Original Article

Corneal curvature, asphericity, and aberrations after transepithelial photorefractive keratectomy and femtosecond laser-assisted *in situ* keratomileusis for myopia: A prospective comparative study

Ya-Li Zhang, Xiang-Hui Xu, Li-Jun Cao, Lei Liu

Purpose: We aimed to compare transepithelial photorefractive keratectomy (TPRK) and femtosecond laser-assisted *in situ* keratomileusis (FS-LASIK) for myopia treatment by analyzing corneal curvature, asphericity (Q-value), and corneal aberration. **Methods:** Corneal topography was measured before and 6 months after the TPRK or FS-LASIK surgery. We measured and compared corneal curvature (sagittal curvature in the 1- to 7-mm zones), change in keratometric measurements (Kmpost – Kmpre, ΔK), Q-values (from the vertex of the 6-, 7-, 8-, and 9-mm zones), higher-order aberration (HOA), vertical and horizontal trefoil ($Z3^{-3}$ and $Z3^{3}$), vertical and horizontal coma ($Z3^{-1}$ and $Z3^{1}$), and spherical aberration ($Z4^{0}$) between the two surgery groups. **Results:** The sagittal curvature Δ K in the 1-mm zone after TPRK was significantly higher than after FS-LASIK. The Δ K/ΔSE (ΔSE [spherical equivalent] = SEpre – SEpost) ratio in the 1- to 4-mm diameter zones was significantly higher after TPRK than after FS-LASIK. The preoperative Q-values of the 6- and 7-mm zones did not differ between the treatment groups, but postoperative values were significantly higher following FS-LASIK than following TPRK. HOA, $Z4^{0}$, and $Z3^{-1}$ were all significantly higher after surgery in both groups. Postoperative $Z3^{-3}$ was significantly higher following TPRK but not following FS-LASIK. There were no postoperative differences in aberrations in either group; however, the change in HOA and $Z3^{-1}$ was significantly greater following FS-LASIK. **Conclusion:** TPRK changes the corneal curvature to a greater extent and the visual quality (Q-value, aberrations) to a lesser extent than FS-LASIK.

Key words: Asphericity, corneal aberrations, corneal curvature, corneal topography, femtosecond laser-assisted *in situ* keratomileusis (FS-LASIK), keratometry, myopia, sagittal curvature, transepithelial photorefractive keratectomy (TPRK)

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Femtosecond laser-assisted *in situ* keratomileusis (FS-LASIK) and transepithelial photorefractive keratectomy (TPRK) alter the corneal refractive power by sculpting the desired corneal shape using laser ablation.[1–3] Both techniques are safe, predictable, and effective for myopia correction.[2-4] Moreover, both were reported to produce similar visual and refractive outcomes.[5] During TPRK, excimer laser ablates the corneal epithelium and stroma. In 2012, the reverse single-step technique was introduced.[6] In this method, the refractive component of ablation is applied to the stroma, followed by an epithelial profile. This technique provides a smooth post-ablative stromal bed counter, less haze, fast epithelial healing, and better visual quality.[7,8] In FS-LASIK, the excimer laser is used after femtosecond laser, because of which flap-related complications are inevitable. There are some differences in corneal curvature, asphericity, and aberrations between these surgical procedures,[9–12] but their impact is poorly understood. Thus, this study aimed to compare these parameters between TPRK and FS-LASIK.

Methods

Patients

For this comparative clinical study, all patients met the requirements for TPRK and FS-LASIK. The patients were recruited at our hospital between January and October 2018. Only the right eye of each patient was included in this study. Fifty-six patients consented to undergo the TPRK procedure, and 56 consented to undergo the FS-LASIK procedure. Allocation to either treatment group was based on the patient's selection of the surgical procedure after receiving a thorough explanation of both procedures. The inclusion criteria were as follows: (1) age ≥ 18 years, (2) stable refraction over the previous two years, (3) spherical equivalent < –8.00 diopters, (4) residual stromal bed of at least 300 μm in FS-LASIK or 350 μm in TPRK, and (5) consent to attend all follow-up visits. Exclusion criteria were as follows: (1) systemic or ocular diseases, (2) pregnancy or breastfeeding, (3) forme fruste keratoconus, diagnosed by corneal topography, (4) severely dry eye(s), and (5) collagen vascular diseases. This study was performed following the tenets of the Declaration of Helsinki and was approved by our Institutional Ethics Committee. All participants provided informed consent.

Preoperative assessment

All patients underwent a complete ophthalmologic examination before surgery. The examination consisted

Department of Ophthalmology, The Second People's Hospital of Jinan, Jinan, China

Correspondence to: Dr. Li-Jun Cao, Department of Ophthalmology, The Second Peopls's Hospital of Jinan, 148 Jingyi Road, Jinan 250001, Shandong Province, China. E-mail: 1120059538@qq.com

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of measurements of uncorrected visual acuity (UCVA), best-corrected distance visual acuity (BCVA), cycloplegic refraction, manifest refraction (sphere, cylinder, and spherical equivalent), intraocular pressure, corneal pachymetry, corneal topography (Pentacam; Oculus Optikgerate GmbH, Wetzlar, Germany), slit-lamp evaluation, and fundoscopy. The corneal aberrations, corneal curvature, and asphericity were obtained from the corneal topography assessment.

Surgical procedures

All surgical procedures were performed by experienced surgeons. After applying a topical anesthetic (oxybuprocaine hydrochloride; Santen Pharmaceutical Co. Ltd., Osaka, Japan), the standard surgical procedures were performed.

For the FS-LASIK surgery, flaps were created using a VisuMax femtosecond laser (Carl Zeiss Meditec AG, Jena, Germany) set with the following parameters: frequency, 500 kHz; energy cut index, 27 to 29; 90° side-cut angle; superior hinge; flap diameter, 8.1 mm; and attempted flap depth, 105–110 µm. The excimer laser ablation was then completed using the SmartPulse technology (Schwind Amaris 750 laser suite, Schwind eye-tech-solutions GmbH, Kleinostheim, Germany). All treatments had aberration-free profiles (aspheric). An ablation zone of between 6.0 and 7.0 mm in diameter was used based on the mesopic pupil size. After surgery, all patients received topical 0.1% fluorometholone (Santen Pharmaceutical Co. Ltd.) four times daily for 1 week, followed by three times daily for 3 weeks. For 1 week after the surgery, 0.3% levofloxacin (Bausch & Lomb Freda Inc., Jinan, Shandong, China) was administered three times daily. Artificial tears were administered as needed.

For the TPRK surgery, the epithelium and stroma were ablated in a single step using the aberration-free TPRK mode of the Schwind Amaris 750 laser (Schwind eye-tech-solutions GmbH). Epithelial ablation was set to 55 µm centrally and 65 µm peripherally, based on a previous population-based epithelial profile study. The SmartPulse technology was used for single step TPRK. The optical zone diameter varied among treatments between 6.0 and 7.0 mm, based on the mesopic pupil diameter and refractive error. Single-step laser delivery was carried out immediately after the epithelial ablation, and the cornea was then cooled with 20 mL of chilled balanced salt solution. After surgery, all patients received topical 0.1% fluorometholone (Santen Pharmaceutical Co. Ltd.) four times daily for one month, followed by treatment of three, two, and one time daily, one month each. In addition, 0.3% levofloxacin (Bausch & Lomb Freda Inc.) was administered three times daily for 1 week after the surgery. Artificial tears were administered as needed.

Postoperative assessment

Examinations were performed 1 day, 3 days, 1 week, and one, two, three, four, and six months after the surgery. UCVA and BCVA were recorded in the logMAR format. UCVA, BCVA, manifest refraction, intraocular pressure, and slit-lamp examination were performed during each visit. Corneal topography was evaluated at the 3- and 6-month follow-up visits.

Sagittal curvature in the 1- to 8-mm zones and corneal aberrations were recorded from the Pentacam HR (Oculus Optikgerate GmbH) measurements. The anterior, simulated keratometer readings at a ring of 15° around the corneal apex, termed k-values, were also recorded from the Pentacam HR measurements. In our study, the surgically-induced changes in corneal curvature (K) were calculated as $\Delta K = (Kmpost - Kmpre)$, where $Km = (K1 + K2)/2$. K1 represents the keratometry value for the flat meridian and K2 for the steep meridian. Kmpost represents the postoperative Km, and Kmpre represents the preoperative Km.

For corneal aberrations, we analyzed the Zernike coefficients of vertical trefoil ($Z3^{-3}$), horizontal trefoil ($Z3^{3}$), vertical coma ($Z3^{-1}$), horizontal coma ($Z3^{1}$), and spherical aberration ($Z4^{0}$). The parameters of corneal higher-order aberration (HOA) were also analyzed. All the parameters were recorded using the Pentacam HR.

A difference in the spherical equivalent (ΔSE) was defined as the preoperative spherical equivalent (SEpre) minus the postoperative spherical equivalent (SEpost); $\Delta SE = SEpre - SEpost$.

Statistical analysis

All statistical analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation. The visual acuity outcomes in logMAR notation were compared. Independent-samples Student's *t*-test was used to compare the TPRK and FS-LASIK groups. The Mann–Whitney rank–sum *U* test was used to analyze non-normally distributed data. A Chi-squared test was used to analyze sex differences between the groups. Pearson's linear correlation was used to investigate the linear relationships between the change of SA and corneal refractive power. Differences with $P < 0.05$ were considered statistically significant for all tests.

Results

A total of 56 eyes of 56 patients in each group were included in the final analysis. Table 1 shows the baseline characteristics of the participants in both groups. The groups did not differ in age, sex, k-value, or spherical equivalent ($p > 0.05$).

All surgeries were completed successfully, and no complications have occurred at any point during the treatment. All eyes achieved the target refraction. For TPRK, the Pearson's index of intended and achieved correction was 0.97 ($p < 0.01$); for FS-LASIK, the index was 0.99 ($p = < 0.01$). The optical zones in TPRK and FS-LASIK were similar (6.47 ± 0.16 mm and 6.43 ± 0.17 mm, respectively). The groups were also similar in the corneal stroma ablation depth (73.13 ± 14.22 µm and 75.72 ± 13.60 µm, respectively).

When differences in keratometry measurements (ΔK) were calculated in the 1.0- to 7.0-mm diameter zones from the apex, a significant difference was found between the groups in the 1-mm zone [Table 2 and Fig. S1]. The Δ K/ΔSE ratio was compared in the 1- to 7.0-mm diameter zones from the apex. It differed between the groups in the 1- to 4-mm diameter zones [Table 3].

As shown in Table 4 and Fig. S2, the pre- and post-surgery Q-values did not differ between the groups. The post-surgical Q-values and the change in Q-values between before and after the surgery differed between the groups in the 6- and 7-mm zones.

The corneal higher-order aberrations showed no difference between the groups before or after the surgery. In the TPRK group, there were significant differences in corneal HOA, spherical aberration, vertical coma, and horizontal trefoil between the pre- and post-surgical evaluations. Similar comparison in the FS-LASIK group found significant differences in corneal HOA, spherical aberration, and vertical coma. The difference in aberration values (△) between before and after surgery in the corneal HOA and vertical coma were 0.30 ± 0.25 and –0.17 ± 0.26, respectively, in the TPRK group, and 0.42 ± 0.28 and –0.32 ± 0.31, respectively, in the FS-LASIK group. The groups differed in both values [Table 5].

Discussion

TPRK and FS-LASIK are now commonly used for correcting myopia and astigmatism, and both procedures have been shown to be safe and effective.[5] In the present study, the Pearson index of intended and achieved correction was 0.97 and 0.99 in the TPRK and FS-LASIK groups, respectively. In other words, both procedures showed good predictability in the correction of myopia, in agreement with the findings of previous studies.[3,5] These days, excimer laser procedures for refractive surgery have different ablation profiles, including customized and aspherical ablation, and wavefront- or topography-guided treatment.[9,13-14] In this study, both procedures applied aberration-free laser ablation using the Schwind Amaris 750s platform (Schwind eye-tech-solutions). This aspherical ablation method is suitable for most patients. The profile aims to preserve the original spherical aberration value of the eye by delivering additional laser pulses to the periphery to maintain the natural shape of the cornea.[15,16]

Refractive surgery is used to correct refractive error by changing the corneal refractive power. Kim *et al*. found no significant difference in Δ K between LASIK and PRK.[17] In our study, we similarly found no significant difference in Δ K between TPRK and FS-LASIK. However, in this study, the Δ K for TPRK was slightly higher than for FS-LASIK. Furthermore, we found a smooth line in the 1- to 7-mm diameter zones for the Δ K in TPRK, whereas the line was slightly steeper in FS-LASIK [Fig. S1]. It is possible that epithelium regeneration had a major effect on this result. A previous study showed that the corneal epithelium could alter its thickness profile to reduce surface irregularities and reestablish a smooth optical surface.[18] Reinstein *et al*. found that a lenticular change occurs in the epithelial thickness profile, with more central thickening (within 1.5 mm) than in the paracentral area (annulus between 3.0 mm and 3.4 mm) after LASIK.[19] However, after TPRK, a significant epithelial thickening was observed in the lenticular mid-peripheral area (between the 5-mm and 6-mm diameter rings), but not in the central 2-mm diameter zone.[20]

The Δ K/ΔSE indices in the TPRK group were significantly higher than those in the FS-LASIK group in the 1- to 4-mm diameter zones. These are the primary zones involved in the correction of myopia. A study by Maldonado-Bas and Onnis reported keratometric flattening of 4.98 D (11.29%) in patients requiring correction of -3.00 to -6.00 D (-5.12 ± 0.81 D), and 7.07 D (15.94%) in patients requiring correction of -6.00 to -10.00 D (-8.33 ± 1.24 D).[21] These findings contradict those of the present study. In the TPRK group, we observed keratometric flattening of approximately 4.26 D (10%, mean Δ K/ΔSE = 0.90), while keratometric flattening in the FS-LASIK group was 4.20 D (16%, mean Δ K/ΔSE = 0.84). The reason for this difference in Δ K/ΔSE is the creation of a flap in FS-LASIK. Ortiz *et al*. found that the refractive change in corneal curvature was smaller after FS-LASIK than after LASIK performed using a mechanical microkeratome.[22] In addition, Zhang *et al*. found that the changes in corneal curvature differed between small incision lenticule extraction (SMILE) and FS-LASIK, and suggested that this might be due to the creation of a flap.[23] The combined use of the ΔK/ΔSE and postoperative refraction parameters may

Table 1: Patient characteristics and average preoperative values

Parameter	TPRK	FS-LASIK	t^*/χ^2	*P*
Eyes (*n*)	56	56		
Sex (Male/Female)	27/29	28/28	0.00	0.83
Age (years)	24.82±5.03 (18~36)	23.20±5.65 (18~38)	1.58	0.12
Spherical (D)	-4.46±1.00 (-7.00 ~ -2.50)	-4.53±1.17 (-7.00 ~ -2.50)	0.33	0.74
Cylinder (D)	-0.49±0.49 (-1.75~0.00)	-0.52±0.58 (-2.50~0.00)	0.37	0.72
SE (D)	-4.71±1.04 (-7.00 ~ -2.75)	-4.79±1.15 (-7.00 ~ -2.50)	0.40	0.69
Ks	43.23±1.58 (40.80~46.10)	42.82±0.92 (40.40~45.00)	-1.68	0.10

FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis; SE, spherical equivalent; TPRK, transepithelial photorefractive keratectomy; Preoperative k are the anterior, simulated keratometer readings on a ring of 15° around the corneal apex. *Student's t-test. Continuous variables are reported as mean±standard deviation

Table 2: Comparison ofΔK between the two groups

	ΔK1	ΔK2	ΔK3	ΔK4	ΔK5	ΔK6	ΔK7
TPRK	-4.10±1.08	-4.18±1.04	-4.27±0.97	-4.25±0.91	-4.11±0.81	-3.84±0.75	-3.40±0.67
FS-LASIK	-3.66±1.01	-3.81±1.01	-3.99±1.03	-4.09±1.01	-4.25±0.82	-3.87±0.75	-3.31±0.65
t	-2.183	-1.85	-1.44	-0.85	0.87	0.19	-0.69
P	0.03	0.07	0.15	0.40	0.39	0.85	0.49

FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis; Δ, change; K, keratometry measurements; TPRK, transepithelial photorefractive keratectomy. *P*<0.007 indicates a significant difference (corrected for multiple comparisons; Bonferroni-Hlim). ΔK (1~7 mm) = postoperative K (1~7 mm) - preoperative K (1~7 mm). Variables are reported as mean±standard deviation

Table 3: Comparison ofΔK/ΔSE between the two groups

	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm	7 mm
TPRK	0.86	0.88	0.90	0.90	0.87	0.81	0.72
FS-LASIK	0.75	0.78	0.82	0.84	0.89	0.81	0.69
t	5.61	5.56	5.20	4.04	-0.77	0.51	2.35
P	<0.001*	<0.001*	<0.001*	<0.001*	0.45	0.61	0.021

FS-LASIK= Femtosecond laser-assisted *in situ* keratomileusis; Δ= Change; K= Keratometry measurements; SE= Spherical equivalent; TPRK= Transepithelial photorefractive keratectomy. **P*<0.007 indicates a significant difference allow for a more precise evaluation of over- or under-correction following surgery. We suggest that the Δ K/ΔSE index should be considered during surgical preparation.

The corneal Q-value could reflect the change in corneal power from the center to the periphery. Corneal curvature changes are associated with changes in corneal asphericity. In the present study, the anterior corneal Q-value in both groups changed from negative to positive after surgery. The postoperative Q-values in the 6- and 7-mm zones were lower, and the change was smaller, in the TPRK group when compared to the FS-LASIK group. However, the differences in Δ K between the groups were insignificant. The optical zone diameters were 6.47 ± 0.16 mm and 6.43 ± 0.17 mm, and the Q-value changes were most obvious in the 6- and 7-mm zones. Previous studies found that the smaller the postoperative Q-value, the more prolate the corneal shape, and the better the visual function.[24,25]

In this study, both surgical techniques used the same laser ablation pattern. Postoperatively, TPRK showed an epithelial profile change with more thickening in the mid-peripheral zone, resulting in increased postoperative oblateness.[20] In FS-LASIK, the existence of corneal-flap affected the change in corneal curvature and asphericity. We can conclude that different surgical procedures result in different changes in corneal curvature and asphericity. In this study, we found that the non-flap surface procedure of TPRK resulted in a better corneal asphericity than FS-LASIK.

The change in corneal asphericity is related to visual quality after refractive surgery.[24] Both surgical approached changed the aberration of the cornea. In TPRK, the aberrations of HOA, SA, vertical coma, and vertical trefoil have all significantly increased postoperatively. In FS-LASIK, the aberrations of HOA, SA, and vertical coma have significantly increased postoperatively. However, the postoperative measurements of these parameters did not differ between the groups. The changes in HOA and vertical coma from the pre- to the postsurgical evaluation were smaller after TPRK than after FS-LASIK. This might be due to the creation of a flap in FS-LASIK, or because of the smaller Δ K values [Fig. S1].

Lee *et al*. found a larger vertical coma following SMILE than TPRK and suggested that this might be because the SMILE procedure was performed without eye-tracking.[26] In the present study, the laser ablation system was the same in both surgical approaches; therefore, the reason for the difference might be the flap creation and the hinge position.

Table 4: Comparison of Q-values between the two groups

	Q6	Q7	Q8	Q9
Pre-TPRK	-0.30±0.14	-0.34±0.14	-0.37±0.18	-0.44±0.13
Pre-FS	-0.28±0.09	-0.33±0.10	-0.38±0.10	-0.44±0.10
t	-0.604	-0.56	0.37	-0.14
P	0.55	0.58	0.71	0.89
Post-TPRK	0.64±0.34	0.61±0.31	0.51±0.28	0.34±0.24
Post-FS	0.82±0.43	0.76±0.39	0.61±0.33	0.40±0.28
t	-2.48	-2.25	-1.74	-1.26
P	0.02*	0.03*	0.09	0.21
△TPRK	0.94±0.34	0.95±0.31	0.88±0.31	0.78±0.24
△FS	1.11±0.42	1.11±0.37	0.99±0.31	0.84±0.25
t	-2.34	-2.12	-1.89	-1.26
P	0.02*	0.04*	0.06	0.21

△TPRK=post-TPRK - pre-TPRK. △FS=post-FS-LASIK - pre-FS-LASIK. FS, femtosecond; Δ, change; TPRK= Transepithelial photorefractive keratectomy; FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis. **P*<0.05=significant difference. Variables are reported as mean±standard deviation

Table 5: Comparison of corneal aberrations between the two groups

	HOA	SA	Vertical coma	Horizontal coma	Vertical trefoil	Horizontal trefoil
Pre-TPRK	0.41±0.10	0.17±0.08	-0.02±0.22	-0.03±0.12	-0.03±0.14	0.00±0.14
Pre-FS-LASIK	0.37±0.12	0.17±0.06	0.03±0.19	0.01±0.12	-0.07±0.13	-0.01±0.14
t	1.65	0.18	−1.64	−1.87	1.44	0.21
P	0.10	0.86	0.06	0.06	0.45	0.56
Pre-TPRK	0.41±0.10	0.17±0.08	−0.02±0.22	−0.03±0.12	−0.03±0.14	0.00±0.14
Post TPRK	0.71±0.22	0.41±0.16	−0.19±0.32	−0.03±0.31	−0.10±0.12	−0.02±0.11
t	−9.03	−10.57	4.81	−0.01	3.07	1.25
P	<0.01*	<0.01*	<0.01*	1.00	<0.01*	0.22
Pre-FS-LASIK	0.37±0.12	0.17±0.06	0.03±0.19	0.01±0.12	−0.07±0.13	−0.01±0.14
Post FS-LASIK	0.80±0.28	0.41±0.16	−0.30±0.36	−0.04±0.39	−0.09±0.16	0.00±0.11
t	−10.88	−11.27	7.53	1.15	1.17	−0.34
P	<0.01*	<0.01*	<0.01*	0.26	0.25	0.73
Post TPRK	0.71±0.22	0.41±0.16	−0.19±0.32	−0.03±0.31	−0.10±0.12	−0.02±0.11
Post FS-LASIK	0.80±0.28	0.41±0.16	−0.30±0.36	−0.04±0.39	−0.09±0.16	0.00±0.11
t	−1.68	−0.11	0.94	0.19	−0.49	−1.17
P	0.09	0.92	0.35	0.85	0.63	0.25
△TPRK	0.30±0.25	0.24±0.17	−0.17±0.26	0.00±0.28	−0.07±0.17	0.02±0.13
△FS	0.42±0.28	0.24±0.15	−0.32±0.31	−0.06±0.35	−0.02±0.14	0.01±0.14
t	−1.68	−0.11	0.94	0.19	−1.68	−1.11
P	0.02*	0.85	<0.01*	0.36	0.10	0.27

FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis; HOA= Higher order aberration; SA, spherical aberration; TPRK, transepithelial photorefractive keratectomy. △TPRK=post-TPRK - pre-TPRK. △FS=post-FS-LASIK - pre-FS-LASIK. **P*<0.05=significant difference. Variables are reported as mean±standard deviation

Previous studies have shown that spherical aberration and coma have major effects on visual function.[26,27] Jun *et al*. found that the main type of induced HOA after surgery was spherical aberration, and that an aberration-free profile is likely to affect the spherical aberration to the same extent as a corneal wave-front-guided profile.[15,28] The change in spherical aberration in our study was not significant because we used the same aberration-free ablation profile. This result is similar to the findings of Jun *et al*. (0.24 vs. 0.30).[28]

The current study has some limitations, including the number of participants and the range of refraction errors corrected. The small sample size may have detracted from the statistical power of the results. Further studies with larger sample size, and studies that include patients with severe myopia, are needed in the future.

Conclusion

In summary, both TPRK and FS-LASIK change the corneal curvature, asphericity, and high-order aberrations, especially the spherical aberration and vertical coma. Compared to FS-LASIK, TPRK is associated with a greater change in corneal curvature, and a smaller change in visual quality (Q-value, aberrations). The combined use of these parameters may allow for a more precise evaluation of the surgical nomogram and help choose the optimal surgical procedure.

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Conflicts of interest

There are no conflicts of interest.

References

1. Yuen LH, Chan WK, Koh J, Mehta JS, Tan DT, SingLasik Research Group. A 10-year prospective audit of LASIK outcomes for myopia in 37,932 eyes at a single institution in Asia. Ophthalmology 2010;117:1236–44.
2. Perez–Straziota C, Randleman JB. Femtosecond-assisted LASIK: Complications and management. Int Ophthalmol Clin 2016;56:59–66.
3. Adib–Moghaddam S, Soleyman–Jahi S, Sanjari Moghaddam A, Hoorshad N, Tefagh G, Haydar AA, *et al*. Efficacy and safety of transepithelial photorefractive keratectomy. J Cataract Refract Surg 2018;44:1267–79.
4. dos Santos AM, Torricelli AA, Marino GK, Garcia R, Netto MV, Bechara SJ, *et al*. Femtosecond laser-assisted LASIK flap complications. J Refract Surg 2016;32:52–9.
5. Luger MH, Ewering T, Arba–Mosquera S. Myopia correction with transepithelial photorefractive keratectomy versus femtosecond-assisted laser *in situ* keratomileusis: One-year case-matched analysis. J Cataract Refract Surg 2016;42:1579–87.
6. Adib-Moghaddam S, Soleyman-Jahi S, Salmanian B, Omidvari AH, Adili-Aghdam F, Noorizadeh F, *et al*. Single-step transepithelial photorefractive keratectomy in myopia and astigmatism: 18-month follow-up. J Cataract Refract Surg 2016;42:1570–8.
7. Aslanides IM, Georgoudis PN, Selimis VD, Mukherjee AN. Single-step transepithelial ASLA (SCHWIND) with mitomycin-C for the correction of high myopia: long term follow-up. Clin Ophthalmol 2014;9:33–41.
8. Aslanides IM, Padroni S, Mosquera SA, Ioannides A, Mukherjee A. Comparison of single-step reverse transepithelial all-surface laser ablation (ASLA) to alcohol-assisted photorefractive keratectomy. Clin Ophthalmol 2012;6:973–80.
9. Tawfik A, Eid AM, Hasanen R, Moftah IA. Q-value customized ablation (custom-Q) versus wavefront optimized ablation for primary myopia and myopic astigmatism. Int Ophthalmol 2014;34:259–62.
10. El-Mayah E, Anis M, Salem M, Pinero D, Hosny M. Comparison between Q-adjusted LASIK and small-incision lenticule extraction for correction of myopia and myopic astigmatism. Eye Contact Lens 2018;44(Suppl 2):S426–32.
11. Kanellopoulos AJ, Asimellis G. Refractive and keratometric stability in high myopic LASIK with high-frequency femtosecond and excimer lasers. J Refract Surg 2013;29:832–7.
12. Gyldenkerne A, Ivarsen A, Hjortdal JO. Comparison of corneal shape changes and aberrations induced by FS-LASIK and SMILE for myopia. J Refract Surg 2015;31:223–9.
13. Seiler T, Dastjerdi MH. Customized corneal ablation. Curr Opin Ophthalmol 2002;13:256–60.
14. Toda I, Ide T, Fukumoto T, Tsubota K. Visual outcomes after LASIK using topography-guided vs. wavefront-guided customized ablation systems. J Refract Surg 2016;32:727–32.
15. He L, Manche EE. Contralateral eye-to-eye comparison of wavefront-guided and wavefront-optimized photorefractive keratectomy: A randomized clinical trial. JAMA Ophthalmol 2015;133:51–9.
16. Arbelaez MC, Arba Mosquera S. The SCHWIND AMARIS total-tech laser as an all-rounder in refractive surgery. Middle East Afr J Ophthalmol 2009;16:46–53.
17. Kim G, Christiansen SM, Moshirfar M. Change in keratometry after myopic laser *in situ* keratomileusis and photorefractive keratectomy. J Cataract Refract Surg 2014;40:564–74.
18. Reinstein DZ, Archer T. Combined artemis very high-frequency digital ultrasound-assisted transepithelial phototherapeutic keratectomy and wavefront-guided treatment following multiple corneal refractive procedures. J Cataract Refract Surg 2006;32:1870–6.
19. Reinstein DZ, Archer TJ, Gobbe M. Change in epithelial thickness profile 24 hours and longitudinally for 1 year after myopic LASIK: Three-dimensional display with artemis very high-frequency digital ultrasound. J Refract Surg 2012;28:195–201.
20. Hou J, Wang Y, Lei Y, Zheng X, Zhang Y. Corneal epithelial remodeling and its effect on corneal asphericity after transepithelial photorefractive keratectomy for myopia. J Ophthalmol 2016;2016:8582362. doi: 10.1155/2016/8582362.
21. Maldonado–Bas A, Onnis R. Results of laser *in situ* keratomileusis in different degrees of myopia. Ophthalmology 1998;105:606–11.
22. Ortiz D, Alió JL, Piñero D. Measurement of corneal curvature change after mechanical laser *in situ* keratomileusis flap creation and femtosecond laser flap creation. J Cataract Refract Surg 2008;34:238–42.
23. Zhang YL, Cao LJ, Chen HW, Xu XH, Li ZN, Liu L. Comparison of changes in refractive error and corneal curvature following small-incision lenticule extraction and femtosecond laser-assisted *in situ* keratomileusis surgery. Indian J Ophthalmol 2018;66:1562–7.
24. Jiménez JR, Alarcón A, Anera RG, Jiménez Del Barco L. Q-optimized algorithms: theoretical analysis of factors influencing visual quality after myopic corneal refractive surgery. J Refract Surg 2016;32:612–7.
25. Lin DTC, Holland SP, Verma S, Hogden J, Arba-Mosquera S. Postoperative corneal asphericity in low, moderate, and high myopic eyes after transepithelial PRK using a new pulse allocation. J Refract Surg 2017;33:820–6.
26. Lee H, Yong Kang DS, Reinstein DZ, Arba-Mosquera S, Kim EK, Seo KY, *et al*. Comparing corneal higher-order aberrations in corneal wavefront-guided transepithelial photorefractive keratectomy versus small-incision lenticule extraction. J Cataract Refract Surg 2018;44:725–33.
27. Wang J, Ren Y, Liang K, Jiang Z, Tao L. Changes of corneal high-order aberrations after femtosecond laser-assisted *in situ* keratomileusis. Medicine (Baltimore) 2018;97:e0618.
28. Jun I, Kang DS, Tan J, Choi JY, Heo W, Kim JY, *et al*. Comparison of clinical outcomes between wavefront-optimized versus corneal wavefront-guided transepithelial photorefractive keratectomy for myopic astigmatism. J Cataract Refract Surg 2017;43:174–82.

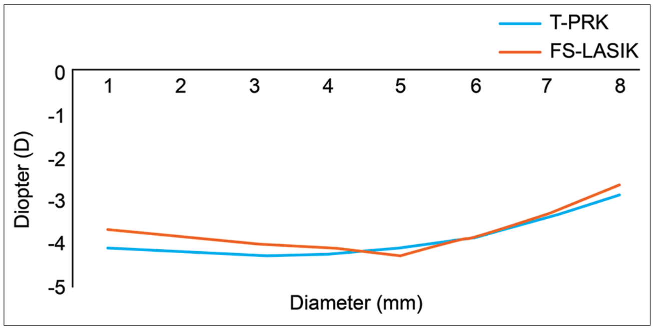

Figure S1: The ΔK in the 1- to 7-mm diameter zones for TPRK and FS-LASIK. FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis; ΔK, difference between keratometry measurements before and after treatment; TPRK, transepithelial photorefractive keratectomy

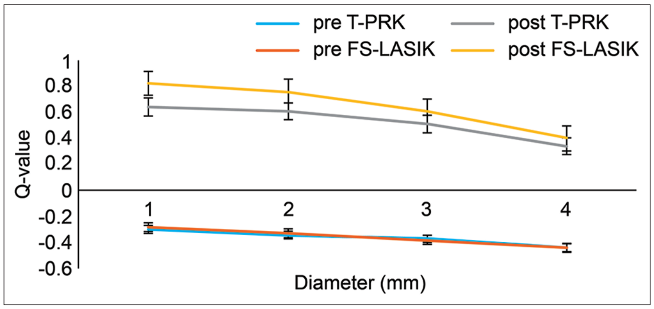

Figure S2: Change in the anterior corneal Q-value before and after surgeries. TPRK, transepithelial photorefractive keratectomy; FS-LASIK, femtosecond laser-assisted *in situ* keratomileusis; Pre, preoperative; Post, postoperative