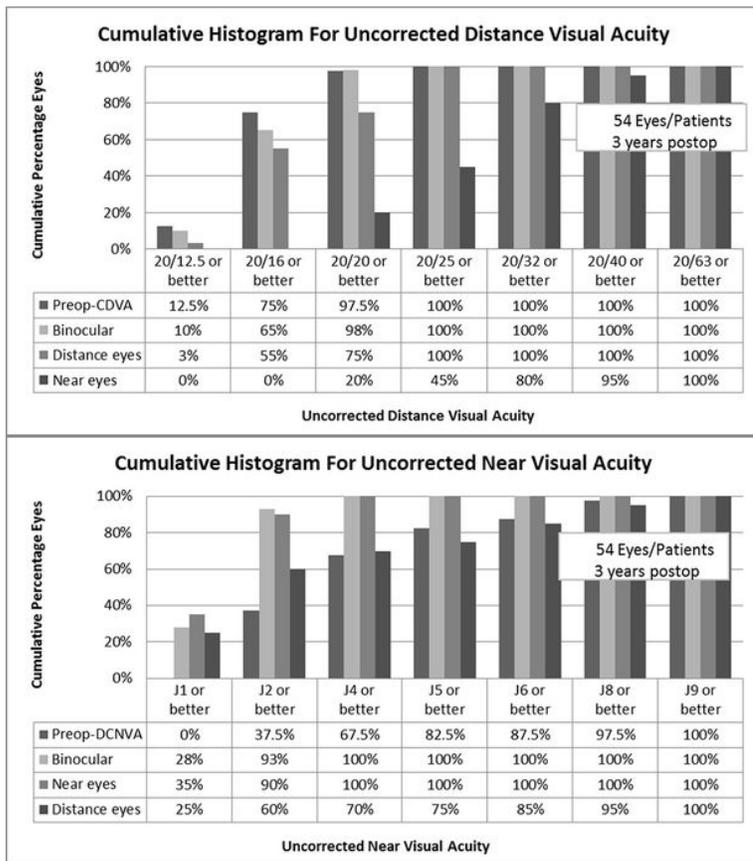


Figure 2

Changes in binocular uncorrected visual acuity at 3 years after treatment with aspheric micro-monovision LASIK. Preop-CDVA = preoperative corrected distance visual acuity; Preop-DCNVA = preoperative distance corrected near visual acuity.

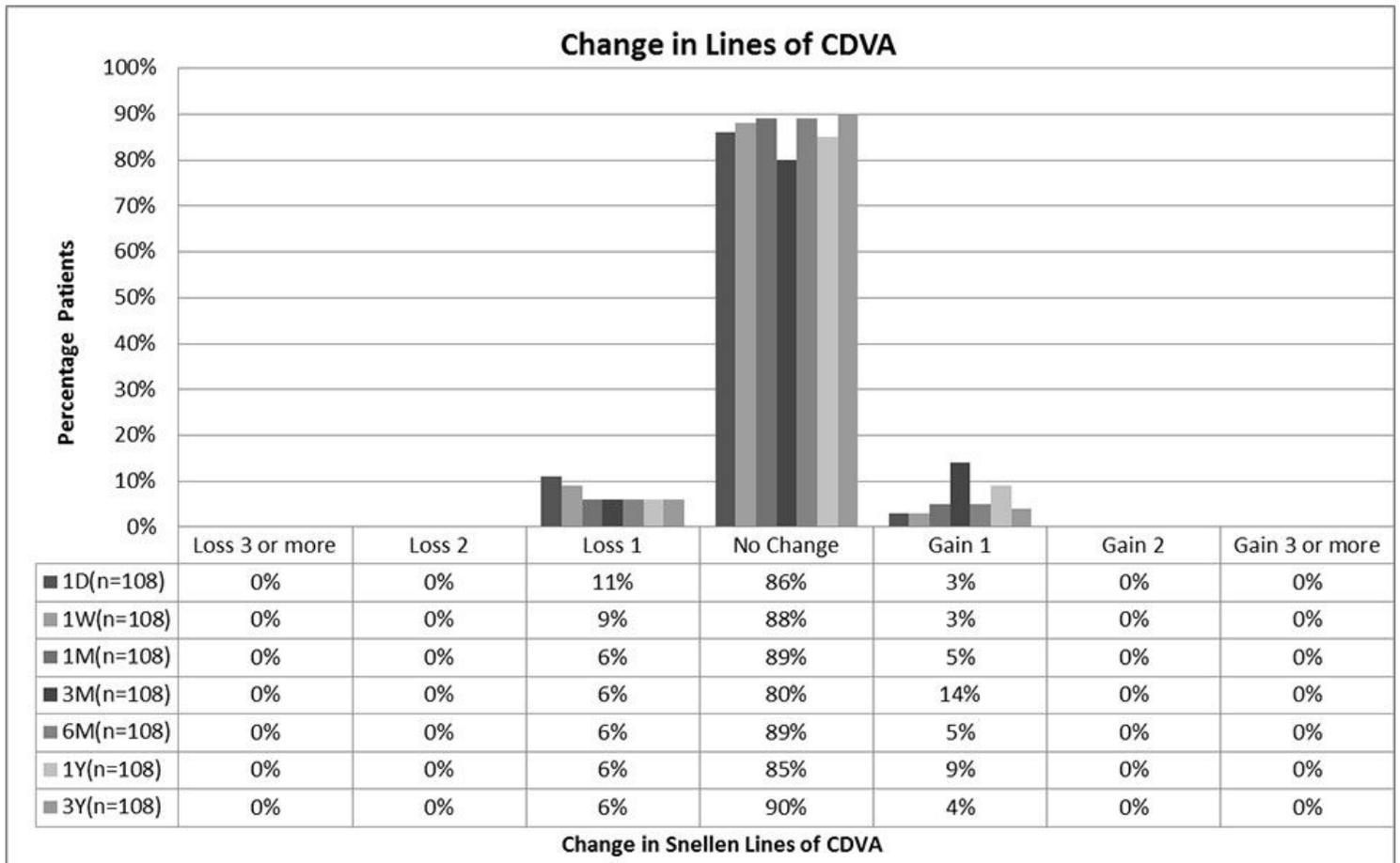


Figure 3

Changes in lines of corrected distance visual acuity (CDVA) at 3 years after treatment with aspheric micro-monovision LASIK. D, W, M, and Y represent days, weeks, months, and years, respectively.

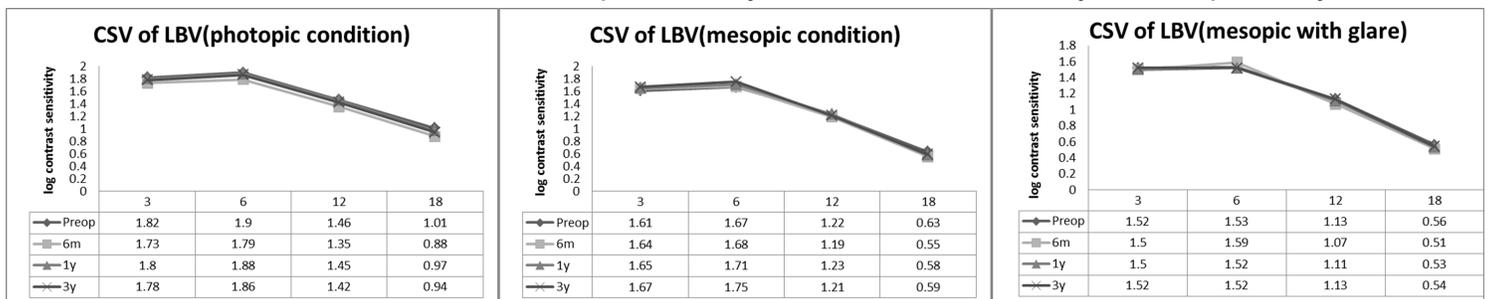


Figure 4

The preoperative and postoperative contrast sensitivity visual acuity (CSV). Preop=preoperative contrast sensitivity, m and y represent months and years, respectively.

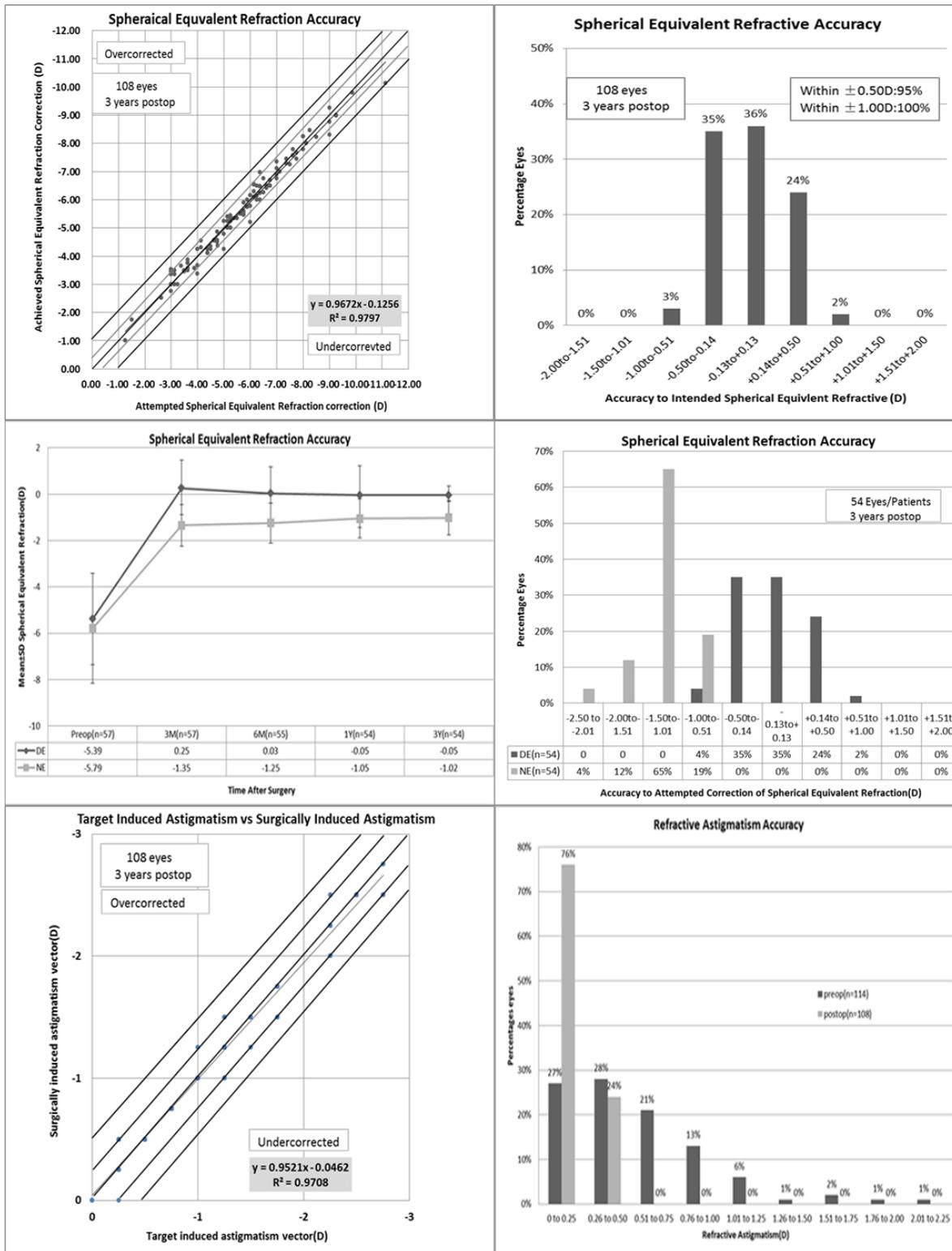


Figure 5

Refractive outcomes of patients. W, M, and Y represent weeks, months, and years, respectively. D in 1D (middle left) represents day, and in other figures, D = diopter. DE: distance eyes, NE: near eyes.

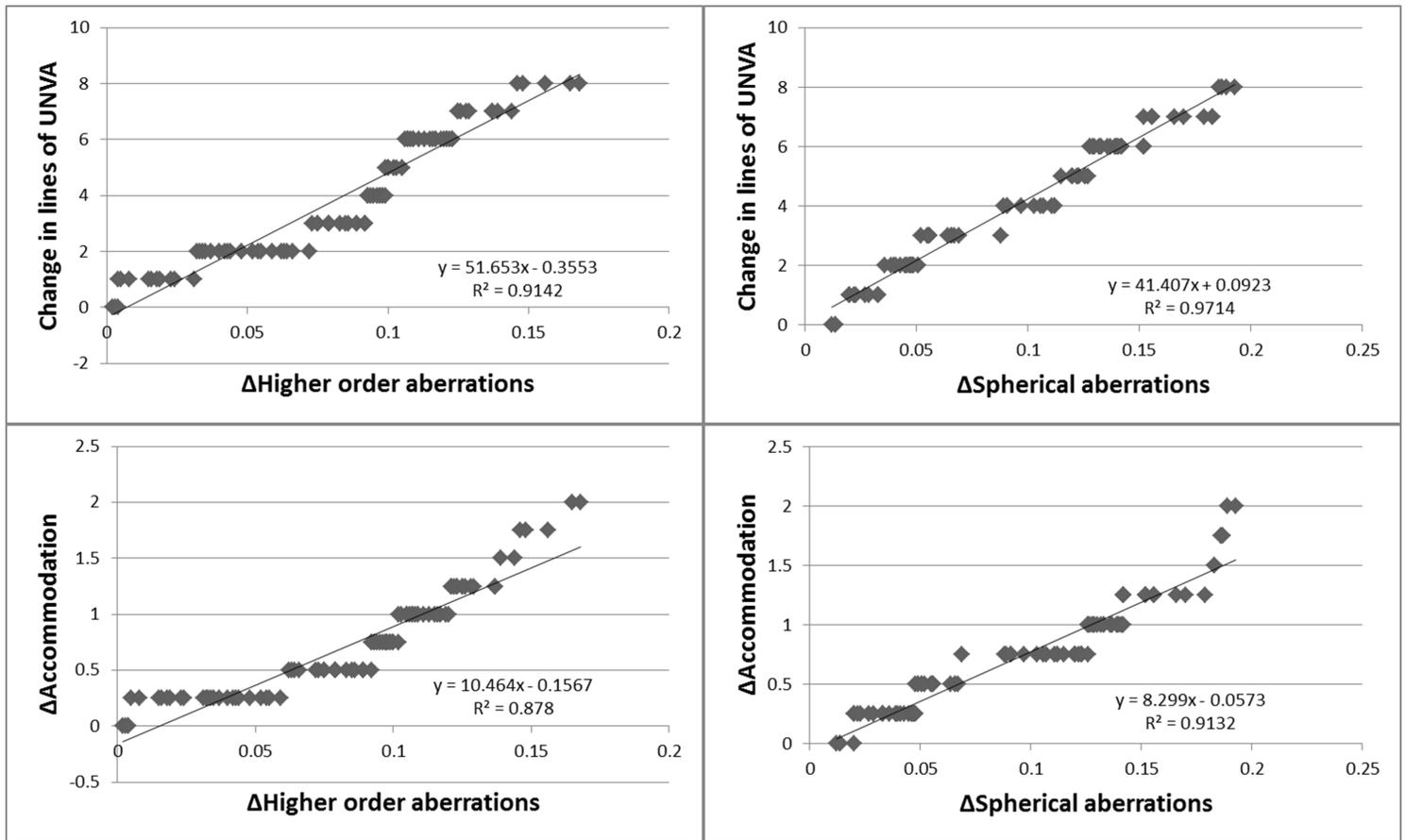


Figure 6

Linear regression plots show the relationship between change in lines of uncorrected near visual acuity (UNVA) and change in higher order aberrations and spherical aberrations. Δ Higher order aberrations means the magnitude of the higher order aberration change from pre- to postoperation. Δ Spherical aberrations means the magnitude of the spherical aberration change from pre- to postoperation. Δ Accommodation means the magnitude of the accommodation change from pre- to postoperation.

Supplementary Files

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