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Early changes in peripheral retinal defocus after corneal refractive surgery in adults with myopia and their relationship with axial length in a retrospective cohort study

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Abstract

Background

Serial data on early peripheral refractive changes after corneal refractive surgery in adults are limited. This study characterized preoperative peripheral retinal defocus, its early postoperative remodeling after small-incision lenticule extraction (SMILE) and femtosecond laser-assisted in situ keratomileusis (FS-LASIK), and its relationship with short-term axial length changes.

Methods

This single-center retrospective cohort study included 185 patients (185 eyes): 92 underwent FS-LASIK and 93 underwent SMILE. One eligible eye per patient was randomly selected. Eyes were classified as high or low-to-moderate myopia by preoperative spherical equivalent. Peripheral refraction was measured using multispectral refraction topography (MRT), including total, nasal, temporal, and eccentricity-based refraction difference values, before surgery and at postoperative week 1 and months 1 and 3. Axial length was measured at each visit. Analyses included paired-samples t tests, mixed-design repeated-measures analysis of variance, Spearman correlation, and hierarchical multiple linear regression. Change scores were calculated from week 1 to month 3.

Results

Preoperatively, relative hyperopic defocus increased with retinal eccentricity ($P < 0.001$), with nasotemporal asymmetry. The mean nasotemporal pattern differed by myopia level; among eccentricity-based measures, only the 15°–30° zone differed between groups ($P = 0.008$). At month 3, all peripheral defocus parameters were higher than preoperatively (all $P < 0.001$), with mean increases of 0.196–0.380 D. From week 1 to month 3, all defocus parameters showed significant time effects (all $P < 0.05$), without significant time-by-procedure interactions. Mean axial length increased by 0.031 mm ($P < 0.001$). Changes in peripheral defocus were not significantly associated with axial length changes in correlation or multivariable regression analyses.

Conclusions

Adults with myopia showed eccentricity-dependent peripheral defocus and nasotemporal asymmetry before surgery. Peripheral defocus shifted toward greater relative hyperopia at 3 months and continued to remodel during early recovery, with similar trajectories after SMILE and FS-LASIK. Peripheral defocus changes were not associated with short-term axial length changes.

Background

Myopia is highly prevalent worldwide. Experimental studies have shown that peripheral retinal defocus can influence axial eye growth and central refractive development [1, 2]. Relative peripheral refraction (RPR) describes the refractive difference between the central and peripheral retina. Peripheral hyperopic defocus has been associated with axial elongation, whereas peripheral myopic defocus may reduce the stimulus for myopia progression [3, 4]. Optical strategies based on peripheral defocus, including orthokeratology and multifocal or defocus soft contact lenses, are widely used for myopia control in children and adolescents [5].

Multispectral refraction topography (MRT) provides a two-dimensional assessment of peripheral refraction over a wide retinal field [6]. Central and peripheral measurements obtained with MRT have shown good repeatability and agreement [7]. The technique has been used to characterize peripheral refraction in different myopic populations and after refractive surgery [8–11]. In a recent longitudinal MRT study, greater orthokeratology-induced myopic shifts in selected peripheral regions were associated with less axial elongation over 1 year [3].

Most RPR studies have focused on children and adolescents. Serial data on early peripheral refractive changes after corneal refractive surgery in adults are limited [8, 10, 12, 13]. Small-incision lenticule extraction (SMILE) and femtosecond laser-assisted in situ keratomileusis (FS-LASIK) correct central refractive error and can also change peripheral refraction [8, 12, 13]. Previous studies have often compared preoperative measurements with a single postoperative time point, leaving the early postoperative course less well defined [8, 10, 12]. The relationship between peripheral refraction and axial length (AL) in adults also remains incompletely understood [10, 14]. In particular, whether early postoperative changes in peripheral refraction are associated with concurrent short-term AL changes remains unclear. MRT reports refraction difference values (RDVs); positive values indicate relative hyperopic defocus and negative values indicate relative myopic defocus [7]. In this study, we used MRT to assess peripheral refraction before surgery and at 1 week, 1 month, and 3 months after SMILE or FS-LASIK. We evaluated both the net change from the preoperative state to 3 months and the serial postoperative trajectory from week 1 to month 3, and examined the relationship between regional RDV changes and short-term AL changes.

Methods

Participants

This single-center retrospective cohort study included consecutive adults with myopia who underwent corneal refractive surgery at the Refractive Surgery Center of Xi'an People's Hospital (Xi'an Fourth Hospital) between April and November 2025. A total of 185 patients were included. When both eyes met the eligibility criteria, one eye was randomly selected, giving 185 study eyes.

This study was approved by the Ethics Committee of Xi'an People's Hospital (approval No. KJLL-Z-K-2023001) and was conducted in accordance with the Declaration of Helsinki. The requirement for

informed consent was waived by the Ethics Committee because of the retrospective nature of the study.

Inclusion criteria were: (1) age 18–40 years; (2) best-corrected visual acuity (BCVA) of 1.0 or better; (3) spherical equivalent (SE) from − 9.50 to − 0.50 D and cylinder ≤ 2.00 D; and (4) corneal biomechanical and tomographic findings suitable for corneal refractive surgery.

Exclusion criteria were: (1) poor MRT image quality or measurement confidence < 90% [11]; (2) an inadequate contact lens washout period (soft spherical lenses < 1 week, soft toric or rigid gas-permeable lenses < 3 weeks, or orthokeratology lenses < 3 months) [15], or previous use of orthokeratology or multifocal soft contact lenses; (3) previous ocular surgery; (4) keratoconus, severe dry eye, glaucoma, uveitis, retinal degeneration, or other relevant ocular disease; and (5) incomplete follow-up or missing scheduled examinations.

Eyes were grouped by surgical procedure (SMILE or FS-LASIK). Based on preoperative cycloplegic SE, eyes were also classified as high myopia (HM; SE ≤ -6.00 D) or low-to-moderate myopia (LM; -6.00 D < SE ≤ -0.50 D).

Examinations

All participants were examined 1 day before surgery and at 1 week, 1 month, and 3 months after surgery. All measurements were performed by the same technician.

Peripheral refraction was measured with a multispectral refraction topographer (MSIC2000, Shengda Tongze, Shenzhen, China) under dark-room conditions without pharmacologic pupil dilation. MRT-derived refraction difference values (RDVs) included the total refraction difference value (TRDV), nasal RDV (RDV-N), temporal RDV (RDV-T), and three concentric 15° zones centered on the fovea: RDV15 (0°–15°), RDV30 (15°–30°), and RDV45 (30°–45°). For consistency with the software output used in this study, these three zones are referred to as RDV15, RDV30, and RDV45 throughout the manuscript (Fig. 1).

Axial length (AL), anterior chamber depth (ACD), and lens thickness (LT) were measured with an optical biometer (IOLMaster 700, Carl Zeiss Meditec AG, Jena, Germany). After cycloplegia, objective and subjective refraction were performed using an autorefractor (ARK-1, NIDEK, Japan) and a phoropter (RT-5100, NIDEK, Japan). SE was calculated as sphere + 0.5 × cylinder. Flat and steep keratometry (K1 and K2) were measured with a Pentacam anterior segment analyzer (Oculus, Germany). Mean keratometry (Mean K) was calculated as (K1 + K2)/2.

Surgical Procedures

All procedures were performed by the same surgeon. The surgical procedure was selected based on the preoperative evaluation and patient preference. SMILE was performed with the VisuMax femtosecond laser system (Carl Zeiss Meditec, Germany). For FS-LASIK, the corneal flap was created with the

VisuMax femtosecond laser, followed by stromal ablation with the STAR S4-IR excimer laser system (Johnson & Johnson Vision, USA).

Outcomes

Peripheral refraction parameters (TRDV, RDV-N, RDV-T, RDV15, RDV30, and RDV45) and AL were assessed at each study visit. Preoperative and 3-month RDV values were directly compared to evaluate the overall postoperative shift relative to the preoperative state. Postoperative week 1 was used as the reference time point for change-score analyses. Changes were calculated as ΔRDV = RDV at 3 months − RDV at 1 week and ΔAL = AL at 3 months − AL at 1 week. This reference point was chosen to avoid using the immediate postoperative period in the change-score analysis.

Statistical Analysis

Statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Normally distributed continuous variables are presented as mean ± standard deviation (SD). Between-group comparisons were performed with the independent-samples t test, with Welch's t test used when the assumption of equal variance was violated. When the assumption of normality was violated, between-group comparisons were performed with the Mann-Whitney U test. Preoperative and 3-month postoperative peripheral RDV values were compared using paired-samples t tests. Categorical variables were compared with the chi-square test. Preoperative differences among RDV15, RDV30, and RDV45 were assessed using one-way repeated-measures analysis of variance, with Greenhouse-Geisser correction when the sphericity assumption was violated and Bonferroni-adjusted pairwise comparisons as appropriate.

Postoperative longitudinal changes were assessed with mixed-design repeated-measures analysis of variance, with time as the within-subject factor and surgical procedure as the between-subject factor. The Greenhouse-Geisser correction was used when the sphericity assumption was violated. Bonferroni-adjusted pairwise comparisons were used for post hoc analyses. Spearman rank correlation was used to assess the relationship between ΔAL and changes in peripheral RDV parameters.

Hierarchical multiple linear regression was performed with ΔAL as the dependent variable. The base model included age, sex, preoperative SE, preoperative AL, Mean K, and surgical procedure. Three models were then examined: an overall-defocus model with ΔTRDV, a direction-based model with ΔRDV-N and ΔRDV-T, and an eccentricity-based model with ΔRDV15, ΔRDV30, and ΔRDV45. Variance inflation factors (VIFs) were used to assess multicollinearity. Complete cases were used for regression analyses. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

The study included 185 patients (185 eyes), with 92 eyes in the FS-LASIK group and 93 in the SMILE group. The groups differed in age, sex distribution, preoperative SE, AL, K1, K2, and the proportion of high myopia (all $P < 0.01$). Patients in the FS-LASIK group were older and had greater preoperative myopia, longer baseline AL, steeper keratometry, and a higher proportion of high myopia. Men accounted for a larger proportion of the SMILE group than of the FS-LASIK group (66.7% vs 42.4%, $P < 0.001$). ACD and LT did not differ between groups (both $P > 0.05$) (Table 1).

Table 1
Baseline characteristics.

Characteristic	FS-LASIK (n = 92)	SMILE (n = 93)	Statistic (t/ χ^2)	P value	Effect size
Age, years	26.01 ± 7.18	22.37 ± 6.74	3.561	< 0.001	0.524
SE, D	-6.56 ± 1.85	-4.81 ± 1.50	-7.068	< 0.001	-1.039
AL, mm	26.22 ± 1.04	25.62 ± 0.89	4.232	< 0.001	0.622
K1, D	42.67 ± 1.25	42.18 ± 1.26	2.632	0.009	0.389
K2, D	44.10 ± 1.31	43.54 ± 1.34	2.856	0.005	0.422
ACD, mm	3.76 ± 0.27	3.72 ± 0.26	1.082	0.281	0.159
LT, mm	3.56 ± 0.27	3.49 ± 0.25	1.840	0.067	0.271
Myopia group, n (%)			39.303	< 0.001	--
High myopia (HM)	63 (68.5%)	21 (22.6%)			
Low-to-moderate myopia (LM)	29 (31.5%)	72 (77.4%)			
Sex, n (%)			10.994	< 0.001	--
Male	39 (42.4%)	62 (66.7%)			
Female	53 (57.6%)	31 (33.3%)			

Data are presented as mean ± SD or n (%). Continuous variables were compared with independent-samples t tests, and categorical variables with chi-square tests.

Preoperative Spatial Distribution of Peripheral Retinal Defocus

Before surgery, peripheral hyperopic defocus increased with retinal eccentricity. The eccentricity effect was significant ($F = 234.148$, $P < 0.001$), with RDV45 > RDV30 > RDV15. All pairwise comparisons among the three eccentricity-based RDV parameters were significant (all $P < 0.001$). Mean nasal RDV was also higher than mean temporal RDV in the overall cohort, showing a nasotemporal asymmetry.

After stratification by preoperative SE, the LM group had a higher mean nasal than temporal RDV, whereas the HM group showed the opposite mean pattern. RDV-N and RDV-T both differed between the HM and LM groups (RDV-N: t = -2.271, P = 0.024; RDV-T: t = 3.423, P = 0.001). Among the eccentricity-based measures, only RDV30 differed between groups (t = 2.663, P = 0.008), with greater hyperopic defocus in the HM group. TRDV, RDV15, and RDV45 were similar between HM and LM (all P > 0.05) (Tables 2 and 3).

Table 2
Preoperative peripheral RDV across eccentricities.

Parameter	Mean ± SD	Within-subject effect	Adjusted P value
RDV15	-0.051 ± 0.044	F = 234.148	< 0.001
RDV30	0.020 ± 0.079		
RDV45	0.141 ± 0.172		
Mauchly's test: W = 0.210, P < 0.001; Greenhouse-Geisser correction, ε = 0.559. All pairwise comparisons among RDV15, RDV30, and RDV45 were significant at P < 0.001. Partial η^2 = 0.560.			

Table 3
Preoperative peripheral defocus parameters in the HM and LM groups.

Parameter	HM (n = 84), mean ± SD	LM (n = 101), mean ± SD	t/t'	P value
TRDV‡	0.117 ± 0.304	0.009 ± 0.482	1.817	0.071
RDV-T	0.238 ± 0.518	-0.036 ± 0.561	3.423	0.001
RDV-N	0.038 ± 0.572	0.259 ± 0.722	-2.271	0.024
RDV15	-0.049 ± 0.035	-0.053 ± 0.050	0.481	0.631
RDV30	0.037 ± 0.069	0.006 ± 0.084	2.663	0.008
RDV45‡	0.151 ± 0.138	0.133 ± 0.195	0.715	0.475
Independent-samples t tests were used for between-group comparisons. ‡For TRDV and RDV45, variance was unequal by Levene's test; Welch's t test with Satterthwaite-adjusted degrees of freedom was used.				

Changes in Peripheral Defocus and Axial Length After Surgery

To evaluate the overall postoperative change in peripheral refraction, preoperative RDV values were compared with those at month 3. All RDV parameters were significantly higher at month 3 than preoperatively (all P < 0.001), with mean increases ranging from 0.196 to 0.380 D. Notably, mean RDV15 shifted from a negative preoperative value to a positive value at month 3, indicating a group-level shift

from relative myopic to relative hyperopic defocus. Overall, peripheral refraction showed a significant shift toward greater relative hyperopic defocus at 3 months (Table 4).

Table 4
Comparison of peripheral RDV parameters before surgery and at postoperative month 3

Parameter	Preoperative, mean ± SD	Month 3, mean ± SD	Mean paired difference	95% CI	t	P value
TRDV	0.059 ± 0.424	0.353 ± 0.251	0.295	0.235 to 0.354	9.827	< 0.001
RDV-N	0.159 ± 0.666	0.499 ± 0.339	0.340	0.245 to 0.435	7.050	< 0.001
RDV-T	0.088 ± 0.558	0.468 ± 0.365	0.380	0.294 to 0.467	8.677	< 0.001
RDV15	−0.051 ± 0.044	0.145 ± 0.099	0.196	0.182 to 0.209	28.630	< 0.001
RDV30	0.020 ± 0.079	0.230 ± 0.116	0.210	0.197 to 0.223	31.038	< 0.001
RDV45	0.141 ± 0.172	0.361 ± 0.173	0.220	0.206 to 0.233	32.515	< 0.001

Data are presented as mean ± SD. Mean paired difference = value at postoperative month 3 − preoperative value. Paired-samples t tests were used.

We next examined the serial postoperative trajectory from week 1 to month 3. Mixed-design repeated-measures analysis showed significant time effects for all peripheral RDV parameters (all $P < 0.05$). Overall, RDV showed a further shift toward greater hyperopic defocus by month 3, although several parameters showed a small fluctuation at month 1.

RDV-T, RDV-N, RDV15, and RDV30 showed significant main effects of surgical procedure (all $P < 0.05$), whereas TRDV and RDV45 did not. No RDV parameter showed a significant time-by-procedure interaction (all $P > 0.05$), indicating similar early postoperative trajectories in the FS-LASIK and SMILE groups (Table 5).

Table 5
Peripheral RDV and axial length at 1 week, 1 month, and 3 months after surgery.

Parameter	Time	FS-LASIK (n = 92)	SMILE (n = 93)	Overall (N = 185)	Time P	Procedure P	Interaction P
RDV-T	1W	0.502 ± 0.894	0.036 ± 1.111	0.267 ± 1.033	< 0.001	0.001	0.067
	1M	0.308 ± 0.859	0.173 ± 0.874	0.240 ± 0.866			
	3M	0.552 ± 0.297	0.385 ± 0.407	0.468 ± 0.365			
RDV-N	1W	0.130 ± 0.694	0.407 ± 0.686	0.269 ± 0.702	< 0.001	< 0.001	0.145
	1M	0.280 ± 0.634	0.530 ± 0.655	0.406 ± 0.655			
	3M	0.455 ± 0.297	0.543 ± 0.372	0.499 ± 0.339			
TRDV	1W	0.242 ± 0.515	0.176 ± 0.505	0.209 ± 0.510	< 0.001	0.373	0.746
	1M	0.230 ± 0.416	0.215 ± 0.414	0.222 ± 0.414			
	3M	0.371 ± 0.210	0.336 ± 0.286	0.353 ± 0.251			
RDV15	1W	0.037 ± 0.081	-0.002 ± 0.077	0.017 ± 0.081	< 0.001	< 0.001	0.549
	1M	0.063 ± 0.092	0.013 ± 0.086	0.038 ± 0.092			
	3M	0.161 ± 0.093	0.128 ± 0.102	0.145 ± 0.099			
RDV30	1W	0.131 ± 0.117	0.085 ± 0.129	0.108 ± 0.125	< 0.001	< 0.001	0.773
	1M	0.153 ± 0.118	0.095 ± 0.118	0.124 ± 0.121			
	3M	0.254 ± 0.113	0.207 ± 0.115	0.230 ± 0.116			
RDV45	1W	0.303 ± 0.228	0.286 ± 0.240	0.294 ± 0.234	< 0.001	0.274	0.682

Mixed-design repeated-measures analysis of variance was used. P values for time effects were Greenhouse-Geisser corrected. Interaction P values refer to the corrected time-by-procedure term.

Parameter	Time	FS-LASIK (n = 92)	SMILE (n = 93)	Overall (N = 185)	Time P	Procedure P	Interaction P
	1M	0.295 ± 0.196	0.264 ± 0.236	0.279 ± 0.217			
	3M	0.381 ± 0.159	0.341 ± 0.184	0.361 ± 0.173			
AL, mm	1W	26.089 ± 1.028	25.525 ± 0.834	25.805 ± 0.975	< 0.001	< 0.001	0.158
	1M	26.114 ± 1.037	25.544 ± 0.833	25.828 ± 0.980			
	3M	26.110 ± 1.036	25.565 ± 0.842	25.836 ± 0.980			

Mixed-design repeated-measures analysis of variance was used. P values for time effects were Greenhouse-Geisser corrected. Interaction P values refer to the corrected time-by-procedure term.

AL also showed a significant time effect (F = 11.240, P < 0.001). Mean AL increased from 25.805 ± 0.975 mm at week 1 to 25.828 ± 0.980 mm at month 1 and 25.836 ± 0.980 mm at month 3. Bonferroni-adjusted comparisons showed greater AL at months 1 and 3 than at week 1 (both P < 0.001), with no difference between months 1 and 3 (P = 0.274). The mean increase from week 1 to month 3 was 0.031 mm. The time-by-procedure interaction was not significant (P = 0.158) (Tables 5 and 6).

Table 6
Between-procedure comparison of changes from postoperative week 1 to month 3.

Change variable	FS-LASIK mean rank (n = 92)	SMILE mean rank (n = 93)	Z	Two-sided P
ΔAL	88.29	97.66	-1.192	0.233
ΔTRDV	91.10	94.88	0.481	0.631
ΔRDV-T	85.62	100.30	1.865	0.062
ΔRDV-N	98.94	87.12	-1.501	0.133
ΔRDV15	91.29	94.69	0.433	0.665
ΔRDV30	93.01	92.99	-0.001	0.999
ΔRDV45	96.22	89.81	-0.814	0.416

Δ = value at 3 months - value at 1 week. Between-procedure comparisons used the Mann-Whitney U test; α = 0.05.

Association Between Peripheral Defocus Changes and Short-Term Axial Length Changes

Spearman rank correlation showed no significant relationship between ΔAL and ΔTRDV, ΔRDV-N, ΔRDV-T, ΔRDV15, ΔRDV30, or ΔRDV45 (ρ = 0.033–0.121, all P > 0.05). Hierarchical multiple linear regression was then performed with ΔAL as the dependent variable. Two eyes had missing covariate data, leaving 183 eyes for the multivariable analyses.

Adding ΔTRDV to the overall-defocus model did not improve model fit (ΔR^2 = 0.003, F change = 0.571, P = 0.451), and ΔTRDV was not independently associated with ΔAL (β = 0.056, P = 0.451). Adding ΔRDV-T and ΔRDV-N to the direction-based model also did not improve model fit (ΔR^2 = 0.008, F change = 0.686, P = 0.505); neither variable was independently associated with ΔAL (P = 0.602 and 0.327, respectively). In the eccentricity-based model, ΔRDV15, ΔRDV30, and ΔRDV45 did not improve model fit (ΔR^2 = 0.007, F change = 0.424, P = 0.736), and none was independently associated with ΔAL (all P > 0.05). All VIFs were < 5, with no evidence of serious multicollinearity (Table 7).

Table 7
Multivariable linear regression of peripheral defocus changes and ΔAL.

Model	Variable	B	SE	β	95% CI	P value	VIF
Overall-defocus model	ΔTRDV	0.009	0.012	0.056	-0.014 to 0.032	0.451	1.007
Direction-based model	ΔRDV-T	0.003	0.006	0.040	-0.009 to 0.015	0.602	1.067
	ΔRDV-N	0.008	0.009	0.075	-0.009 to 0.025	0.327	1.057
Eccentricity-based model	ΔRDV15	0.082	0.091	0.106	-0.097 to 0.262	0.365	2.466
	ΔRDV30	-0.055	0.093	-0.085	-0.238 to 0.128	0.555	3.724
	ΔRDV45	0.032	0.045	0.073	-0.056 to 0.120	0.477	1.873

Regression analyses included 183 eyes because 2 cases had missing covariate data. All models adjusted for age, sex, preoperative SE, preoperative AL, Mean K, and surgical procedure. The overall-defocus model additionally included ΔTRDV; the direction-based model included ΔRDV-T and ΔRDV-N; and the eccentricity-based model included ΔRDV15, ΔRDV30, and ΔRDV45.

Discussion

Before surgery, peripheral refraction showed a clear eccentricity-dependent pattern, with greater hyperopic defocus at larger retinal eccentricities. Mean nasal and temporal RDV values were also asymmetric. Similar peripheral refractive patterns have been reported in adults with myopia [16–19]. The HM group showed the opposite mean nasotemporal pattern to the LM group, and RDV30 was the only eccentricity-based measure that differed between the two myopia groups. Differences in refractive status and posterior eye shape in high myopia may contribute to this spatial pattern [17].

A key finding of this study was that peripheral refraction at 3 months showed a significant shift toward greater relative hyperopic defocus compared with the preoperative state. Serial measurements from postoperative week 1 to month 3 further demonstrated significant time-dependent remodeling across all RDV parameters, indicating continued peripheral refractive remodeling during early recovery. These findings suggest that the peripheral optical profile does not stabilize immediately after corneal refractive surgery but continues to evolve over the first several months.

The direction of the preoperative-to-3-month change in our cohort differs from that reported in several previous studies. Du et al. [8] reported reduced relative hyperopic defocus at 3 months after SMILE using MRT, while Zhang et al. [13] reported a similar postoperative shift using a modified wide-field Shack-Hartmann aberrometer. More recently, Qu et al. [20] reported reduced peripheral hyperopic defocus after keratorefractive lenticule extraction (KLEx) and found that RDV changes were associated with central corneal cutting thickness and percent tissue altered. Differences in baseline ocular characteristics, surgical design parameters, retinal zone definitions, and measurement methods may partly account for these divergent findings. In particular, the present study included both SMILE and FS-LASIK and used three concentric MRT zones of 0°-15°, 15°-30°, and 30°-45°, limiting direct comparison with studies using different procedures, eccentricity ranges, or measurement systems.

The overall preoperative-to-3-month hyperopic shift and continued postoperative RDV remodeling may be related to corneal reshaping and postoperative tissue remodeling. Corneal refractive surgery alters central corneal power and the central-peripheral refractive gradient, while epithelial remodeling, stromal healing, corneal asphericity, and higher-order aberrations may continue to evolve for several months [21–24]. The RDV pattern observed in our cohort may therefore reflect continued reconstruction of the central-peripheral optical relationship rather than a stable optical state established immediately after surgery.

Although several RDV parameters differed in their overall levels between FS-LASIK and SMILE, no significant time-by-procedure interactions were observed, indicating broadly similar postoperative trajectories. Both procedures reshape the central cornea and undergo subsequent corneal remodeling despite their different surgical approaches [21, 23]. Because baseline characteristics differed substantially between the two groups, procedure-related main effects should be interpreted cautiously.

Mean AL increased by 0.031 mm from postoperative week 1 to month 3, with most of the change occurring during the first postoperative month. In contrast, peripheral RDV continued to remodel throughout the 3-month period, suggesting that the two processes did not follow closely matched temporal patterns. Neither Spearman correlation nor multivariable regression showed a significant association between ΔAL and overall, directional, or eccentricity-based ΔRDV measures. Although experimental and pediatric studies support a role of peripheral defocus in ocular growth regulation [25, 26], longitudinal evidence in adults remains limited [14, 27]. The lack of association in the present study may reflect lower defocus sensitivity in adult eyes, different time scales of optical and structural change, and the small magnitude of short-term AL variation. Moreover, short-term AL changes after refractive

surgery may be influenced by biometric measurement factors and should not be interpreted as direct evidence of true ocular growth.

This study has several limitations. First, follow-up was limited to 3 months, precluding assessment of the longer-term stability of postoperative peripheral refraction. Second, the retrospective design and baseline differences between the surgical groups may have resulted in residual confounding despite statistical adjustment. Third, detailed surgical design parameters, such as optical zone diameter and tissue removal, were not incorporated into the present analyses; corneal Q value, anterior and posterior corneal shape, and higher-order aberrations were also not directly assessed. These factors may be relevant to both the observed postoperative RDV changes and the differences from previous studies. Prospective studies with larger samples, longer follow-up, and integrated assessment of surgical parameters, corneal morphology, wavefront aberrations, and ocular biometry are warranted.

Conclusions

Adults with myopia showed an eccentricity-dependent pattern and nasotemporal asymmetry in peripheral retinal defocus before surgery, with different nasotemporal patterns between high and low-to-moderate myopia. At 3 months, peripheral RDV was significantly shifted toward greater relative hyperopic defocus compared with the preoperative state and continued to show time-dependent remodeling during the early postoperative period, with broadly similar trajectories after SMILE and FS-LASIK. AL increased slightly, mainly during the first postoperative month, but its short-term change was not associated with overall, nasotemporal, or eccentricity-based RDV changes.

Abbreviations

ACD
anterior chamber depth
AL
axial length
BCVA
best-corrected visual acuity
CI
confidence interval
FS-LASIK
femtosecond laser-assisted in situ keratomileusis
HM
high myopia
K1
flat keratometry
K2
steep keratometry

KLEx
keratorefractive lenticule extraction
LM
low-to-moderate myopia
LT
lens thickness
Mean K
mean keratometry
MRT
multispectral refraction topography
RDV
refraction difference value
RDV-N
nasal refraction difference value
RDV-T
temporal refraction difference value
RDV15
refraction difference value within 0°–15°
RDV30
refraction difference value within 15°–30°
RDV45
refraction difference value within 30°–45°
RPR
relative peripheral refraction
SD
standard deviation
SE
spherical equivalent
SMILE
small-incision lenticule extraction
TRDV
total refraction difference value
VIF
variance inflation factor.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Xi'an People's Hospital (approval No. KJLL-Z-K-2023001) and was conducted in accordance with the Declaration of Helsinki. The requirement for

informed consent was waived by the Ethics Committee because of the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

J.H. and Y.F. conceived the study, collected clinical data, performed statistical analysis, drafted and revised the manuscript. Y.Z., R.L., R.L. and Y.Z. assisted with data collection, case screening, and table preparation. X.W. helped with literature sorting and preliminary data sorting. Y.L. (Yong Li) participated in result interpretation and manuscript revision. S.W. contributed to study design and provided statistical methodology guidance. J.L. supervised the whole project, interpreted the data, and critically revised the manuscript. All authors reviewed and approved the final version of the manuscript.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to patient privacy restrictions but are available from the corresponding author on reasonable request.

References

1. Benavente-Perez A, Nour A, Troilo D. Axial eye growth and refractive error development can be modified by exposing the peripheral retina to relative myopic or hyperopic defocus. Invest Ophthalmol Vis Sci. 2014;55:6765–73. 10.1167/iovs.14-14524.

2. Smith EL, Hung LF, Huang J. Relative peripheral hyperopic defocus alters central refractive development in infant monkeys. Vis Res. 2009;49:2386–92. 10.1016/j.visres.2009.07.011.
3. Wen K, Wu Y, Yang B, Liu L. Novel quantitative analysis of relative peripheral refraction changes in orthokeratology and their relationship with one-year axial elongation. Photodiagnosis Photodyn Ther. 2025;55:104739. 10.1016/j.pdpdt.2025.104739.
4. Smith EL, Hung LF, Arumugam B. Visual regulation of refractive development: insights from animal studies. Eye (Lond). 2014;28:180–8. 10.1038/eye.2013.277.
5. Erdinest N, London N, Lavy I, Berkow D, Landau D, Morad Y, et al. Peripheral defocus and myopia management: a mini-review. Korean J Ophthalmol. 2023;37:70–81. 10.3341/kjo.2022.0125.
6. Li Z, Yang Z, Liao Y, Zhan Z, Zeng R, Zhang Y, et al. Relative peripheral refraction characteristics and their relationship with retinal microvasculature in young adults: using a novel quantitative approach. Photodiagnosis Photodyn Ther. 2022;38:102750. 10.1016/j.pdpdt.2022.102750.
7. Lu W, Ji R, Ding W, Tian Y, Long K, Guo Z, et al. Agreement and repeatability of central and peripheral refraction by one novel multispectral-based refractor. Front Med (Lausanne). 2021;8:777685. 10.3389/fmed.2021.777685.
8. Du Y, Zhou Y, Ding M, Zhang M, Guo Y. Changes in relative peripheral refraction and optical quality in Chinese myopic patients after small-incision lenticule extraction surgery. PLoS ONE. 2023;18:e0291681. 10.1371/journal.pone.0291681.
9. Bao T, Qin L, Hou G, Jiang H, Wang L, Wang Y, et al. Association between peripheral retinal defocus and myopia by multispectral refraction topography in Chinese children. Clin Ophthalmol. 2024;18:517–23. 10.2147/OPTH.S450224.
10. Li Y, Yang C, Mei B, Su D, Yue Y, Zhou YH. Analysis of the impact of FS-LASIK on peripheral retinal defocus and its influencing factors in myopic adults. Eye (Lond). 2026;40:341–7. 10.1038/s41433-025-04154-w.
11. Tong YT, Du YQ, Ge SS, Chen L, Ma XQ, Guo YJ, et al. Relative peripheral refractive errors in Chinese children with myopic anisometropia. Int J Ophthalmol. 2024;17:2074–81. 10.18240/ijo.2024.11.14.
12. Lin Z, Lu Y, Artal P, Yang Z, Lan W. Two-dimensional peripheral refraction and image quality for four types of refractive surgeries. J Refract Surg. 2023;39:40–7. 10.3928/1081597X-20221115-01.
13. Zhang L, Wang Y, Zhao X, Cui T. Peripheral refraction and aberrations in myopic eyes after small-incision lenticule extraction (SMILE) surgery. Sci Rep. 2025;15:6524. 10.1038/s41598-025-90181-2.
14. Koomson NY, Kobia-Acquah E, Abdul-Kabir M, Aderonke UM, Kwaw RJ, Arkhurst EE. Relationship between peripheral refraction, axial lengths and parental myopia of young adult myopes. J Optom. 2022;15:122–8. 10.1016/j.optom.2020.10.007.
15. Expert Work Group of Expert Consensus on Preoperative Refraction and Simulation of Monocular Vision for Laser Vision Correction in China. (2023), Division of Refractive Surgery Branch of Ophthalmology, China National Health Association. Expert consensus on preoperative refraction and simulation of monocular vision for laser vision correction in China (2023). Chin J Exp Ophthalmol. 2023;41:1145–1151. 10.3760/cma.j.cn115989-20230809-00064. [In Chinese].

16. Atchison DA, Pritchard N, Schmid KL. Peripheral refraction along the horizontal and vertical visual fields in myopia. Vis Res. 2006;46:1450–8. 10.1016/j.visres.2005.10.023.
17. Verkicharla PK, Mathur A, Mallen EA, Pope JM, Atchison DA. Eye shape and retinal shape, and their relation to peripheral refraction. Ophthalmic Physiol Opt. 2012;32:184–99. 10.1111/j.1475-1313.2012.00906.x.
18. Wu Q, Zhang X, Tian Q, Feng J, Guo X, Liu Y, et al. Analysis of the peripheral refraction in myopic adults using a novel multispectral refraction topography. Heliyon. 2024;10:e36020. 10.1016/j.heliyon.2024.e36020.
19. Du Y, Zhang M, Zhou Y, Liang S, Tong Y, Ma X. Observations on relative peripheral refraction in Chinese adults with myopia based on a novel application of multispectral refraction topography. Sci Rep. 2024;14:25854. 10.1038/s41598-024-77289-7.
20. Qu S, Tian H, Yang X, Chen Q, Song F, Bai S, et al. Influence of design parameters on peripheral defocus after keratorefractive lenticule extraction. Sci Rep. 2026;16:31242. 10.1038/s41598-026-60744-y.
21. Chen P, Hou X, Yu N, Ye Y, Wei H, Zhuang J, et al. Corneal epithelial remodeling following cylinder correction with SMILE or FS-LASIK: a contralateral comparative study. J Refract Surg. 2024;40:e728–41. 10.3928/1081597X-20240826-04.
22. Xu M, Yang F, Pazo EE, Li Q, Yang Z, Huang Y, et al. Effects of corneal epithelial remodeling on corneal asphericity after FS-LASIK and Trans-PRK: a prospective study. Indian J Ophthalmol. 2025;73:134–40. 10.4103/IJO.IJO_623_24.
23. Yang X, Niu J, Wu H, Song S, Zhou Y. Within-cohort associations between corneal epithelial remodeling and anterior corneal higher-order aberrations after FS-LASIK and keratorefractive lenticule extraction (KLEx; SMILE): a two-cohort descriptive study. Sci Rep. 2026;16:12656. 10.1038/s41598-026-40156-8.
24. Zhu M, Xin Y, Vinciguerra R, Wang Z, Warsame AM, Wang C, et al. Corneal epithelial remodeling in a 6-month follow-up period in myopic corneal refractive surgeries. J Refract Surg. 2023;39:187–96. 10.3928/1081597X-20230113-02.
25. Smith EL, Kee CS, Ramamirtham R, Qiao-Grider Y, Hung LF. Peripheral vision can influence eye growth and refractive development in infant monkeys. Invest Ophthalmol Vis Sci. 2005;46:3965–72. 10.1167/iovs.05-0445.
26. Leighton RE, Breslin KM, Richardson P, Doyle L, McCullough SJ, Saunders KJ. Relative peripheral hyperopia leads to greater short-term axial length growth in White children with myopia. Ophthalmic Physiol Opt. 2023;43:985–96. 10.1111/opo.13185.
27. Hartwig A, Charman WN, Radhakrishnan H. Baseline peripheral refractive error and changes in axial refraction during one year in a young adult population. J Optom. 2016;9:32–9. 10.1016/j.optom.2015.06.001.

Figures

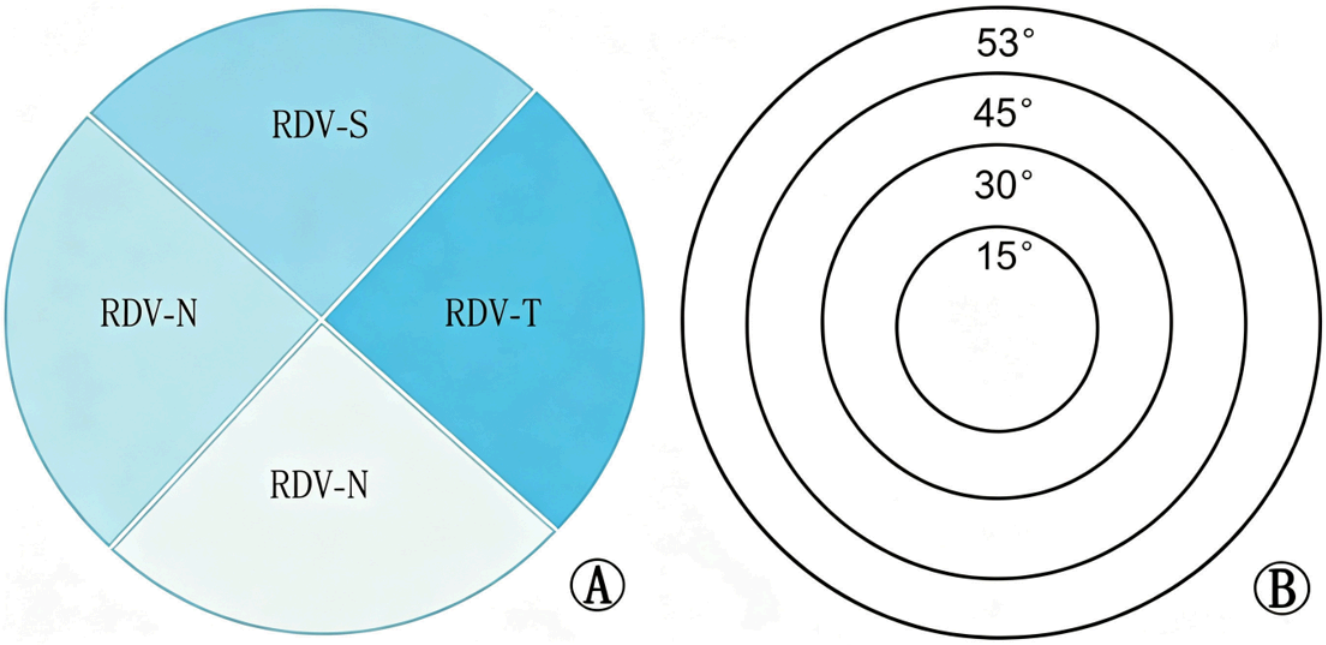


Figure 1

Retinal zones used for peripheral defocus analysis. Representative multispectral refraction topography output showing the three 15° concentric zones: RDV15 (0°–15°), RDV30 (15°–30°), and RDV45 (30°–45°).