


Comparison of Refractive Outcomes and Visual Quality Between Topography-Guided LASIK and Small Incision Lenticule Extraction: A 6-Month Prospective Study

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Purpose: To compare the postoperative refractive outcomes and visual quality between topography-guided laser in situ keratomileusis (TG-LASIK) and small incision lenticule extraction (SMILE) over a 6-month follow-up.

Patients and Methods: This study included 100 eyes of 50 patients, 50 eyes received TG-LASIK and 50 underwent SMILE. The outcomes measured included uncorrected distance visual acuity (UDVA), spherical equivalent (SEQ), cylinder, contrast sensitivity, and objective visual quality including objective scattering index (OSI), modulation transfer function (MTF) cutoff and Strehl Ratio (SR).

Results: Baseline characteristics differed between groups, with the SMILE group being younger and demonstrating better preoperative UDVA and lower cylinder. At 6 months, 98% of TG-LASIK eyes and 100% of SMILE eyes achieved UDVA of 0.0 logMAR or better, with no significant difference between groups ($P = 0.315$). A significantly higher percentage of eyes in the TG-LASIK group achieved SEQ within ± 0.25 D (58% vs 36%, $P = 0.028$) and ± 0.50 D (88% vs 64%, $P = 0.01$). Despite treating significantly higher preoperative astigmatism, TG-LASIK achieved comparable correction accuracy to SMILE. Objective visual quality was similar between groups at 3 and 6 months; SMILE showed higher MTF cutoff at 1 month ($P = 0.027$). TG-LASIK demonstrated significantly higher contrast sensitivity at 6.0 c/d ($P < 0.001$) and 18.0 c/d ($P < 0.001$) at 6 months.

Conclusion: Both TG-LASIK and SMILE are effective and safe for myopia and astigmatism correction. TG-LASIK demonstrated higher refractive precision and better contrast sensitivity at higher spatial frequencies compared to SMILE.

Plain Language Summary: Conventional FS-LASIK and SMILE have been widely compared in previous studies. However, TG-LASIK differs from both procedures by using individualized corneal topography to guide customized ablation and is often applied in eyes with higher astigmatism or greater refractive complexity in routine practice.

Whether this customized approach provides meaningful clinical advantages over SMILE under real-world conditions remains unclear.

Both TG-LASIK and SMILE provided comparable visual acuity outcomes at 6 months after surgery. TG-LASIK achieved higher refractive precision, with a greater proportion of eyes reaching the intended spherical equivalent target. Although objective visual quality parameters were largely similar between the two groups, TG-LASIK was associated with better contrast sensitivity at higher spatial frequencies.

Keywords: topography-guided LASIK, small incision lenticule extraction, Myopia, astigmatism, contrast sensitivity, visual quality

Introduction

Over the past few decades, small incision lenticule extraction (SMILE) and femtosecond laser in situ keratomileusis (FS-LASIK) have both emerged as effective and safe procedures for the correction of refractive errors such as myopia and astigmatism.^{1–3} SMILE is a flapless, minimally invasive procedure that creates a lenticule within the corneal stroma, which is then removed through a small incision. FS-LASIK, one of the most widely performed refractive surgeries, uses a femtosecond laser to create a corneal flap, followed by reshaping of the cornea with excimer laser ablation.^{4–7}

Topography-guided LASIK (TG-LASIK) is a more recent advancement in refractive surgery, utilizing detailed corneal topographic data to customize the ablation pattern. It stands out by utilizing topographical data to direct laser reshaping of the cornea. Its principle relies on the corneal shape, as optical quality is closely linked to corneal topography. This method offers the advantage of reducing the induction of higher-order aberrations (HOAs) and improving contrast sensitivity, particularly in patients with irregular corneas or pre-existing aberrations.^{8–11} TG-LASIK has demonstrated consistent and stable visual outcomes, making it a valuable option for personalized refractive surgery.¹² Large-scale studies, such as that by Wallerstein et al involving more than 25,000 TG-LASIK eyes, have further confirmed the safety, accuracy, and refractive predictability of this platform across a wide range of myopic and astigmatic corrections.¹³

While previous studies have compared TG-LASIK and SMILE,^{2,3,14–17} most of these have focused primarily on visual acuity and refractive outcomes, with limited attention to objective optical quality measures. Contrast sensitivity, which reflects functional vision more closely than visual acuity alone, has also been inconsistently reported across studies and rarely evaluated across multiple spatial frequencies over time. Therefore, a comparative study incorporating both objective visual quality and contrast sensitivity, conducted in a Chinese population, may provide additional clinical insights. The present study aimed to compare the efficacy and safety of TG-LASIK and SMILE, including refractive outcomes, objective visual quality, and contrast sensitivity between TG-LASIK and SMILE over a 6-month follow-up period.

Materials and Methods

Subjects

This prospective, observational study was carried out at Beijing Tongren Hospital from June 2021 to May 2022. A total of 50 patients (100 eyes) were enrolled, including 25 patients (50 eyes) in the TG-LASIK group and 25 patients (50 eyes) in the SMILE group. Both eyes of each patient were included when eligible. The inclusion criteria were as follows: (1) patients aged 18 to 40 years with surgical expectations to be glasses-free; (2) spherical refractions ranging from -0.75 to -10.00 diopters (D), with or without cylinder up to -4.00 D; (3) stable refraction for more than 1 year; (4) corrected distance visual acuity (CDVA) of both eyes reaching a 0.1 logarithm of the minimum angle of resolution (logMAR); (5) cessation of wearing soft contact lenses for 1 week or rigid contact lenses for 3 weeks. Exclusion criteria included (1) a residual stromal bed less than $280\mu\text{m}$; (2) suspicion of keratoconus on corneal topography; (3) previous ocular surgery or history of herpes viral infection, uncontrolled diabetic mellitus, systemic immune diseases, pregnancy or under lactation.

The study adhered to the tenets of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Beijing Tongren Hospital, Capital Medical University (No. TERC2024-KY166). A written informed consent was obtained from each patient prior to the surgical procedure.

The primary endpoint of this study was refractive outcomes at 6 months postoperatively, including uncorrected distance visual acuity (UDVA) and spherical equivalent (SEQ). Secondary endpoints included astigmatic correction accuracy assessed by vector analysis, objective visual quality, and contrast sensitivity across five spatial frequencies at each follow-up visit. Objective visual quality was measured by Optical Quality Analysis System (OQAS, Visiometrics, Terrassa, Spain) and included the objective scattering index (OSI), modulation transfer function (MTF) cutoff, and Strehl ratio (SR).

Preoperative Assessment and Surgical Technique

All patients underwent preoperative assessment including UDVA, CDVA and manifest refraction, the slit-lamp biomicroscopy, funduscopy examinations, the Topographic Modeling System (TMS-4, Tomey Corporation, Nagoya, Aichi, Japan), a reference biometer (Lenstar LS 900, HAAG-STREIT AG, Switzerland) and corneal topography (VARIO Topolyzer, WaveLight, Alcon Laboratories, Inc., Fort Worth, TX, United States). The surgery was performed by the same experienced

surgeon to ensure consistency. TG-LASIK was performed using the WaveLight FS200 femtosecond laser (Alcon Vision, LLC, Fort Worth, TX, USA) to create the corneal flap (thickness 110 μm , diameter 8.5 mm, side-cut angle 90°, hinge angle 50°). The Wavelight EX500 excimer (Alcon Vision, LLC, Fort Worth, TX, USA) was used for ablation with an optical zone of 6–6.5 mm.

Corneal topography data were acquired with the Topolyzer VARIO system; a minimum of 8 high-quality scans were captured, and only scans meeting manufacturer quality standards (no missing data, consistent axis alignment, and minimal eyelid interference) were accepted. Ablation planning followed the Topography-Modified Refraction (TMR) protocol, which integrates manifest refraction with topography-measured astigmatism and axis to optimize alignment. Iris registration and cyclotorsion compensation were applied to ensure accurate ablation.

SMILE was performed using the VisuMax femtosecond laser system (Carl Zeiss Meditec, Oberkochen, Germany). A stromal lenticule was created with a cap thickness of 110 μm and a cap diameter of 7.0–7.5 mm. The lenticule diameter ranged from 6.0 to 6.5 mm. The laser spot and track spacing were both set to 4.5 μm , and a 2.0 mm side incision was placed at the 120° meridian for lenticule extraction.

Postoperative Care and Follow-up

Postoperative care was identical for both groups. All patients were treated with topical 0.3% levofloxacin four times daily for 2 weeks. Topical 0.1% fluorometholone was prescribed with a tapering regimen from four times daily to once daily over 30 days. In addition, 0.3% sodium hyaluronate was administered four times daily for 3 months.

Follow-up visits were scheduled at 1 day, 1 week, 1 month, 3 months, and 6 months postoperatively. During each visit, patients underwent UDVA, manifest refraction, slit-lamp examination. Contrast sensitivity and objective visual quality were assessed at 1, 3, and 6 months postoperatively. Contrast sensitivity was measured using the Functional Vision Analyzer (Vision Tester, Stereo Optical Company Inc., Chicago, IL, United States) under mesopic conditions at a calibrated target luminance of 3.0 cd/m^2 , with undilated pupils. The spatial frequencies of the stimuli were 1.5, 3.0, 6.0, 12.0, and 18.0 cycles per degree (c/d). Objective visual quality was measured by OQAS, a double-pass retinal imaging instrument that quantifies intraocular scattering and optical quality. Measurements were performed under undilated pupils. Three consecutive readings were obtained for each eye, and the mean value was used for analysis. All measurements were performed by the same experienced examiner. The MTF cutoff reflects the resolving capacity of the optical system, with higher values indicating better optical quality. The SR represents optical performance relative to an ideal system, ranging from 0 to 1, with higher values indicating better optical quality. The OSI quantifies intraocular light scatter, with lower values indicating better optical quality. Values below approximately 2.0 are generally considered within the normal range, higher values indicate increased scattering, which may be associated with corneal haze, interface irregularity, or early lens changes, and correlates with symptoms such as glare and reduced contrast sensitivity. These parameters provide complementary, instrument-based assessments of retinal image quality that are independent of subjective patient responses.

Statistical Analysis

Visual acuity values assessed were converted to the logarithm of the minimum angle of resolution (logMAR). The Shapiro–Wilk test was used for confirming normality of data. Comparisons of normally distributed variables were performed using the paired *t*-test, whereas the Wilcoxon signed-rank test was applied for variables without a normal distribution. To analyze intragroup differences during the follow-up period, repeated measures ANOVA was applied for the normally distributed data and the Friedman test was employed on the non-normally distributed data. The intergroup comparison of categorical variables was conducted using the chi-squared test. Vector analysis of astigmatism was performed according to the Alpins method, calculating Target Induced Astigmatism (TIA), Surgically Induced Astigmatism (SIA), Difference Vector (DV), Correction Index (CI = SIA/TIA), Index of Success (IOS = DV/TIA) and Angle of Error (AE).^{18,19} Data analysis was conducted using SPSS 23.0 (IBM Corp., Armonk, NY, USA) and graphs were generated using GraphPad Prism 9.4.0 (GraphPad Software, San Diego, CA, USA). A *P* value < 0.05 was considered statistically significant. When multiple comparisons were performed, a Bonferroni-adjusted significance level of $\alpha = 0.01$ was applied.

Results

Baseline Patient Data

The study enrolled 50 patients (100 eyes), comprising 25 patients (50 eyes) in the TG-LASIK group and 25 patients (50 eyes) in the SMILE group. Baseline characteristics are summarized in [Table 1](#).

The mean age was significantly higher in the TG-LASIK group compared to the SMILE group ($P = 0.003$). There were no significant differences in gender distribution between the two groups. The SMILE group demonstrated better preoperative UDVA ($P = 0.001$). Importantly, the preoperative cylinder was significantly higher in the TG-LASIK group than in the SMILE group ($P < 0.001$).

Visual and Refractive Outcomes

[Figures 1](#) and [2](#) collectively summarize postoperative refractive outcomes using standardized refractive surgery outcome graphs that demonstrate surgical efficacy, safety, predictability, stability, and astigmatic correction at 6 months postoperatively.

UDVA and CDVA: Both groups achieved excellent postoperative UDVA. At 6 months, 98% of TG-LASIK eyes and 100% of SMILE eyes achieved UDVA of 0.0 logMAR or better, with no significant difference between groups ($P = 0.315$). 88% of TG-LASIK and 96% of SMILE eyes saw the same number of lines or better of UDVA compared to preoperative CDVA. ([Figures 1A, B](#) and [2A, B](#)). 2% of eyes in the TG-LASIK group and no eyes in the SMILE group lost two or more lines of CDVA ([Figures 1C](#) and [2C](#)).

SEQ: Linear regression analysis of attempted versus achieved SEQ showed slopes of $1.06x + 0.55$ D ($R^2 = 0.97$) for TG-LASIK and $0.86x - 1.07$ D ($R^2 = 0.75$) for SMILE ([Figures 1D](#) and [2D](#)). TG-LASIK demonstrated superior refractive precision, with significantly more eyes achieving SEQ within ± 0.50 D (88% vs 64%, $P = 0.01$) at 6 months ([Figure 1E](#) and [2E](#)). Both groups showed significant changes in SEQ over time (TG-LASIK: $P = 0.001$; SMILE: $P < 0.001$). At 1 month, the TG-LASIK group had a mean SEQ of 0.02 ± 0.43 D, while the SMILE group showed -0.28 ± 0.65 D ($P = 0.007$). At 6 months, TG-LASIK maintained stable refraction at -0.15 ± 0.41 D, while SMILE demonstrated a hyperopic shift to $+0.24 \pm 0.61$ D ($P < 0.001$; [Figures 1F](#) and [2F](#)).

Table 1 Baseline Clinical Data in the Two Groups Mean \pm SD (LB, UB)

Parameter	TG-LASIK	SMILE	P value
Age (y)	28.92 \pm 4.80 (20, 37)	25.76 \pm 5.50 (17, 36)	0.003
Gender			0.185
Male	8	4	
Female	17	21	
UDVA (logMAR)	1.25 \pm 0.30 (0.10, 0.70)	1.05 \pm 0.30 (0.40, 1.52)	0.001
CDVA (logMAR)	-0.06 \pm 0.04 (-0.08, 0.10)	-0.05 \pm 0.04 (-0.08, 0)	0.931
Sphere (D)	-5.17 \pm 2.10 (-9.75, -0.75)	-5.52 \pm 1.13 (-7.50, -3.50)	0.304
Cylinder (D)	-2.00 \pm 0.87 (-3.75, -0.50)	-0.82 \pm 0.59 (-2.0, 0)	<0.001
MRSE (D)	-6.18 \pm 2.07 (-11.38, -2.38)	-5.93 \pm 1.17 (-8.0, -4.0)	0.464
K ₁ (D)	42.39 \pm 1.15 (40.31, 45.12)	42.87 \pm 1.22 (40.09, 44.80)	0.045
K ₂ (D)	44.54 \pm 1.30 (41.72, 47.60)	44.23 \pm 1.44 (40.95, 46.96)	0.274
K _m (D)	43.44 \pm 1.15 (41.20, 46.36)	43.55 \pm 1.31 (40.52, 45.88)	0.656
SRI	0.16 \pm 0.15 (0.02, 0.49)	0.13 \pm 0.12 (0.02, 0.50)	0.266
SAI	0.35 \pm 0.14 (0.15, 0.73)	0.35 \pm 0.17 (0.13, 0.85)	0.747
AL (mm)	25.90 \pm 0.98 (24.08, 27.81)	25.97 \pm 0.92 (23.96, 27.80)	0.725
WTW (mm)	12.04 \pm 0.41 (11.32, 13.35)	11.88 \pm 0.36 (11.06, 13.35)	0.054
PD (mm)	5.56 \pm 0.95 (3.55, 7.18)	5.45 \pm 0.88 (3.59, 7.22)	0.558

Abbreviations: SE, standard error of the mean; LB, lower bound; UB, upper bound; TG-LASIK, Topography-guided laser in situ keratomileusis; SMILE, small incision lenticule extraction; UDVA, uncorrected distance visual acuity; CDVA, corrected distance visual acuity; MRSE, manifest refraction spherical equivalent; K₁, flat keratometry; K₂, steep keratometry; K_m, mean keratometry; SRI, surface regularity index; SAI, surface asymmetry index; AL, axial length; CCT, cornea thickness; WTW, white to white; PD, pupil diameter.

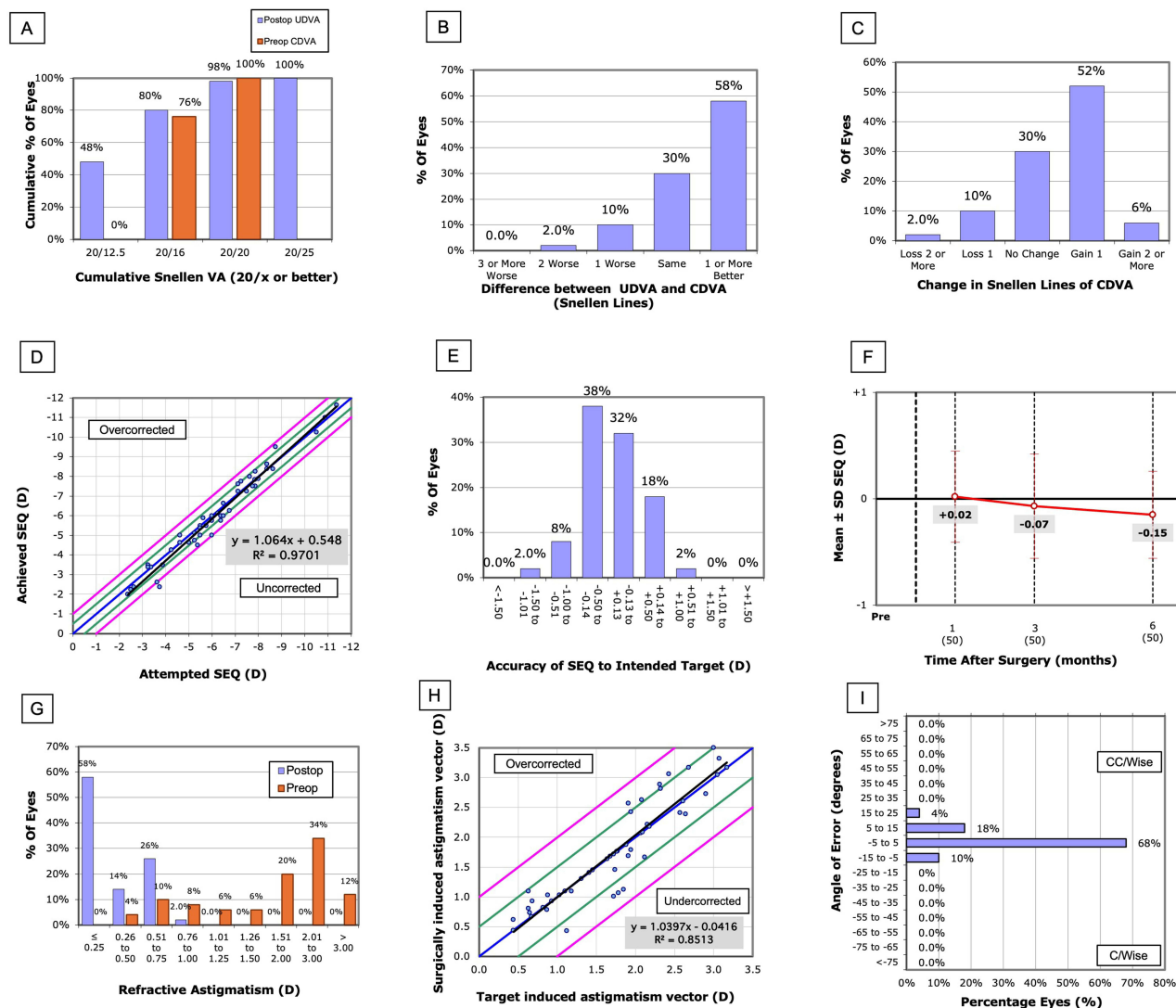


Figure 1 Standard refractive surgery outcome graphs for TG-LASIK at 6 months postoperatively (A) Cumulative uncorrected distance visual acuity (UDVA) (Snellen 20/x or better). (B) Difference between uncorrected and corrected distance visual acuity (UDVA vs CDVA). (C) Attempted versus achieved spherical equivalent refraction (SEQ). (D) Distribution of postoperative SEQ (refractive accuracy). (E) Distribution of refractive astigmatism (D). (F) Stability of SEQ over time. (G) Correlation between target-induced astigmatism (TIA) and surgically induced astigmatism (SIA). (H) Scatter plot of magnitude of error. (I) Histogram of astigmatism angle of error.

Astigmatism Correction: At 1, 3, and 6 months postoperatively, both groups showed significant improvement in cylinder compared to baseline (TG-LASIK: $P = 0.003$; SMILE: $P = 0.024$). At 6 months, 72% of TG-LASIK eyes and 84% of SMILE eyes achieved residual cylinder ≤ 0.50 D, with no significant difference between groups ($P = 0.148$; Figures 1G and 2G). There were no significant differences when comparing the two groups at each follow-up point. Linear regression analysis of TIA showed a mean regression value of $1.04x - 0.04$ D ($R^2 = 0.85$) for TG-LASIK and $0.81x + 0.14$ D ($R^2 = 0.697$) for SMILE (Figures 1H and 2H). The mean DV was 0.04 D \times 40° in the TG-LASIK group and 0.09 D \times 16° in the SMILE group. Vector analysis showed comparable correction accuracy between groups, with CI values close to 1.0 (1.03 vs 0.97, $P = 0.361$) (Figures 3 and 4). IOS was numerically lower in TG-LASIK (0.22 compared to 0.32, $P = 0.248$), as was AE (1.11° compared to 3.37° , $P = 0.433$, Figures 1I and 2I).

Objective Visual Quality

As shown in Table 2, OSI showed no difference within or between the TG-LASIK and SMILE group at 1, 3, 6 months after the surgery. OSI remained stable in both groups. For MTF cutoff, SMILE demonstrated significantly higher values

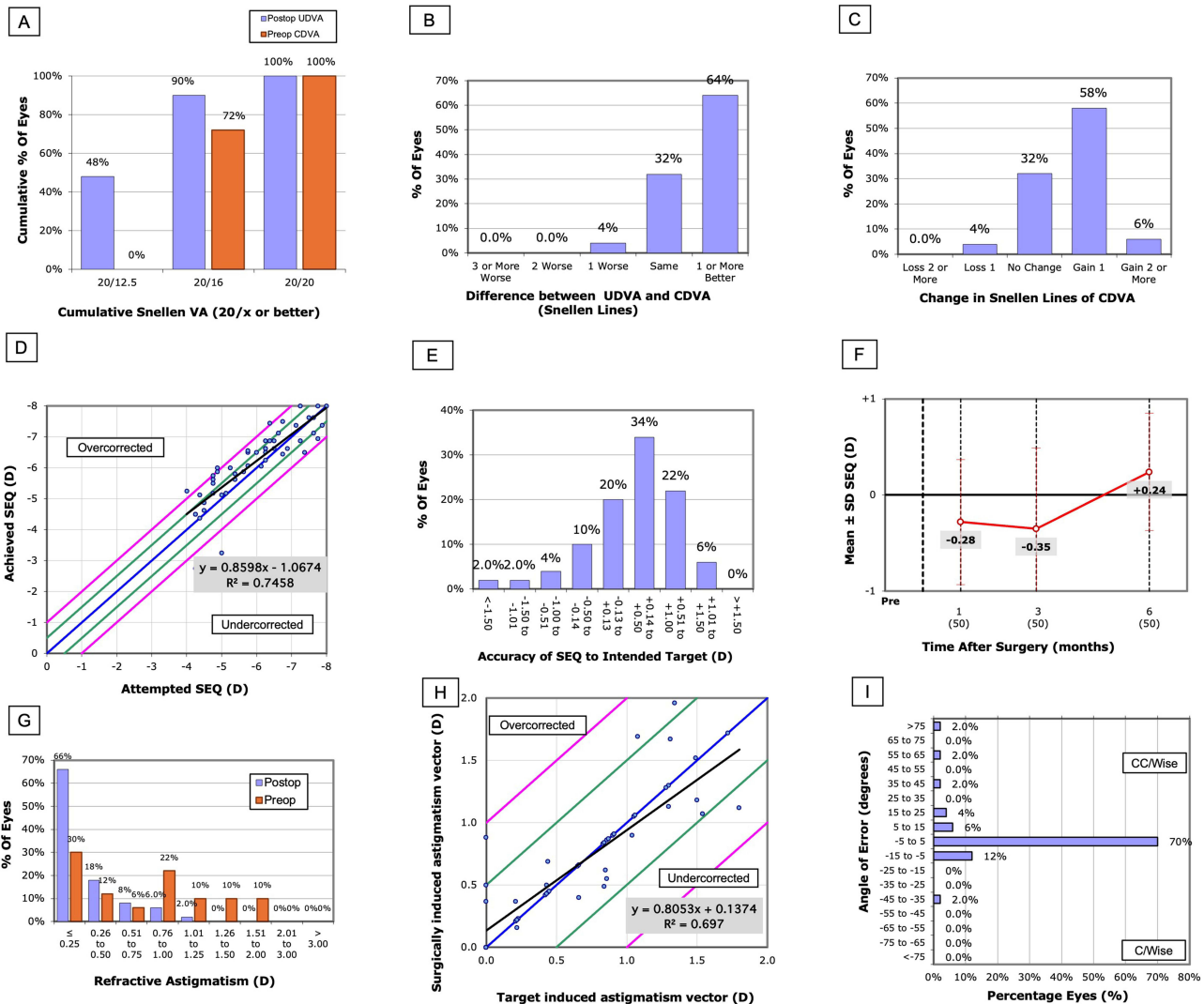


Figure 2 Standard refractive surgery outcome graphs for SMILE at 6 months postoperatively (A) Cumulative uncorrected distance visual acuity (UDVA) (Snellen 20/x or better). (B) Difference between uncorrected and corrected distance visual acuity (UDVA vs CDVA). (C) Attempted versus achieved spherical equivalent refraction (SEQ). (D) Distribution of postoperative SEQ (refractive accuracy). (E) Distribution of refractive astigmatism (D). (F) Stability of SEQ over time. (G) Correlation between target-induced astigmatism (TIA) and surgically induced astigmatism (SIA). (H) Scatter plot of magnitude of error. (I) Histogram of astigmatism angle of error. Visual acuity is presented in Snellen notation, with statistical analyses using logMAR values.

than TG-LASIK at 1 month ($P = 0.027$), but this difference was not present at 3 or 6 months, with both groups showing stable values throughout follow-up. SR showed no significant between-group difference at any time point. Within both groups, SR remained stable over the 6-month period.

Contrast Sensitivity

At the lower spatial frequency of 1.5 c/d (Figure 5A), the TG-LASIK group showed lower contrast sensitivity at baseline compared to the SMILE group. However, contrast sensitivity improved over time in the TG-LASIK group, and no significant differences were observed between the two groups at postoperative time points.

For 3.0 c/d (Figure 5B) and 12.0 c/d (Figure 5D), both groups exhibited an increase in contrast sensitivity postoperatively. The contrast sensitivity was similar between the TG-LASIK and SMILE groups across all time points, with no statistically significant differences observed.

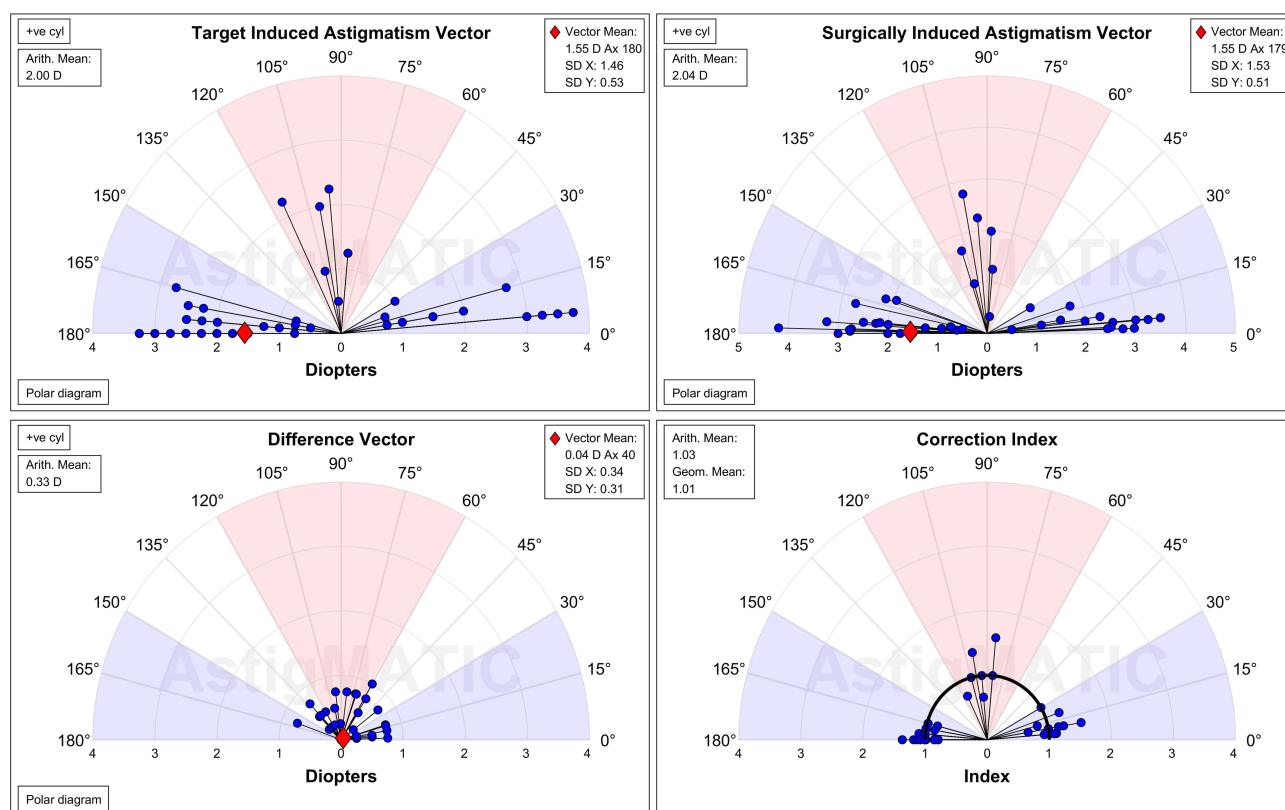


Figure 3 Vector analysis for TG-LASIK at 6 months postoperatively.

At 6.0 c/d (Figure 5C), a significant difference between the two groups was observed at the 6 months after the surgery ($P < 0.001$). TG-LASIK significantly improved from baseline by the 6-month postoperative period. The SMILE group also showed a slight increase in contrast sensitivity.

At the highest spatial frequency at 18.0 c/d (Figure 5E), the TG-LASIK group exhibited a gradual improvement in contrast sensitivity over time. The SMILE group, however, showed more variable results, with an initial improvement at 1 month followed by a slight decrease by 6 months. At 6 months after surgery, TG-LASIK and SMILE showed a significant difference in contrast sensitivity at the spatial frequency of 18 c/d (TG-LASIK: 0.81 ± 0.48 , SMILE: 0.33 ± 0.27 , $P < 0.001$). No significant differences were found at 1.5, 3.0, or 12.0 c/d at any follow-up time point. Detailed contrast sensitivity values at each spatial frequency and time point are provided in Table 3.

Discussion

This study aimed to evaluate the outcomes of TG-LASIK and SMILE surgeries in terms of visual acuity and refractive results over a 6-month postoperative period, comparing the efficacy, safety, and stability of both procedures.

It is demonstrated that both the TG-LASIK and SMILE groups achieved satisfactory visual outcomes at 6 months, with no significant differences in UDVA, which is consistent with the finding of previous studies.^{3,14–16,20,21} Zhang et al found that there were no significant differences in UDVA between the TG-LASIK and SMILE eyes and postoperative SEQ was similar between the groups at the 6-month follow-up.³ Similarly, Sitto et al similarly reported comparable UDVA between TG-LASIK and SMILE at 12 months in a prospective contralateral-eye design.¹⁴ Our results align with this in terms of UDVA, where both groups in our study achieved similar percentages of eyes with UDVA better than or equal to -0.1 logMAR and 0.0 logMAR.³ These findings suggest that both TG-LASIK and SMILE provide satisfactory visual acuity outcomes at 6 months.

Regarding refractive outcomes, our study found that a significantly higher percentage of eyes in the TG-LASIK group achieved an SEQ within 0.25 D and 0.50 D compared to the SMILE group. The findings match those observed in

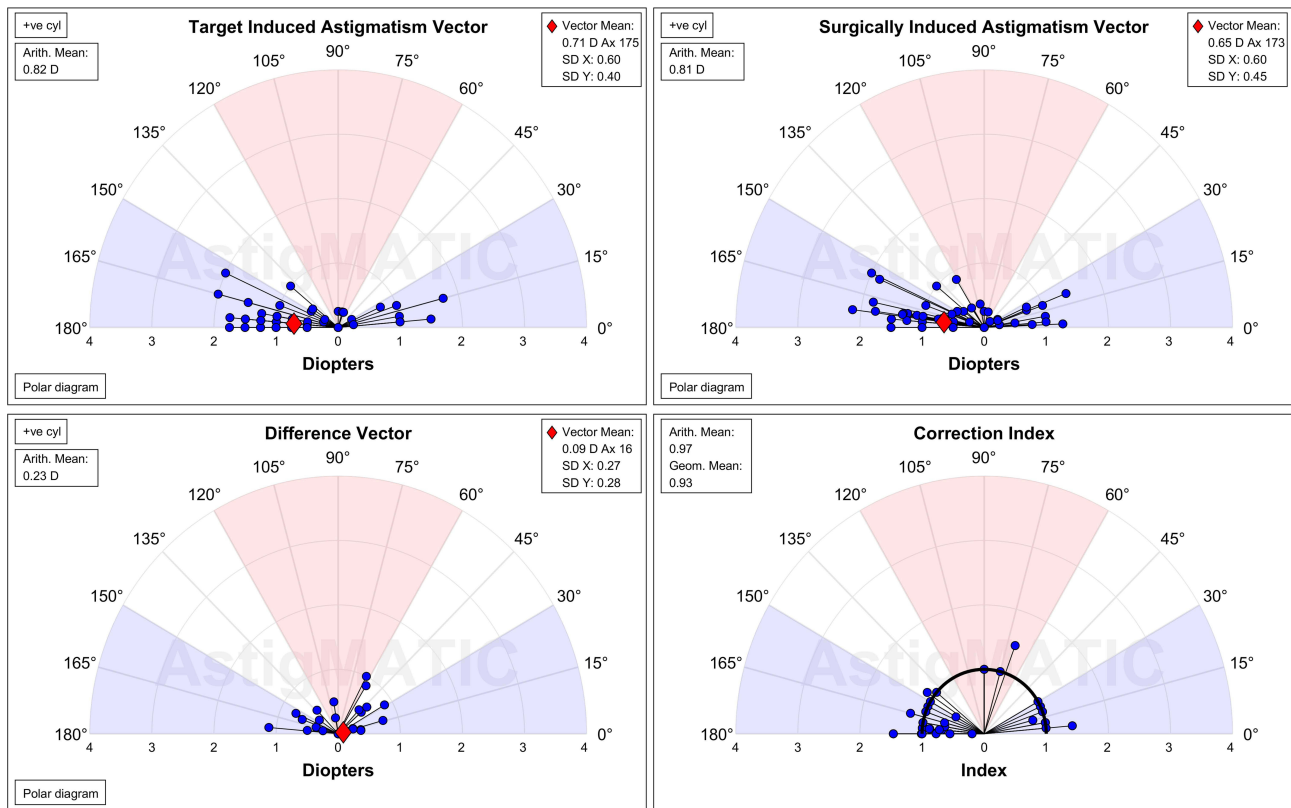


Figure 4 Vector analysis for SMILE at 6 months postoperatively.

Hidenaga Kobashi’s study. In his study, 95.5% of the LASIK group achieved SEQ within ± 0.50 D, compared to 77.3% of the SMILE group ($P < 0.05$).²⁰ Our results also demonstrated a similar trend, with 88% of TG-LASIK eyes achieving SEQ within ± 0.50 D, compared to 64% in the SMILE group, suggesting the greater refractive precision of TG-LASIK.

In terms of astigmatism correction, our study found no significant differences between TG-LASIK and SMILE in the percentage of eyes achieving cylinder ≤ 0.25 D or ≤ 0.50 D postoperatively. Vector analysis revealed that the TG-LASIK

Table 2 Postoperative Objective Visual Quality Mean \pm SD (LB, UB)

Parameter	1Month	3Month	6Month	P value
OSI				
TG-LASIK	0.91 \pm 0.60 (0.30, 2.75)	0.87 \pm 0.65 (0.25, 3.48)	0.79 \pm 0.43 (0.24, 2.38)	0.358
SMILE	0.71 \pm 0.32 (0.20, 1.58)	0.75 \pm 0.37 (0.17, 2.02)	0.73 \pm 0.48 (0.12, 2.66)	0.426
P value	0.738	0.881	0.582	
MTF Cutoff				
TG-LASIK	35.31 \pm 10.13 (14.92, 53.73)	37.73 \pm 11.18 (13.59, 53.50)	36.91 \pm 10.57 (13.70, 54.92)	0.235
SMILE	39.63 \pm 8.91 (17.45, 54.21)	37.73 \pm 9.48 (19.24, 56.14)	39.42 \pm 10.21 (16.26, 57.44)	0.472
P value	0.027	0.998	0.234	
SR				
TG-Lasik	0.19 \pm 0.05 (0.11, 0.32)	0.20 \pm 0.05 (0.09, 0.30)	0.20 \pm 0.04 (0.11, 0.29)	0.257
SMILE	0.22 \pm 0.07 (0.17, 0.38)	0.22 \pm 0.07 (0.10, 0.44)	0.22 \pm 0.06 (0.11, 0.43)	0.939
P value	0.054	0.13	0.073	

Notes: P values at each time point indicate intergroup comparisons, while the P values in the final column reflect changes over time within each group.

Abbreviations: SE, standard error of the mean; LB, lower bound; UB, upper bound; TG-LASIK, Topography-guided laser in situ keratomileusis; SMILE, small incision lenticule extraction; OSI, objective scattering index; MTF Cutoff, modulation transfer function cutoff; SR, Strehl Ratio.

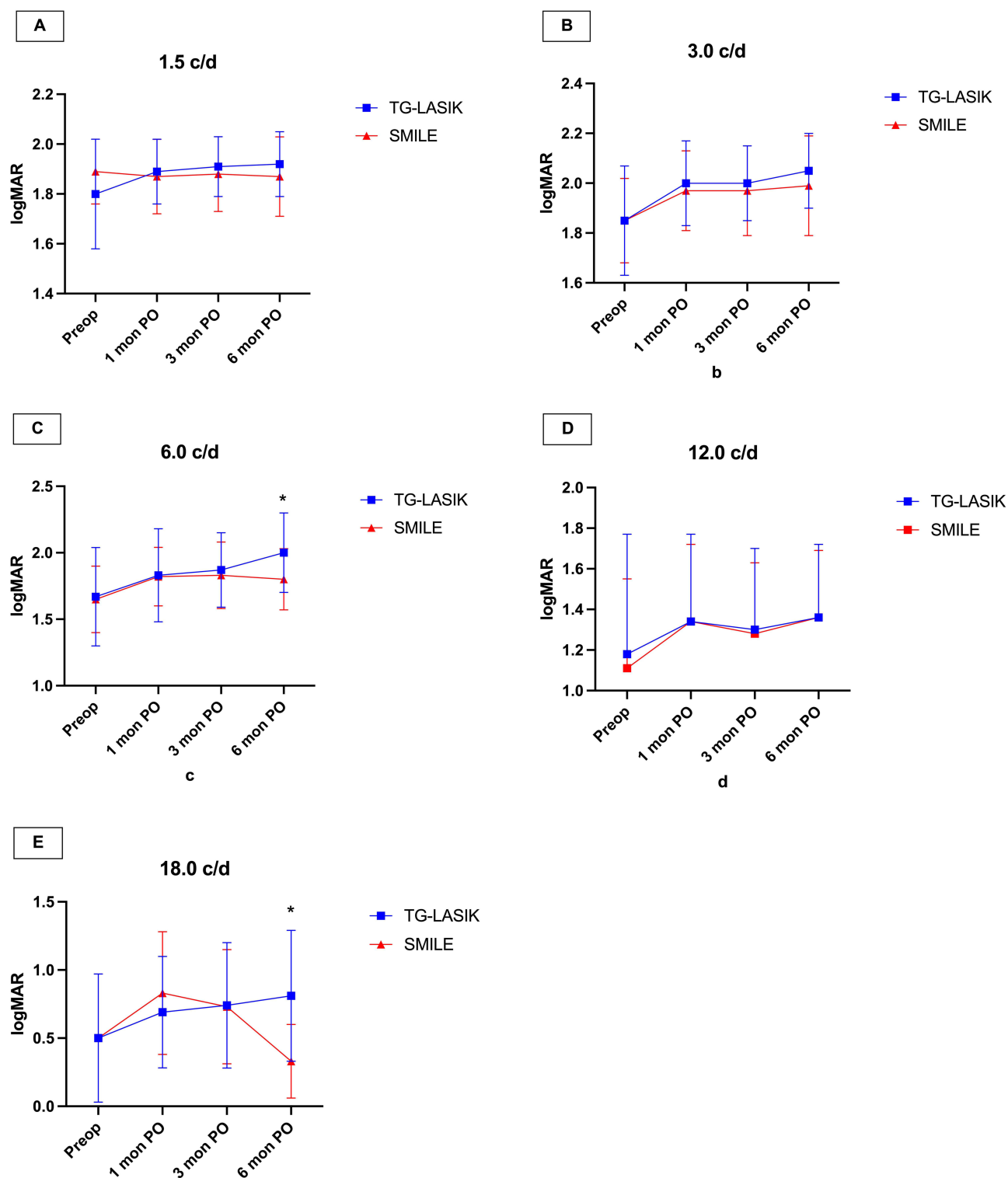


Figure 5 The Log values of contrast sensitivity at different frequencies (A) 1.5 c/d; (B) 3.0 c/d; (C) 6.0 c/d; (D) 12.0 c/d; (E) 18.0 c/d. * $P < 0.01$ indicates statistical significance.

group treated significantly higher preoperative astigmatism, reflecting the clinical practice of using TG-LASIK for moderate to high astigmatism. Despite the baseline difference, both groups demonstrated comparable correction accuracy, with CI values close to 1.0 and low DV. The TG-LASIK showed numerically lower IOS and AE, suggesting

Table 3 Postoperative Contrast Sensitivity Mean \pm SD (LB, UB)

Follow-Up	Spatial Frequency (c/d)	TG-LASIK	SMILE	P value
Preoperative	1.5	1.80 \pm 0.22	1.89 \pm 0.13	0.015
	3.0	1.85 \pm 0.22	1.85 \pm 0.17	0.955
	6.0	1.67 \pm 0.37	1.65 \pm 0.25	0.790
	12.0	1.18 \pm 0.59	1.11 \pm 0.44	0.534
	18.0	0.50 \pm 0.47	0.50 \pm 0.47	0.727
1 Month	1.5	1.89 \pm 0.13	1.87 \pm 0.15	0.556
	3.0	2.00 \pm 0.17	1.97 \pm 0.16	0.384
	6.0	1.83 \pm 0.35	1.82 \pm 0.22	0.662
	12.0	1.34 \pm 0.43	1.34 \pm 0.38	0.255
	18.0	0.69 \pm 0.41	0.83 \pm 0.45	0.047
3 Months	1.5	1.91 \pm 0.12	1.88 \pm 0.15	0.513
	3.0	2.00 \pm 0.15	1.97 \pm 0.18	0.444
	6.0	1.87 \pm 0.28	1.83 \pm 0.25	0.295
	12.0	1.30 \pm 0.40	1.28 \pm 0.35	0.583
	18.0	0.74 \pm 0.46	0.73 \pm 0.42	0.958
6 Months	1.5	1.92 \pm 0.13	1.87 \pm 0.16	0.136
	3.0	2.05 \pm 0.15	1.99 \pm 0.20	0.151
	6.0	2.00 \pm 0.30	1.80 \pm 0.23	<0.001
	12.0	1.36 \pm 0.36	1.36 \pm 0.33	0.452
	18.0	0.81 \pm 0.48	0.33 \pm 0.27	<0.001

a trend toward improved precision in astigmatism correction and axis alignment. Sitto et al also noted residual astigmatism as a limitation in their SMILE group, attributing it partly to the absence of automated cyclotorsion compensation.¹⁴ This may partly explain the comparable correction accuracy observed between the two groups despite the higher preoperative astigmatism in the TG-LASIK group.

No significant differences in OSI and MTF Cutoff between TG-LASIK and SMILE group suggests that both surgeries provide comparable objective visual quality. The significant differences in MTF cutoff at 1 month indicate that SMILE may initially provide slightly better optical performance compared to TG-LASIK. However, this difference was no longer present at 3 and 6 months, indicating comparable optical quality between the two procedures at longer follow-up. This is partially consistent with previous findings showing that MTF cutoff is higher after SMILE than FS-LASIK in the early postoperative period.²² The convergence of outcomes by 3 months in our study may be attributed to the individualized topography-guided ablation profile of TG-LASIK, which optimizes corneal optical quality and may offset the early advantage in the SMILE group. A recent prospective contralateral study reported better subjective visual quality in the TG-LASIK group compared to SMILE.²³ These findings may indicate a potential advantage of TG-LASIK in visual quality-related outcomes. However, these results were primarily based on subjective assessments, highlighting the need for further validation using objective optical quality parameters.

Regarding contrast sensitivity, our results showed improvement in both groups, with TG-LASIK achieving significantly higher values at 6.0 c/d and 18.0 c/d at 6 months ($P < 0.001$). This pattern is consistent with findings from two prior studies using different measurement approaches.^{14,15} Kanellopoulos reported numerically higher contrast sensitivity at 6 c/d in the TG-LASIK group compared to SMILE at 3 months (7.2 ± 1.01 vs 6.20 ± 1.52), though between-group statistical comparisons were not reported. Similarly, Sitto et al demonstrated that TG-LASIK showed better mesopic low-contrast visual acuity than SMILE at 1 month. This advantage may reflect the role of active centration, iris registration, and cyclotorsion compensation in TG-LASIK, which reduce induced HOAs and preserve corneal optical regularity which known to influence contrast sensitivity, particularly at higher spatial frequencies. Similarly, Jain et al found that TG-LASIK was associated with better contrast sensitivity and reduced higher-order aberrations (HOAs) This improvement in contrast sensitivity aligns with recent literature reporting enhanced outcomes following personalized LASIK techniques, supporting the notion that TG-LASIK may provide improved contrast sensitivity, particularly at higher spatial frequencies.^{21,24,25}

Regarding safety, no eyes in the SMILE group lost two or more lines of CDVA. In the TG-LASIK group, 2% of eyes (1 eye) experienced a loss of two or more lines of CDVA. However, this was an isolated finding and did not reach statistical significance between groups. For TG-LASIK, flap-related complications such as epithelial ingrowth, flap striae, and diffuse lamellar keratitis (DLK) have been well described, although their incidence has declined substantially with modern femtosecond laser technology; no such complications were observed in our study. For SMILE, suction loss during lenticule creation and difficult lenticule dissection may affect early visual recovery and none were observed in our study. Given the 6-month follow-up, these long-term outcomes require further evaluation. Our findings suggest that TG-LASIK may be preferred in patients requiring more precise astigmatism correction or those with higher visual quality demands, given its better performance in contrast sensitivity at higher spatial frequencies.

The limitations of the present study are as follows. First, the non-randomized design may introduce potential selection bias. Second, the baseline difference existed between groups, including age, UDVA and cylinder and they may act as potential confounding factors; although covariate adjustment was not performed for all primary analyses, the comparable CDVA at baseline suggests equivalent optical potential between groups. In addition, the 6-months follow-up and limited sample size may reduce the ability to assess long-term stability and detect modest differences between groups. Furthermore, the predominance of female participants may limit the generalizability of the findings. Finally, the absence of preoperative OQAS measurements precluded within-group analysis of changes in objective optical quality from baseline, thereby limiting the ability to assess postoperative improvements.

Conclusion

In conclusion, both TG-LASIK and SMILE are highly effective in treating myopia and myopic astigmatism. The objective visual quality parameters were comparable between the two methods, suggesting that both can offer similar visual quality. However, TG-LASIK exhibited superior refractive precision and may enhance contrast sensitivity compared to SMILE, especially at higher spatial frequencies. Future research with larger sample sizes, longer follow-up periods, and more comprehensive measures of visual quality is needed to confirm these findings.

Abbreviations

TG-LASIK, Topography-guided laser in situ keratomileusis; SMILE, small incision lenticule extraction; UDVA, uncorrected distance visual acuity; SEQ, spherical equivalent; OSI, objective scattering index; MTF, modulation transfer function; SR, Strehl Ratio; HOAs, higher-order aberrations; CDVA, corrected distance visual acuity; logMAR, logarithm of the minimum angle of resolution; TIA, target induced astigmatism; SIA, surgically induced astigmatism; DV, difference vector; CI, correction index; IOS, index of success; AE, Angle of Error.

Data Sharing Statement

The datasets used in the study are available from the corresponding author, Yan Zheng, upon reasonable request due to privacy regulations.

Ethics Approval

This study was conducted following the ethical standards in the Declaration of Helsinki and the study received ethics approval from the Beijing Tongren Hospital Medical Ethics Committee.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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