· Clinical Research ·

A 3-month comparison study of subjective and objective visual quality of small incision lenticule extraction and transepithelial photorefractive keratectomy in patients with low and moderate myopia

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Abstract
● **AIM:** To compare the subjective and objective visual quality between small incision lenticule extraction (SMILE) and transepithelial photorefractive keratectomy (tPRK) in patients with low and moderate myopia.
● **METHODS:** Patients undertaking SMILE or tPRK for the correction of low and moderate myopia were consecutively recruited in this prospective cohort study with a 3-month follow-up period. Objective evaluation [visual acuity test, manifest refraction, wavefront aberrations, the total cut-off value of the total modulation transfer function ($MTF_{cut-off}$), and Strehl ratio (SR)] and subjective evaluation of visual quality (quality-of-life questionnaire) were conducted before surgery and at days 1, 7, 30, and 90 after surgery.
● **RESULTS:** A total of 47 patients (94 eyes) with SMILE and 22 patients (22 eyes) with tPRK were enrolled. The uncorrected visual acuity (UCVA) was better in SMILE patients on day 7 after surgery (1.13±0.13 *vs* 0.99±0.17, t=4.85, P<0.001) but was comparable at days 30 and 90. At day 90, the SMILE group had a lower spherical equivalent (SE) than the tPRK group (0.04±0.31 *vs* 0.19±0.43, t=2.08, P=0.042). Total higher order aberrations (HOAs) were induced in both surgical types, which were more evident in the tPRK group with 3-mm pupil diameter (0.16±0.07 *vs* 0.11±0.05, t=4.27, P<0.001) and 5-mm pupil diameter (0.39±0.17 *vs* 0.36±0.11, t=2.33, P=0.022). The $MTF_{cut-off}$ and SR showed a trend of improvement in both SMILE and tPRK patients but were statistically better in the SMILE group with both pupil diameters. There was a significant improvement of contrast sensitivity (CS) over baseline levels at the spatial frequency of 18 cycles/degree (c/d) in the SMILE group (F=2.72, P=0.033) and at 3 c/d (F=3.03, P=0.031), 12 c/d (F=3.72, P=0.013), and 18 c/d (F=4.62, P=0.004) in the tPRK group. The subjective quality of life questionnaire showed a steady improvement in the SMILE group (F=8.31, P<0.001) but not the tPRK group.
● **CONCLUSION:** SMILE and tPRK are both safe and effective ways to correct low and moderate myopia. A generally better and quicker recovery of visual quality favors the application of SMILE in qualified patients.
● **KEYWORDS:** corneal refractive surgery; small incision lenticule extraction; transepithelial photorefractive keratectomy; myopia; visual quality
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INTRODUCTION
For patients with low and moderate myopia, small incision lenticule extraction (SMILE) and transepithelial photorefractive keratectomy (tPRK) are two common flapless surgical methods to correct refractive errors, with accumulating evidence supporting their favorable predictability, safety, efficacy, and stability[1-2]. SMILE applies entirely the femtosecond laser, a kind of pulsed energy with ultra-short duration, to generate numerous tiny CO_2 bubbles at the desired cutting interface and achieves precise tissue separation. Only a small side cut is made to remove the stromal lenticule by the surgeon, and the whole corneal epithelial surface remains untouched and protected. tPRK is also an advancement from conventional photorefractive keratectomy (PRK) surgery that

doesn't rely on mechanical or ethanol-based removal of the corneal epithelium. It applies the excimer laser to achieve precise ablation of both corneal epithelium and stroma, which is free of contact or manual operation by the surgeon.

Besides post-operational refractive outcomes, the visual quality is another focus of surgeons' attention, which decides patients' satisfaction[3]. Although both SMILE and tPRK generally achieve precise correction to aimed refractive targets and result in good visual acuity, problems of glare, halos, poor night vision, and surgical-associated eye discomforts are commonly reported and may bother patients' daily life and work[4-5]. Due to the different tissue removal profiles of SMILE and tPRK, there is a difference in the induction of higher-order aberrations (HOAs) and corneal tissue remodeling after surgery, which can contribute to the difference in visual quality recovery over time[6]. Thus, a comprehensive comparison of both objective visual quality [including aberrations, contrast sensitivity, the cut-off value of the modulation transfer function ($MTF_{cut-off}$), and Strehl ratio (SR)] and subjective visual quality by self-filled quality-of-life (QoL) questionnaires of SMILE and tPRK is needed. But currently, very few direct comparison studies are available with controversial evidence. Thus, our study aims to provide new evidence regarding the assessment of post-operational visual quality in low and moderate myopic patients.

SUBJECTS AND METHODS

Ethical Approval The study was approved by the Ethics Committee of West China Hospital (approval number 2022-956) and has been registered in the Chinese Clinical Trial Registry (ChiCTR2200064492), which adhered to the Declaration of Helsinki. All participants were informed about the study process and signed written informed consent before recruitment and were free to quit at any time.

Participants This is a prospective cohort study that consecutively recruited low and moderate myopic patients undertaking SMILE or tPRK surgery in our center. Patients suitable for corneal refractive surgery were informed about the advantages and risks of different surgical methods before selecting on their own. Patients willing to participate were recruited and were asked to return on scheduled follow-up time on days 1, 7, 30, and 90 after the surgery. The inclusion criteria were: 1) age range: 18-40 years old; 2) normal corneal topography and no corneal clouding; 3) low and moderate myopia (diopter range -0.50 to -6.00 D). The diopter should remain stable for at least 2y before surgery; 4) estimated post-operational corneal stromal bed thickness >280 μm; 5) preoperative best corrected visual acuity (BCVA) ≥1.0; 6) no history of other eye surgeries; 7) no history of psychological diseases. Exclusion criteria were: 1) history of cataract, glaucoma, corneal clouding, and fundus abnormalities; 2) history of eye surgery; 3) abnormal pupil, including extra large pupil (pupil diameter >4.5 mm on topography examination), posterior synechia, and discoria; 4) history of systemic diseases, including diabetes, hypertension, systemic autoimmune diseases, and endocrine disorders; 5) patients with unrealistic expectations for the surgery.

Surgical Procedures and Postoperative Medications All surgeries were conducted by the same surgeon (Deng YP) following the standard established procedures in the same sterile operation room. Room temperature and humidity were fixed and controlled automatically. In brief, SMILE surgery was performed with the VisualMax femtosecond laser system (Carl Zeiss Meditec., Germany) under topical anesthesia. Surgical parameters were set to fixed values, including pulse energy of 135 nJ, corneal cap thickness of 120 μm, cap diameter of 7.5 mm, lenticule diameter of 6.5 mm, and the side cut angle at 1 o'clock position with a length of 2 mm. tPRK surgery was performed with the excimer laser system (SCHWIND AMARIS 750S, Germany) using a single continuous profile under topical anesthesia. Patients were asked to stare at the green blinking light during the whole procedure and an automatic tracing system was applied to calibrate the decentration of pupil. After surgery, patients were asked to adhere to the standard topical therapy, including antibiotics, steroids, and lubricating eye drops for as long as 1mo.

Visual Acuity and Manifest Refraction Patients were followed up on days 1, 7, 30, and 90 after the surgery and evaluated. The uncorrected distance visual acuity (UCVA) was obtained with the standard logarithmic visual acuity chart. Manifest refraction was read directly from the refractometer (KR-880, Topcon, Japan). At each follow-up time, patients were evaluated with the slit lamp (SLM-4, Kanghua Medical Device Co., China) by the surgeon to check for any surgery-associated complications.

Wavefront Aberrations, $MTF_{cut-off}$, and Strehl Ratio Wavefront aberrations were obtained with the iTrace aberrometer (iTrace 6.0.1, Tracey, USA) by the same technician. Both corneal HOAs and total HOA were recorded under pupil diameters of 3 and 5 mm, respectively. Patients were asked to stay in the darkroom for 5-10min to achieve desired pupil dilation before the examination. The total $MTF_{cut-off}$ and SR under pupil diameters of 3 and 5 mm were calculated by the software. The average value of 3 repeated examinations was recorded.

Contrast Sensitivity Contrast sensitivity (CS) was measured with the standard chart (CSV-1000E, Vector Vision, USA) at 4 spatial frequencies [3, 6, 12, and 18 cycles/degree (c/d)] under photopic conditions at a distance of 3 m.

Subjective Quality-of-Life Questionnaire Patients were asked to fill out a subjective QoL questionnaire before surgery and at each follow-up visit. The questionnaire was translated and modified from a validated published form, which contained 18 questions assessing different aspects of visual quality and their impacts on daily life[7]. Patients were informed about the basic information of the questionnaire and filled out the form on their own.

Statistical Analysis All data were analyzed using SAS 9.3 software (North Carolina, USA). Data were first analyzed with the Kolmogorov-Smirnov test to check if they followed the normal distribution, which were demonstrated as mean±standard deviation. The difference between the 2 groups at the same follow-up time was analyzed with the Student's *t*-test. The difference among different follow-up times of the same surgical group was analyzed with one-way repeated measures ANOVA analysis. $P<0.05$ was considered statistically significant.

RESULTS

Demographic Information and Preoperative Evaluation Results A total of 69 patients (138 eyes) were enrolled in this prospective cohort study, including 47 patients (94 eyes) choosing SMILE surgery and 22 patients (44 eyes) choosing tPRK surgery based on their preoperative evaluation results and own willingness. Their spherical diopters ranged from -1.00 to -6.00 D before surgery. Table 1 lists the demographic information and preoperative evaluation results of the 2 surgical groups. Patients in the SMILE group were significantly more myopic than the tPRK group (-4.12±0.98 D in the SMILE group and -3.54±1.27 D in the tPRK group, $P=0.010$). Other preoperative results, including cylindrical diopter, κ angle, corneal and total HOAs under 3 and 5 mm pupil diameters, total $MTF_{cut\text{-}off}$ under 3 and 5 mm pupil diameters, and the QoL questionnaire scores were all comparable between the 2 groups.

Visual and Refractive Outcomes No serious complications that could affect vision were reported after the surgery during the follow-up time. Patients in the SMILE group had lower UCVA before surgery than the tPRK group (0.07±0.01 *vs* 0.38±0.28, $t=7.18$, $P<0.001$). However, at the 1st follow-up visit (day 7 after surgery), the SMILE group had significantly better UCVA than the tPRK group (1.13±0.13 *vs* 0.99±0.17, $t=4.85$, $P<0.001$). At the following visits on days 30 and 90 after surgery, the 2 surgical groups had comparable UCVA (Figure 1A). At day 90, no patients in the SMILE or tPRK group lost 1 or more lines of UCVA compared to pre-operational BCVA, indicating good efficacy.

The spherical equivalent (SE) refraction of both groups improved dramatically after surgery and remained stable at all follow-up visits (Figure 1B). At day 90 after surgery, patients in the SMILE group had statistically lower SE than the tPRK group (0.04±0.31 *vs* 0.19±0.43, $t=2.08$, $P=0.042$).

Total HOAs, Coma, and Spherical Aberrations Table 2 summarizes total HOAs, coma, and spherical aberrations with 3- and 5-mm pupil diameters at different follow-up visits. Higher total HOAs tended to be induced in both surgical groups with either pupil diameter but were comparable between SMILE and tPRK groups at days 30 and 90 after surgery. However, on day 7, the tPRK group had higher total HOAs than the SMILE group with the 3-mm pupil diameter

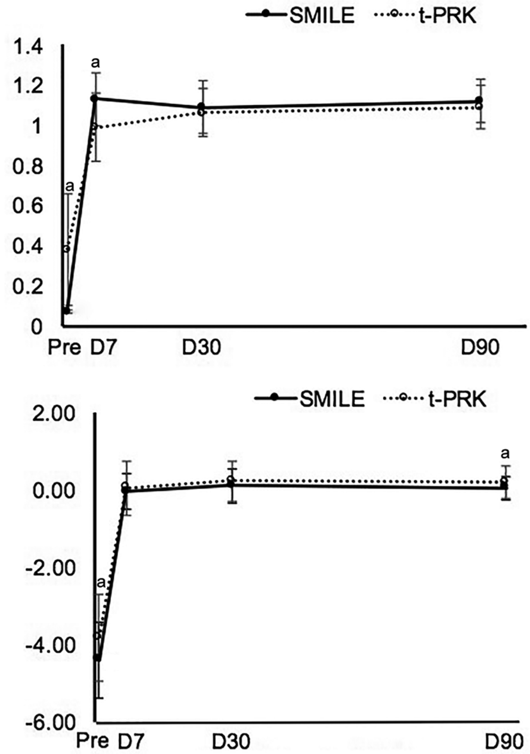

Figure 1 Visual and refractive outcomes of the SMILE and tPRK groups SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; UCVA: Uncorrected distance visual acuity; Pre: Preoperational result; SE: Spherical equivalent. [a]$P<0.05$ between the 2 groups at a specific follow-up visit.

Table 1 Demographic information and preoperative evaluation results

Parameters	SMILE group (*n*=47)	tPRK group (*n*=22)	*P*
Age (y)	27.17±5.06	27.81±5.32	0.637
Gender (male/female)	12/35	10/12	0.098
Spherical diopter (D)	-4.12±0.98	-3.54±1.27	0.010
Cylindrical diopter (D)	-0.53±0.56	-0.53±0.79	0.963
κ angle	0.34±1.56	0.17±0.11	0.302
Corneal HOA (3 mm pupil)	0.09±0.04	0.10±0.08	0.303
Corneal HOA (5 mm pupil)	0.24±0.07	0.30±0.18	0.065
Total HOA (3 mm pupil)	0.09±0.04	0.09±0.04	0.685
Total HOA (5 mm pupil)	0.24±0.08	0.24±0.07	0.821
Total $MTF_{cut\text{-}off}$ (3 mm pupil)	0.40±0.10	0.38±0.13	0.607
Total $MTF_{cut\text{-}off}$ (5 mm pupil)	0.32±0.08	0.32±0.11	0.876
QoL questionnaire score	57.83±8.42	60.41±7.90	0.231

SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; HOA: Higher-order aberrations; $MTF_{cut\text{-}off}$: The cut-off value of the modulation transfer function; QoL: Quality-of-life.

Table 2 Comparison of total HOAs, coma, and spherical aberrations with 3- and 5-mm pupil diameter between SMILE and tPRK groups

Parameters	SMILE group	tPRK group	^aP
3-mm pupil diameter			
Total HOAs			
Preop.	0.09±0.04	0.10±0.08	0.303
Day 7	0.11±0.05	0.16±0.07	<0.001
Day 30	0.11±0.04	0.12±0.05	0.078
Day 90	0.10±0.04	0.12±0.05	0.049
^bP	<0.001	<0.001	
Total spherical aberration			
Preop.	0.03±0.05	0.02±0.02	0.737
Day 7	0.04±0.07	0.04±0.02	0.876
Day 30	0.03±0.02	0.04±0.03	0.015
Day 90	0.03±0.03	0.05±0.03	0.019
^bP	0.077	<0.001	
Total coma aberration			
Preop.	0.03±0.03	0.03±0.02	0.107
Day 7	0.06±0.06	0.07±0.03	0.037
Day 30	0.04±0.03	0.03±0.02	0.114
Day 90	0.04±0.03	0.03±0.02	0.126
^bP	<0.001	<0.001	
5-mm pupil diameter			
Total HOAs			
Preop.	0.24±0.07	0.30±0.18	0.014
Day 7	0.36±0.11	0.39±0.17	0.022
Day 30	0.34±0.09	0.33±0.12	0.473
Day 90	0.34±0.09	0.33±0.12	0.758
^bP	<0.001	0.041	
Total spherical aberration			
Preop.	0.15±0.19	0.12±0.06	0.194
Day 7	0.19±0.06	0.19±0.12	0.831
Day 30	0.17±0.05	0.17±0.11	0.763
Day 90	0.17±0.05	0.17±0.11	0.892
^bP	0.164	0.030	
Total coma aberration			
Preop.	0.13±0.07	0.16±0.08	0.011
Day 7	0.21±0.09	0.18±0.10	0.526
Day 30	0.19±0.10	0.12±0.06	<0.001
Day 90	0.19±0.10	0.12±0.06	<0.001
^bP	<0.001	<0.001	

^aP: Comparison between SMILE and tPRK group at a specific follow-up time; ^bP: Comparison among different follow-up visits of the same surgical group. SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; HOA: Higher-order aberrations.

(0.16±0.07 *vs* 0.11±0.05, t=4.27, P<0.001) and 5-mm pupil diameter (0.39±0.17 *vs* 0.36±0.11, t=2.33, P=0.022).

Compared to preoperative data, SMILE induced higher coma but total spherical aberrations remained stable, which were more evident with the 5-mm pupil diameter. Total spherical aberrations increased significantly in the tPRK group after surgery with both pupil diameters, but total coma showed no obvious change on days 30 and 90 with the 3-mm pupil diameter and decreased dramatically with the 5-mm pupil diameter. On days 30 and 90 after surgery, the tPRK group had statistically higher spherical aberrations but lower coma compared to the SMILE group.

Table 3 Comparison of $MTF_{cut\text{-}off}$ and SR with 3- and 5-mm pupil diameters of SMILE and tPRK groups

Parameters	SMILE group	tPRK group	^aP
3-mm pupil diameter			
$MTF_{cut\text{-}off}$			
Preop.	0.40±0.10	0.38±0.13	0.607
Day 7	0.47±0.12	0.35±0.11	<0.001
Day 30	0.46±0.10	0.38±0.10	<0.001
Day 90	0.54±0.11	0.43±0.11	<0.001
^bP	<0.001	0.023	
SR			
Preop.	0.18±0.14	0.18±0.14	0.982
Day 7	0.28±0.18	0.15±0.11	<0.001
Day 30	0.27±0.18	0.21±0.12	0.077
Day 90	0.29±0.18	0.21±0.11	0.006
^bP	<0.001	0.160	
5-mm pupil diameter			
$MTF_{cut\text{-}off}$			
Preop.	0.32±0.08	0.32±0.11	0.891
Day 7	0.39±0.09	0.32±0.11	0.003
Day 30	0.37±0.09	0.35±0.10	0.262
Day 90	0.39±0.09	0.37±0.11	0.327
^bP	<0.001	<0.001	
SR			
Preop.	0.10±0.14	0.06±0.05	0.052
Day 7	0.12±0.12	0.10±0.08	0.005
Day 30	0.11±0.05	0.11±0.08	0.192
Day 90	0.14±0.05	0.11±0.08	0.018
^bP	0.040	<0.001	

^aP: Comparison between SMILE and tPRK group at a specific follow-up time; ^bP: Comparison among different follow-up visits of the same surgical group. SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; HOA: Higher-order aberrations; $MTF_{cut\text{-}off}$: The cut-off value of the modulation transfer function; SR: Strehl ratio.

Total $MTF_{cut\text{-}off}$ and Strehl Ratio The total $MTF_{cut\text{-}off}$ of the 2 surgical groups is summarized in Table 3. Both groups had comparable baseline $MTF_{cut\text{-}off}$ values and showed a trend of improved $MTF_{cut\text{-}off}$ at 3- and 5-mm pupil diameters, despite an initial decrease at day 7 in the tPRK group. The SMILE group had superior $MTF_{cut\text{-}off}$ at days 7, 30, and 90 than the tPRK group with the 3-mm pupil diameter (all P<0.001) and at day 7 with the 5-mm pupil diameter (P=0.003).

SRs were comparable at baseline and showed a steady improvement during post-operative visits in the SMILE group with the 3-mm pupil diameter (P<0.001) and in both groups with the 5-mm pupil diameter (P=0.040 in SMILE and <0.001 in tPRK). On days 7 and 90, the SMILE group had superior SRs compared to the tPRK group with both pupil diameters.

Contrast Sensitivity The CS at different spatial frequencies is demonstrated in Figure 2. The SMILE group had higher CS at 12 c/d (1.32±0.2 *vs* 1.13±0.31, t=3.80, P<0.001) and 18 c/d (0.91±0.28 *vs* 0.80±0.28, t=1.99, P=0.048) than the tPRK group before surgery. On days 7, 30, and 90 after surgery, the difference of CS at 12 and 18 c/d between the SMILE and tPRK groups generally remained significant, except for 12 c/d at day 60. In addition, at days 60 and 90 after surgery, the CS at 3 c/d was higher in the tPRK group compared to the SMILE group (day 60: 1.61±0.32 *vs* 1.49±0.21, t=2.25, P=0.028; day 90: 1.61±0.32 *vs* 1.50±0.21, t=2.03, P=0.046). Compared to baseline levels, there was a significant improvement in CS at the spatial frequency of 18 c/d in the SMILE group (F=2.72, P=0.033) and at 3 c/d (F=3.03, P=0.031), 12 c/d (F=3.72, P=0.013), and 18 c/d (F=4.62, P=0.004) in the tPRK group.

Subjective QoL Questionnaire The two surgical groups had comparable scores of the subjective QoL questionnaire at baseline (SMILE group 57.83±8.42, tPRK group 60.41±7.90, t=1.24, P=0.223). During postoperative follow-up visits, the SMILE group had a steady and significant improvement of scores (F=8.31, P<0.001), but the change of the tPRK group remained insignificant at day 90. At day 90, the SMILE group had a higher QoL score than the tPRK group (65.00±3.95 *vs* 61.68±3.66, t=2.68, P=0.011; Figure 3).

Surgery-related Complications No serious complications that could lead to permanent visual impairment were reported in either surgical groups. In the tPRK group, 4 eyes of 3 patients developed trace haze (grade 0.5+) at day 30 but spontaneously resolved at day 90. No case of haze formation was reported in the SMILE group. Other surgery-related complications, including infection, diffuse lamellar keratitis, and corneal ectasia, were not reported.

DISCUSSION

SMILE and tPRK are both widely applied ways to correct myopia, with plenty of evidence supporting their good efficacy and safety. As with previous studies, our study provides consistent evidence demonstrating their good post-surgical refractive and visual outcomes. Besides, as the focus of our study, we find better HOAs, $MTF_{cut\text{-}off}$ value, SR, and subjective visual quality scores in patients undertaking SMILE surgery, which favors its application in low and moderate myopia. However, a better post-surgical CS is observed in the tPRK group in our study, potentially due to more precise laser ablation and centration.

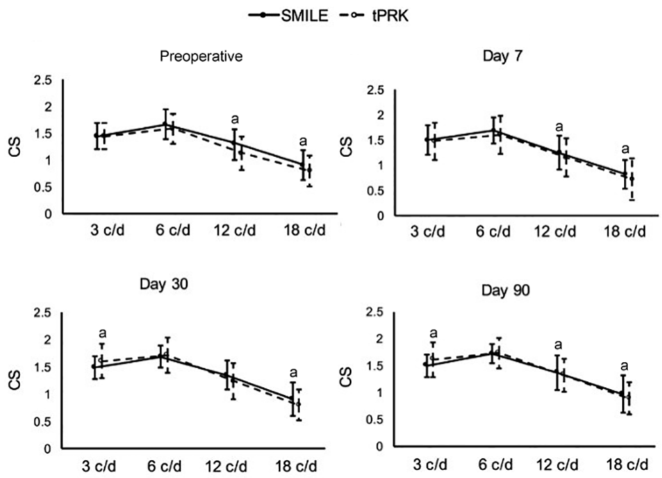

Figure 2 Comparison of contrast sensitivity of different spatial frequencies of SMILE and tPRK groups SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; CS: Contrast sensitivity. [a]P<0.05 between the 2 groups.

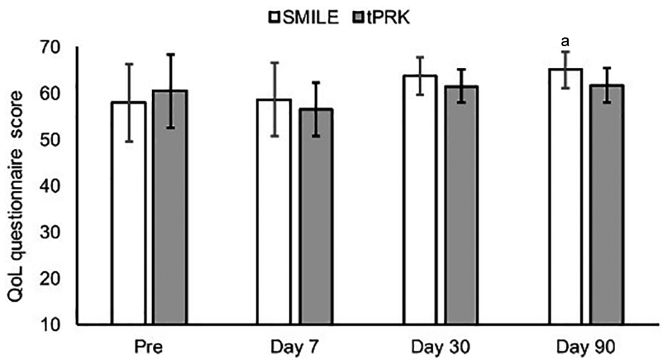

Figure 3 Comparison of subjective QoL questionnaire in SMILE and tPRK groups SMILE: Small incision lenticule extraction; tPRK: Transepithelial photorefractive keratectomy; QoL: Quality-of-life. [a]P<0.05 between the 2 groups.

Previous studies found controversial results of post-surgical visual acuity and remaining SE after SMILE and tPRK surgery. A 6-month follow-up study found comparable post-surgical efficacy, safety, and predictability of the 2 surgical types[8]. However, Ganesh *et al*[9] found a better UCVA and CDVA at 3mo in the SMILE group compared to PRK, despite comparable post-surgical spherical equivalents. Our current study found a quicker recovery of vision to the optimal level in the SMILE group at day 7, but the visual acuity then became comparable at days 30 and 90. In addition, a lower remaining SE was found in SMILE patients at day 90. As revealed by the electron transmission microscopy, SMILE results in better preservation of collagen fibers early after surgery. At day 7, the corneal surface of PRK patients remains irregular due to incomplete epithelization and the ongoing keratinization process[10]. Thus, a quicker visual recovery can be expected in SMILE patients. However, currently, no long-term direct comparison studies between SMILE and tPRK are available, which needs further exploration. In addition, some authors found a higher rate of haze development in surface ablation surgeries, particularly tPRK, which may contribute to a higher proportion of patients who lose 1 or more lines of BCVA and result in compromised safety compared to SMILE and tend to be a particular problem in high myopic patients[9,11]. However, for low and moderate myopia, most patients only develop trace to mild haze, which may not interfere with vision, and enhanced steroid treatment is found unnecessary[12-13]. Our study also found no surgical-related complications or development of visual-disturbing haze in both surgical groups, with no patients losing 1 or more lines at day 90.

Both SMILE and tPRK have been found to induce HOAs after surgery, in which coma and spherical aberrations are considered most relevant to disturbed visual quality[14]. Consistent with previous findings, our study found a significant increase of total HOAs in both surgical types, especially with the 5-mm pupil diameter, indicating poorer visual quality at night. The increases of total HOAs of both SMILE and tPRK groups were most prominent on day 7 after surgery, which decreased afterwards and generally remained stable through the 90-day follow-up period. On day 7, tPRK induced higher total HOAs, but the difference turned insignificant on days 30 and 90. The initial rise of HOAs may be related to the early post-surgical tissue remodeling process. Especially for tPRK, the early asymmetric reepithelization, irregular surface, and activation of keratocytes at the interface may be responsible for its higher HOAs early after surgery[10]. Due to different ablation profiles, our study found SMILE primarily induced coma rather than the spherical aberration. On the contrary, tPRK resulted in new spherical aberration, but coma was even reduced with the 5-mm pupil diameter. The inconsistent change of aberrations was also more evident with the larger pupil diameter. Coma was found to be the predominant contribution of increased HOAs in patients undertaking SMILE surgery[15]. Previous studies have found that an increase in coma was characteristic of SMILE, which could result from the inclination angle of the laser, asymmetric side cut position, and decentration due to the lack of pupil-tracking technique[16-17]. In addition, a 3-year follow-up study found that although a significant decrease of total HOAs and spherical aberrations was observed in SMILE patients from 3mo to 3y after surgery, the rise of coma remained stable[18]. Spherical aberrations result from asymmetric ablation of the central and peripheral cornea, which creates the central flattening of the optical zone. Conventional corneal refractive surgeries, including both SMILE and tPRK, turn the initially prolate cornea into the oblate one and result in a positive Q-value of the anterior surface[19]. However, due to the direct ablation of the anterior surface during tPRK surgery, a greater change of asphericity and consequently a higher induction of spherical aberrations are noted in tPRK patients[20-21]. A 10-year follow-up study of patients undertaking PRK surgery demonstrated that spherical aberrations after PRK were generally maintained through the whole postoperative period, despite potential compensation by corneal stromal remodeling and ectasia[22]. Consequently, a steady proportion of patients complaining of halos and glares at night was reported in a study that followed tPRK patients for 20y[23].

CS is an important reflection of both subjective and objective visual quality that evaluate patients' ability to distinguish the change of illumination. Very few previous studies have directly compared CS in low and moderate myopic patients undertaking SMILE and tPRK surgeries. A recent network Meta-analysis found no significant difference in CS between tPRK and SMILE groups[24]. Lin *et al*[8] conducted a comparison study in myopic patients with no restriction of preoperational diopters and found that the area under the logarithm of the CS function (AULCSF) as a general indicator of CS was improved only in the tPRK group at 6mo after surgery, which was also significantly better than the SMILE group. The finding was consistent with our results, as we found a general and steady improvement of CS at both low and high spatial frequencies in the tPRK group through the 90-day follow-up period after surgery. The baseline level of SMILE and tPRK groups in our study were not comparable at high-frequency levels, but the difference at the low spatial frequency was only evident after surgery. Previous studies also provide controversial evidence regarding the change of CS after surgery. With the induction of HOAs, the post-operational process of stromal and epithelial remodeling, and other surgical-related complications such as haze, some authors found a reduction of CS in early after both SMILE and tPRK surgeries, which could return in 6-12mo[25-26]. However, the application of optimized laser scanning mode, advances in laser platform, and standard postoperative management may contribute to improved CS[27-28]. In addition, the superiority of the excimer laser platform over femtosecond laser, including higher cutting accuracy (0.25 *vs* 4 μm), the pupil-tracking technique, and cyclotorsion-compensation system may explain the better CS of tPRK after surgery over SMILE[28].

Our study found a sustained improvement of the subjective visual quality assessed by self-filled QoL questionnaires in SMILE patients after surgery. On the other side, an initial drop of subjective visual quality was noted in tPRK patients at day 7, which returned to the baseline level at day 30. The QoL questionnaire used in our study was a validated form that comprehensively evaluate visual quality from aspects of near and distance vision, light and dark vision, stereoscopic vision, common visual problems (halos and glare), color vision, eye dryness, and eye discomfort during daily life and work[7]. As with our study, previous studies found SMILE tended to result in better patient satisfaction and comfort after surgery, despite different questionnaires used[9,29]. Surface ablation by tPRK may cause discomfort and pain early after surgery[30]. In addition, SMILE preserves more corneal nerves than tPRK, resulting in a quicker recovery of corneal sensitivity and tear secretion[31]. The higher increase of HOAs, particularly at 1wk after tPRK was also consistent with the early drop of subjective visual quality scores. As found in a previous study, spherical aberrations induced after tPRK surgery may result in halos and glare and was the only significant contributor to low-contrast sensitivity at night[32].

To our best knowledge, very few studies provide a direct comparison between SMILE and tPRK that focuses on a comprehensive evaluation of objective and subjective visual quality. Our study restricts our subjects to low and moderate myopia, who are the major candidates for corneal refractive surgeries. The limitations of our study include a small sample size and a relatively short follow-up time. Besides, the SE and CS at high spatial frequencies were not comparable at baseline and could compromise the rigor of the conclusion.

In conclusion, SMILE and tPRK are both effective and safe methods for the correction of low and moderate myopia. SMILE results in superior subjective visual quality, faster vision recovery, lower HOAs, and higher optical quality. On the other hand, tPRK provides greater improvement of CS.

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REFERENCES

1 Zhang H, Li M, Cen Z. Excimer laser corneal refractive surgery in the clinic: a systematic review and meta-analysis. *Comput Math Methods Med* 2022;2022:7130422.

2 Blum M, Lauer AS, Kunert KS, Sekundo W. 10-year results of small incision lenticule extraction. *J Refract Surg* 2019;35(10):618-623.

3 Chen YG, Liu Y. Paying extremely high attention to customized option and visual quality evaluation of refractive surgery. *Zhonghua Yan Ke Za Zhi* 2022;58(4):241-244.

4 Ma KK, Manche EE. Patient-reported quality of vision in a prospective randomized contralateral-eye trial comparing LASIK and SMILE. *J Cataract Refract Surg* 2022. Epub ahead of print.

5 Kung JS, Manche EE. Quality of vision after wavefront-guided or wavefront-optimized LASIK: a prospective randomized contralateral eye study. *J Refract Surg* 2016;32(4):230-236.

6 Miraftab M, Hashemi H, Aghamirsalim M, Fayyaz S, Asgari S. Matched comparison of corneal higher order aberrations induced by SMILE to femtosecond assisted LASIK and to PRK in correcting moderate and high myopia: 3.00mm *vs*. 6.00mm. *BMC Ophthalmol* 2021;21(1):216.

7 Scott IU, Schein OD, West S, Bandeen-Roche K, Enger C, Folstein MF. Functional status and quality of life measurement among ophthalmic patients. *Arch Ophthalmol* 1994;112(3):329-335.

8 Lin M, Zhou H, Hu Z, Huang J, Lu F, Hu L. Comparison of small incision lenticule extraction and transepithelial photorefractive keratectomy in terms of visual quality in myopia patients. *Acta Ophthalmol* 2021;99(8):e1289-e1296.

9 Ganesh S, Brar S, Patel U. Comparison of ReLEx SMILE and PRK in terms of visual and refractive outcomes for the correction of low myopia. *Int Ophthalmol* 2018;38(3):1147-1154.

10 Wei S, Wang Y, Wu D, Zu P, Zhang H, Su X. Ultrastructural changes and corneal wound healing after SMILE and PRK procedures. *Curr Eye Res* 2016;41(10):1316-1325.

11 Gadde AK, Srirampur A, Katta KR, Mansoori T, Armah SM. Comparison of single-step transepithelial photorefractive keratectomy and conventional photorefractive keratectomy in low to high myopic eyes. *Indian J Ophthalmol* 2020;68(5):755-761.

12 Pakbin M, Khabazkhoob M, Pakravan M, Fotouhi A, Jafarzadehpour E, Aghamirsalim M, Seyedian MA, Hashemi H. Duration of topical steroid application after photorefractive keratectomy with mitomycin C. *J Cataract Refract Surg* 2020;46(4):622-632.

13 Hashemi H, Pakbin M, Pakravan M, *et al*. Effect of short versus long-term steroid on corneal haze after photorefractive keratectomy: a randomized, double-masked clinical trial. *Am J Ophthalmol* 2022; 235:211-220.

14 Liu F, Huang YJ, Xu M, Wang XH, Feng W, Lian JC. High-order aberration and visual quality. *Guoji Yanke Zazhi* 2007;7(4):1113-1115.

15 Miao H, Tian M, Xu Y, Chen Y, Zhou X. Visual outcomes and optical quality after femtosecond laser small incision lenticule extraction: an 18-month prospective study. *J Refract Surg* 2015;31(11):726-731.

16 Lee H, Roberts CJ, Arba-Mosquera S, Kang DSY, Reinstein DZ, Kim TI. Relationship between decentration and induced corneal higher-order aberrations following small-incision lenticule extraction procedure. *Invest Ophthalmol Vis Sci* 2018;59(6):2316-2324.

17 Zhu L, Ji Y, Yang X, Lu X, Wu Q, Wang Q, Xia J, Li M, Hu K, Wan W. Corneal morphological changes after small incision lenticule extraction for myopic anisometropia. *Front Med* (*Lausanne*) 2022;9:977586.

18 Pedersen IB, Ivarsen A, Hjortdal J. Three-year results of small incision lenticule extraction for high myopia: refractive outcomes and aberrations. *J Refract Surg* 2015;31(11):719-724.

19 Su X. Corneal asphericity and the effects of the corneal refractive surgery on it. *Chinese Journal of Experimental Ophthalmology* 2015;33(6):552-555.

20 Zhang YL, Xu XH, Cao LJ, Liu L. Corneal curvature, asphericity, and aberrations after transepithelial photorefractive keratectomy and

femtosecond laser-assisted *in situ* keratomileusis for myopia: a prospective comparative study. *Indian J Ophthalmol* 2020;68(12):2945-2949.

21 Ying J, Zhang J, Cai J, Pan F. Comparative change in anterior corneal asphericity after FS-LASIK and SMILE. *J Refract Surg* 2021;37(3):158-165.

22 Zhang L, Wang Y, Geng W, Zuo T, Jin Y, Yang XY, Wang L. Ocular higher-order aberration features 10 years after photorefractive keratectomy. *Int Ophthalmol* 2013;33(6):651-657.

23 Cennamo G, Menna F, Sinisi F, Cennamo G, Breve MA, Napolitano P, de Bernardo M, Vitiello L, Rosa N. Twenty-year follow-up of excimer laser photorefractive keratectomy: a retrospective observational study. *Ophthalmol Ther* 2020;9(4):917-927.

24 Wen D, McAlinden C, Flitcroft I, *et al*. Postoperative efficacy, predictability, safety, and visual quality of laser corneal refractive surgery: a network meta-analysis. *Am J Ophthalmol* 2017;178:65-78.

25 Tsiogka A, Karmiris E, Samoli E, Spaeth GL. Comparison of central and peripheral contrast sensitivity between healthy and refractive surgery patients using the spaeth/richman contrast sensitivity (SPARCS) test. *J Refract Surg* 2022;38(2):128-133.

26 Chiche A, Trinh L, Saada O, Faure JF, Auclin F, Baudouin C, Denoyer A. Early recovery of quality of vision and optical performance after refractive surgery: small-incision lenticule extraction versus laser insitu keratomileusis. *J Cataract Refract Surg* 2018;44(9):1073-1079.

27 Weng S, Xiang D, Lin L, Lin H, Liu F, Liu Q. Optimal parameters of scanning mode in small incision lenticule extraction (SMILE): clinical results and ultrastructural analysis. *J Refract Surg* 2020;36(1):34-41.

28 Chen LY, Manche EE. Comparison of femtosecond and excimer laser platforms available for corneal refractive surgery. *Curr Opin Ophthalmol* 2016;27(4):316-322.

29 Miao H, Han T, Tian M, Wang X, Zhou X. Visual quality after femtosecond laser small incision lenticule extraction. *Asia Pac J Ophthalmol* (*Phila*) 2017;6(5):465-468.

30 Lv Z, Ma K. A prospective, randomized, double-masked controlled clinical trial of postoperative pain after transepithelial photorefractive keratectomy (trans-PRK). *J Healthc Eng* 2022;2022:2718785.

31 Wang LX, Li Y. Regeneration of corneal nerve after SMILE, FS-LASIK and T-PRK surgery and study its relationship with subjective visual quality. *Zhonghua Yan Ke Za Zhi* 2018;54(10):737-743.

32 Wang Y, Zhao K, Yang X, He J, Wang W. Higher order aberrations and low contrast vision function in myopic eyes (-3.00 to -6.00 D) under mesopic conditions. *J Refract Surg* 2011;27(2):127-134.