Original Article

Vector analysis of astigmatic correction after single-step transepithelial photorefractive keratectomy and femtosecond-assisted laser *in-situ* keratomileusis for low to moderate myopic astigmatism

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Purpose: This study aimed to evaluate the outcomes of astigmatic correction by single-step transepithelial photorefractive keratectomy (TransPRK) and femtosecond-assisted laser *in-situ* keratomileusis (Femto-LASIK) surgeries. **Methods:** A total of 218 subjects received TransPRK or Femto-LASIK surgery for the treatment of myopia and astigmatism (−2.25 to −0.25 D). Refraction errors and uncorrected (UDVA) and corrected distance visual acuity (CDVA) were examined before and at 3 months after surgery. Astigmatism changes were assessed by vector analysis. **Results:** Preoperative parameters of the TransPRK group were similar to the Femto-LASIK group. UDVA and CDVA at 3 months were similar between both groups. Manifest refraction (MR) spherical equivalent in the TransPRK group (0 ± 0.20 D) was slightly lower compared with the Femto-LASIK group at 3 months (0.11 ± 0.25 D, P = 0.001). MR cylinder was -0.06 ± 0.19 D in the TransPRK group and -0.02 ± 0.15 D in the Femto-LASIK group at 3 months (P = 0.135). The index of success (IS) was 0.15 ± 0.36 in the TransPRK group and 0.06 ± 0.17 in the Femto-LASIK group (P = 0.125). The correction index (CI) was 1.03 ± 0.19 in the TransPRK group and 1.01 ± 0.11 in the Femto-LASIK group (P = 0.815). **Conclusion:** For low to moderate myopic astigmatism, TransPRK provided a comparable astigmatic treatment effect as Femto-LASIK. Myopic astigmatism was both slightly overcorrected after TransPRK and Femto-LASIK surgeries.

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Laser *in-situ* keratomileusis (LASIK) is one of the most commonly performed refractive surgeries for the correction of refractive errors.[1] Femtosecond-assisted LASIK (Femto-LASIK) has rapidly gained popularity since the laser creates thinner and more uniform corneal flaps with better accuracy.[2,3] The American Academy of Ophthalmology demonstrated excellent visual results after Femto-LASIK.[4] Chan *et al*.[5] reported that Femto-LASIK offers favorable astigmatic treatment outcomes compared with small incision lenticule extraction (SMILE) in low-moderate myopic astigmatism eyes using vector analysis.

Single-step transepithelial photorefractive keratectomy (TransPRK) was evolved from the Schwind Amaris (SCHWIND eye-tech-solutions, Kleinostheim, Germany) laser.[6] Due to the well-defined epithelial depth, phototherapeutic keratectomy (PTK) and stromal ablation are combined into one procedure.[7] Luger *et al*.[8] reported that the epithelium heals faster after TransPRK due to its sharp epithelial edges and the small epithelial ablation zone. It is unclear whether eyes with different epithelial thicknesses in TransPRK would be affected by the pre-established epithelial profile. TransPRK could induce additional refractive errors, especially astigmatism if the center-to-periphery progression of the corneal epithelial profile deviates from the fixed preparatory epithelial profile.[7,9] However, there is still no study comparing the astigmatic correction outcomes between TransPRK and Femto-LASIK using vector analysis. Herein we aimed to evaluate and compare the outcomes of Femto-LASIK and TransPRK astigmatic correction surgeries in eyes with myopic astigmatism (−2.25 to − 0.25 D) by the Alpins vector analysis.[10]

Methods

Study design

This retrospective study included the study subjects who received Femto-LASIK or TransPRK surgeries for treatment of myopia and myopic astigmatism between August 2016 and October 2019. The research protocol was approved

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by the Human Medical Ethics Committee of Joint Shantou International Eye Center of Shantou University and the Chinese University of Hong Kong, which is in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all study subjects after an explanation of the nature and possible consequences of the study. The study subjects with (1) stable preoperative refraction (an annual increase of myopia less than 0.5 D for ≥2 years) and (2) manifest spherical equivalence less than −8.00 D were included. The study subjects were required to stop wearing soft contact lenses for more than a week or rigid gas-permeable contact lenses for more than four weeks before treatment according to the recommendation from the United States Food and Drug Administration (https://www.fda.gov/medical-devices/lasik/what-should-i-expect-during-and-after-surgery). All treatments were targeted for emmetropia. The study subjects with a history of ocular inflammation, previous ocular trauma, and surgeries were not included. The selection of the types of surgeries depended on the corneal thickness and the willingness of the study subjects.

Ocular examination and postoperative follow-up

All study subjects received complete ocular examinations, including measurement of uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest spherical and cylindrical refraction, cycloplegic refraction, slit-lamp examination, and dilated fundus examination. Total corneal higher-order aberrations (HOAs) were measured using Scheimpflug corneal tomography (Pentacam HR, Oculus Optikgerate GmbH, Germany). Postoperative examinations were conducted on days 1, 3, and 7, and months 1 and 3 after the surgery.

Surgical techniques

Both TransPRK and Femto-LASIK surgeries were performed using the excimer laser (Schwind Amaris 750S; Schwind eye-tech-solutions, GmbH, Kleinostheim, Germany). For the eyes with pupillary offset (the distance between the pupil center and corneal vertex) greater than 0.2 mm,[11] the center of the ablation profile was determined by the topographer (considering 70% as the pupil offset value which is approximately close to the corneal vertex). A pupil center-centered profile was used in all other eyes. An optical zone (OZ) range of 6.1 to 7.7 mm was used. The target for the corrections was emmetropia. Static cyclotorsion control and dynamic cyclotorsion control were used intraoperatively.

For the TransPRK surgery, the eye was rinsed with a balanced salt solution. One-step ablation of the epithelium and stroma was done using the population-based epithelium thickness profile, 55 μm centrally and 65 μm peripherally. After laser ablation, 0.02% mitomycin C was applied to the stromal bed for 40 s when the ablation depth of the corneal stroma was more than 70 μm. The stromal bed was then irrigated with 50 mL of chilled saline. A high-oxygen-content soft bandage contact lens (PureVision, Bausch & Lomb, Rochester, NY) was placed over the cornea for 3 to 7 days. The patients were prescribed 0.1% fluorometholone eye drops, 0.5% levofloxacin eye drops, and diclofenac sodium eye drops four times a day and artificial tears every 4 h before the epithelium was healed. Once the epithelium was completely healed, the contact lens was taken off. 0.5% levofloxacin eye drops were prescribed for another 7 days. 0.1% fluorometholone eye drops were applied for four times a day in the first month and reduced progressively for 4 months. Artificial tears were prescribed four times a day for 4 months.

The Femto-LASIK flaps were created using the 5 MHz FEMTO LDV™ Femtosecond Laser (Ziemer, Port, Switzerland). The hinge of the flap was set superiorly with a planned flap diameter of 8.5 mm and flap thickness of 110 μm. Stroma was ablated using Schwind Amaris 750S laser. The eye tracker was used intraoperatively. After ablating the stromal tissue, the corneal flap was replaced, and the stromal bed was irrigated with saline. Patients were prescribed 0.1% fluorometholone eye drops, 0.5% levofloxacin eye drops four times a day for a week, and artificial tear drops four times a day for 3 months after surgery. The 0.1% fluorometholone eye drops were given 3 times a day and tapered over the course of 3 weeks.

Astigmatism vector analysis

The astigmatism results were reported according to the standardized format.[12] The spectacle plane manifest refraction (MR) astigmatism was transformed into the corneal plane using a vertex distance of 12 mm. Only right eyes were included and analyzed using Alpins vector analysis.[10] The parameters were calculated as follows: (A) Target-induced astigmatism vector (TIA): Changes in astigmatism were intended to be induced by surgery; (B) Surgically induced astigmatism vector (SIA): Changes in astigmatism were actually induced by surgery; (C) Difference vector (DV): Changes in the induced astigmatic would enable the surgery to achieve intended target. It is preferably 0; (D) Magnitude of error (ME), angle of error (AE): ME is the arithmetic difference between the SIA and TIA. AE is the angle between the axis of TIA and SIA; (E) Index of success (IS): The ratio of DV to TIA. It is preferably 0; (F) Coefficient of adjustment (CA): The ratio of TIA to SIA. It is the inverse of the correction index and is preferably 1.0; (G) Correction Index (CI): The ratio of SIA to TIA. It is preferably 1.0.

Statistical analysis

Statistical analysis was performed using SPSS version 22.0 (IBM-SPSS, Chicago, IL). Mann–Whitney *U* test was used to compare variables between groups. The χ^2 test was used to compare proportions across groups. Linear regression was used to analyze correlations of variables. The sample size calculation was referenced to the Alpins vector from previous studies.[5,13] Excel 2016 (Microsoft Corporation, Redmond, WA) was used to construct the standardized graphs. SigmaPlot 14.0 (Systat Software Inc., Chicago, IL) was used to construct the polar scatter graphs.

Results

This study comprised 218 study subjects (218 right eyes) with 109 eyes in each group. The baseline characteristics showed no significant differences between the two groups before surgery [Table 1].

The mean intraoperative dynamic cyclotorsion amplitude was 1.66° ± 1.23° in the TransPRK group and 1.22° ± 0.72° in the Femto-LASIK group with statistically significant differences ($P < 0.01$).

At 3 months postoperatively, there were no significant differences in UDVA and CDVA between the TransPRK group and Femto-LASIK group. Manifest spherical equivalent was slightly but significantly higher in the Femto-LASIK group compared to the TransPRK group 3 months after surgery. Manifest cylinder between the two study groups showed no significant difference at 3 months postoperatively [Table 1].

Efficacy and safety

For the TransPRK and Femto-LASIK groups, UDVA of 99 (90.8%) eyes and 103 (94.5%) eyes, respectively, showed at least 20/20 at 3 months after surgery. The UDVA of all eyes achieved 20/25 in both groups 3 months after surgery [Fig. 1a]. The efficacy index refers to the ratio of postoperative UDVA to preoperative CDVA, which was 1.00 ± 0.16 after TransPRK and 1.03 ± 0.13 after Femto-LASIK at 3 months after surgery.

In the TransPRK and Femto-LASIK groups, CDVA of 32 (29.4%) eyes and 30 (27.5%) eyes gained 1 line, respectively, at 3 months postoperatively. In the TransPRK group and Femto-LASIK group, CDVA of 22 (20.2%) eyes and 8 (7.3%) eyes had lost 1 line, respectively [Fig. 1c]. The safety index, calculated as the ratio of postoperative CDVA to preoperative CDVA, was 1.04 ± 0.16 in the TransPRK group and 1.07 ± 0.15 in the Femto-LASIK group at 3 months postoperatively. Fig. 1 shows the visual results of two groups 3 months after surgery.

Predictability

There were two similar best-fit lines for the attempted versus achieved spherical equivalent (SE) data in the two groups, and a high correlation (R^2 = 0.997 for TransPRK eyes versus R^2 = 0.998 for Femto-LASIK eyes; Figs. 1d and e). At 3 months, 98.2% (107/109) eyes in the TransPRK group and 98.2% (107/109) eyes in the Femto-LASIK group showed less than ± 0.50 D of emmetropia [Fig. 1f].

The attempted cylindrical correction in 99.1% (108/109) eyes in the TransPRK group was within ± 0.50 D at 3 months postoperatively [Fig. 1g], and the attempted cylindrical correction in 100% (109/109) of eyes in the Femto-LASIK group was within ± 0.50 D at 3 months postoperatively [Fig. 1h].

Vector analysis

Table 2 shows the vector analysis outcomes at 3 months. The means of TIA, SIA, DV, ME, AE, absolute AE, IS, CI, and CA showed no significant difference between the TransPRK and Femto-LASIK groups. For the comparison between TIA and SIA, the best-fit lines of the two groups showed similar clustering and scatter distribution [Figs. 2a-c] shows the distribution of AE for both groups.

Figs. 2d and e show the polar scatter graphs of preoperative TIA and postoperative DV for both groups. Astigmatism lies with the rule in both groups preoperatively. Both procedures produced excellent correction for astigmatism.

Subgroup analysis was conducted according to the degree of TIA. Patients were classified into two groups according to the mean TIA (0.67 D). In the eyes with low TIA (0.40 D) and moderate TIA (0.93 D), none of the parameters in the vector analysis showed a significant difference between the TransPRK and Femto-LASIK groups [Table 3].

Preoperative HOAs of the total cornea showed no statistically significant differences between both groups. No significant differences were found in changes in trefoil aberration between the two groups at 3 months after surgery. Changes in root mean square (RMS) HOA, coma, and spherical aberration (SA) in the Femto-LASIK group were significantly higher than that in the TransPRK group at 3 months after surgery [Table 4].

Table 1: Baseline characteristics, postoperative visual acuity, and postoperative refraction three months after transepithelial photorefractive keratectomy and femtosecond-assisted laser *in-situ* keratomileuses

Parameters	TransPRK (*n*=80) Mean±SD	Femto-LASIK (*n*=83) Mean±SD	*P*
Preoperative			
Age (years)	23.20±4.74	22.86±4.11	0.816
UDVA (logMAR)	1.15±0.38	1.26±0.38	0.083
CDVA (logMAR)	-0.05±0.05	-0.05±0.05	0.893
MR sphere (D)	-3.54±1.08	-3.74±1.19	0.228
MR cylinder (D)	-0.69±0.38	-0.80±0.44	0.064
Optical Zone (mm)	6.61±0.23	6.67±0.26	0.171
Ablation Zone (mm)	7.89±0.27	7.54±0.33	<0.001
Transition Zone (mm)	1.28±0.24	0.87±0.24	<0.001
3 months postoperative			
UDVA (logMAR)	-0.04±0.06	-0.06±0.06	0.070
CDVA (logMAR)	-0.06±0.06	-0.07±0.06	0.171
MR SEQ	0±0.20	0.11±0.25	0.001
MR sphere (D)	0.03±0.19	0.12±0.24	0.002
MR cylinder (D)	-0.06±0.19	-0.02±0.15	0.135

TransPRK: transepithelial photorefractive keratectomy; Femto-LASIK: femtosecond-assisted laser *in-situ* keratomileusis; UDVA: uncorrected distance visual acuity; CDVA: corrected distance visual acuity; MR: manifest refraction; SEQ: spherical equivalence

Table 2: Vector analysis of astigmatic correction at 3 months after transepithelial photorefractive keratectomy and femtosecond-assisted laser *in-situ* keratomileusis

Parameters	TransPRK (*n*=109) Mean±SD	Femto-LASIK (*n*=109) Mean±SD	*P*
TIA (D)	0.62±0.34	0.72±0.39	0.121
SIA (D)	0.64±0.34	0.73±0.41	0.116
DV (D)	0.08±0.18	0.05±0.14	0.185
ME (D)	0.01±0.14	0.01±0.11	0.840
AE (°)	0.68±11.71	-0.03±4.12	0.599
Absolute AE (°)	3.43±11.21	1.13±3.96	0.142
IS	0.15±0.36	0.06±0.17	0.125
CI*	1.03±0.19	1.01±0.11	0.815
CA*	1.00±0.19	1.00±0.12	0.816

*Geometric mean±SD. AE: angle of error; CA: coefficient of adjustment; CI: correction index; DV: difference vector; Femto-LASIK: femtosecond-assisted laser *in-situ* keratomileusis; FI: flattening index; IS: index of success; ME: magnitude of error; SIA: surgically induced astigmatism; TIA: target-induced astigmatism; TransPRK: transepithelial photorefractive keratectomy

Table 3: Subgroup analysis of astigmatic correction based on the degree of target-induced astigmatism vector at 3 months after transepithelial photorefractive keratectomy and femtosecond-assisted laser *in-situ* keratomileusis.

Parameter	Sub-group	TransPRK (*n*=109) Mean±SD	Femto-LASIK (*n*=109) Mean±SD	*P*
TIA (D)	*n*=51/58			
	Low TIA	0.40±0. 12	0.40±0.12	0.573
	Moderate TIA	0.93±0.29	1.01±0.31	0.159
SIA (D)	Low TIA	0.42±0.17	0.40±0.13	0.802
	Moderate TIA	0.92±0.30	1.02±0.35	0.174
DV (D)	Low TIA	0.07±0.16	0.02±0.08	0.084
	Moderate TIA	0.10±0.20	0.08±0.18	0.582
ME (D)	Low TIA	0.02±0.09	0.01±0.05	0.460
	Moderate TIA	0±0.17	0.01±0.14	0.710
AE (°)	Low TIA	2.10±14.62	-0.49±3.96	0.739
	Moderate TIA	-1.19±5.69	0.38±4.24	0.300
Absolute AE	Low TIA	4.48±14.06	0.88±3.89	0.079
	Moderate TIA	2.04±5.44	1.34±4.04	0.600
CI*	Low TIA	1.05±0.19	1.01±0.09	0.460
	Moderate TIA	1.01±0.19	1.01±0.12	0.738
CA*	Low TIA	0.98±0.11	0.99±0.08	0.460
	Moderate TIA	1.04±0.26	1.01±0.15	0.735

TIA cut-off point=0.67. AE: angle of error; CA: coefficient of adjustment; CI: correction index; DV: difference vector; ME: Magnitude of error; SIA: surgically induced astigmatism vector; TIA: target-induced astigmatism vector; *n*: number; TransPRK: transepithelial photorefractive keratectomy; Femto-LASIK: femtosecond-assisted laser in-situ keratomileusis.

Table 4: Higher-order aberrations of the total cornea at preoperative and 3 months after transepithelial photorefractive keratectomy and femtosecond-assisted laser in-situ keratomileusis

Parameters	TransPRK (*n*=80) Mean±SD	Femto-LASIK (*n*=83) Mean±SD	*P*
Preoperative			
RMS HOA (μm)	0.39±0.10	0.38±0.10	0.544
Coma (μm)	0.20±0.11	0.21±0.12	0.829
Trefoil (μm)	0.13±0.07	0.12±0.07	0.268
SA (μm)	0.20±0.08	0.20±0.07	0.288
3 months postoperative			
RMS HOA (μm)	0.20±0.21	0.33±0.21	<0.001
Coma (μm)	0.09±0.22	0.28±0.23	<0.001
Trefoil (μm)	0.06±0.14	0.03±0.11	0.094
SA (μm)	0.08±0.17	0.15±0.13	0.004

Femto-LASIK: femtosecond-assisted laser *in-situ* keratomileusis; HOA: higher-order aberration; RMS: root mean square; SA: spherical aberration; TransPRK: transepithelial photorefractive keratectomy; *n*: number

Discussion

The treatments of LASIK and TransPRK are safe and effective for myopia with or without astigmatism.[1,3,6,14-16] The results of our study indicated that both TransPRK and Femto-LASIK show high accuracy for the treatment of myopic astigmatism using vector analysis. Astigmatism was slightly overcorrected after TransPRK and Femto-LASIK. As the mean of OZ and preoperative spherical and cylindrical refraction in TransPRK were higher than Femto-LASIK, the depth of ablation was lower in TransPRK. Therefore, SE and MR sphere correction were more precise in the TransPRK group. Collectively, both procedures resulted in similar visual and refractive outcomes at 3 months postoperatively.

For achieving optimal unaided distance vision after surgery, accurate astigmatic correction is important.[17] In this study, vector analysis showed light overcorrection of astigmatism in the TransPRK group and Femto-LASIK group. CI in both groups was close to 1. Further subgroup analysis according to the degree of TIA showed that CI was 1.01 in the moderate TIA subgroup and CI was 1.05 in the low TIA subgroup in the TransPRK group. Our results indicated that if the TIA is less than 0.67 D, the magnitude of correction increases by 5% (CA = 1.05) improvement in the results of TransPRK. In a research analyzing the astigmatic correction with TransPRK, the CI was close to 1,[18] but other studies showed overcorrection in astigmatism.[13,15,19] Previous studies using vector analysis for astigmatic treatment reported that low preoperative astigmatism eyes were overcorrected, while highly astigmatic eyes were undercorrected for astigmatism after Femto-LASIK surgery.[20,21]

A previous study demonstrated that the percentage of loss of flattening effect is 1.5% when treatment is misaligned by 5°, 13.4% when 15°, 50% when 30°, and 100% when 45°.[22] This proves that alignment and magnitude of treatment are both important for the successful treatment of astigmatism. In this study, the mean and absolute AE were close to 0, indicating the systematic misalignment and variable alignment of flattening were slight in both groups. Recent studies reported that the mean AE was + 9.56 ± 64.64° and 0.44 ± 7.42° after TransPRK surgery.[13,19] Other studies found that AE was 2.40 ± 21.29° and -0.45 ± 2.99° after LASIK surgery.[5,23] Dynamic cyclotorsion control and static cyclotorsion control could be important in the correction of astigmatism. In this study, subgroup analysis showed that low TIA and AE of the TransPRK group were more variable as compared to the Femto-LASIK group. For the eyes with a lower degree of cylindrical correction, our results showed that TransPRK has less favorable astigmatic treatment as compared to Femto-LASIK. The Schwind Amaris 750S machine has a sophisticated, six-axis, eye-tracking system to improve the correction efficiency, and neutralize the cyclotorsion movement of the eyes due to body position changing, the translocation of the pupil center, and the rotation or decentration of the axis during surgery; however, the cooperation from the patients, the wound healing response, and the corneal biomechanics could still affect the measurements of postoperative astigmatism.

A fixed predefined epithelial profile (55 μm centrally and 65 μm periphery) in TransPRK could influence astigmatism correction. Theoretical models have shown that, if the epithelial profile in all four cardinal directions was different, mild astigmatism (≤ 0.63 D) could be induced after TransPRK for normal populations.[7] Therefore, customized epithelial ablations and precise positioning ablative center would be helpful for a more precise correction of astigmatism.

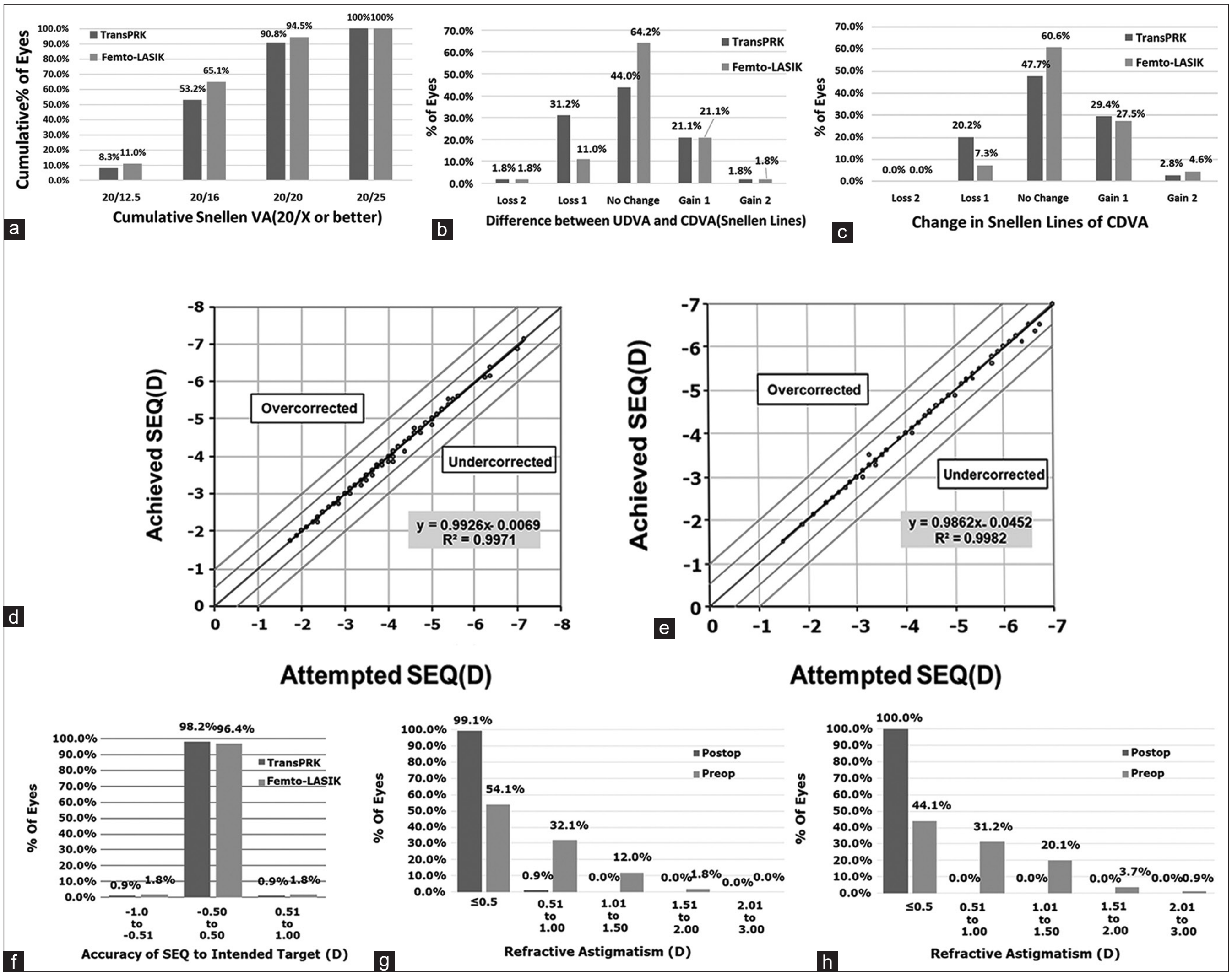

Figure 1: Postoperative visual and refractive outcomes of study subjects for transepithelial photorefractive keratectomy (TransPRK) and femtosecond-assisted laser *in-situ* keratomileusis (Femto-LASIK). (a) Cumulative distribution of the postoperative uncorrected distance visual acuity (UDVA). (b) Difference between postoperative UDVA and preoperative corrected distance visual acuity (CDVA). (c) Change in preoperative and postoperative CDVA. Linear regression analysis of spherical equivalence (SEQ) correction for (d) TransPRK and (e) Femto-LASIK. (f) SEQ refractive accuracy to intended target after surgery. The distribution of astigmatism before and after (g) TransPRK and (h) Femto-LASIK

If OZ is large enough, optimal visual outcomes could be expected after TransPRK surgery. Treating eyes with a thicker central epithelium than the predefined depth leads to a smaller OZ than the planned one. In this study, the intended OZ was the same as or slightly larger than the achieved OZ to avoid suboptimal visual outcomes according to the nomogram.

In this study, the changes in total corneal RMS HOA, SA, and coma increased after surgery in two groups, but the degree of change was higher in the Femto-LASIK group as compared with the TransPRK group at 3 months after surgery. This is likely attributed to the creation of a flap in LASIK as compared to the surface ablation surgeries, such as TransPRK.[24]

There were a few limitations in this study. First, this study is a retrospective study. True epithelial profiles of the study subjects could not be delineated in the retrospective analysis. The comparison between fixed predefined epithelial profile and actual epithelial thickness profile could be conducted in future studies. Second, the follow-up time was relatively short, for 3 months postoperatively. Previous studies reported that no significant differences were found in the manifest refractive spherical equivalent (MRSE) or cylinder between wavefront-optimized versus corneal wavefront-guided TransPRK for myopic astigmatism at 1, 2, 3, and 6 months postoperatively,[25] and in the vector analysis between TransPRK and Femto-LASIK at 1, 3, and 6 months postoperatively.[26] Therefore, the visual and refractive outcomes should be stable after TransPRK and Femto-LASIK at 3 months postoperatively.[18,27] Nevertheless, the evaluation of the visual and refractive outcomes at 6 months postoperatively could be confirmed in further studies. Yet, there could be a concern in the outcome assessment while the patients were still using the fluorometholone eye drops. Third, the preoperative astigmatism was low to moderate. We did not find significant differences in the manifest cylinder between the two groups at 3 months after surgery. Further long-term prospective studies with a larger sample size are warranted to compare higher astigmatic corrections between TransPRK and

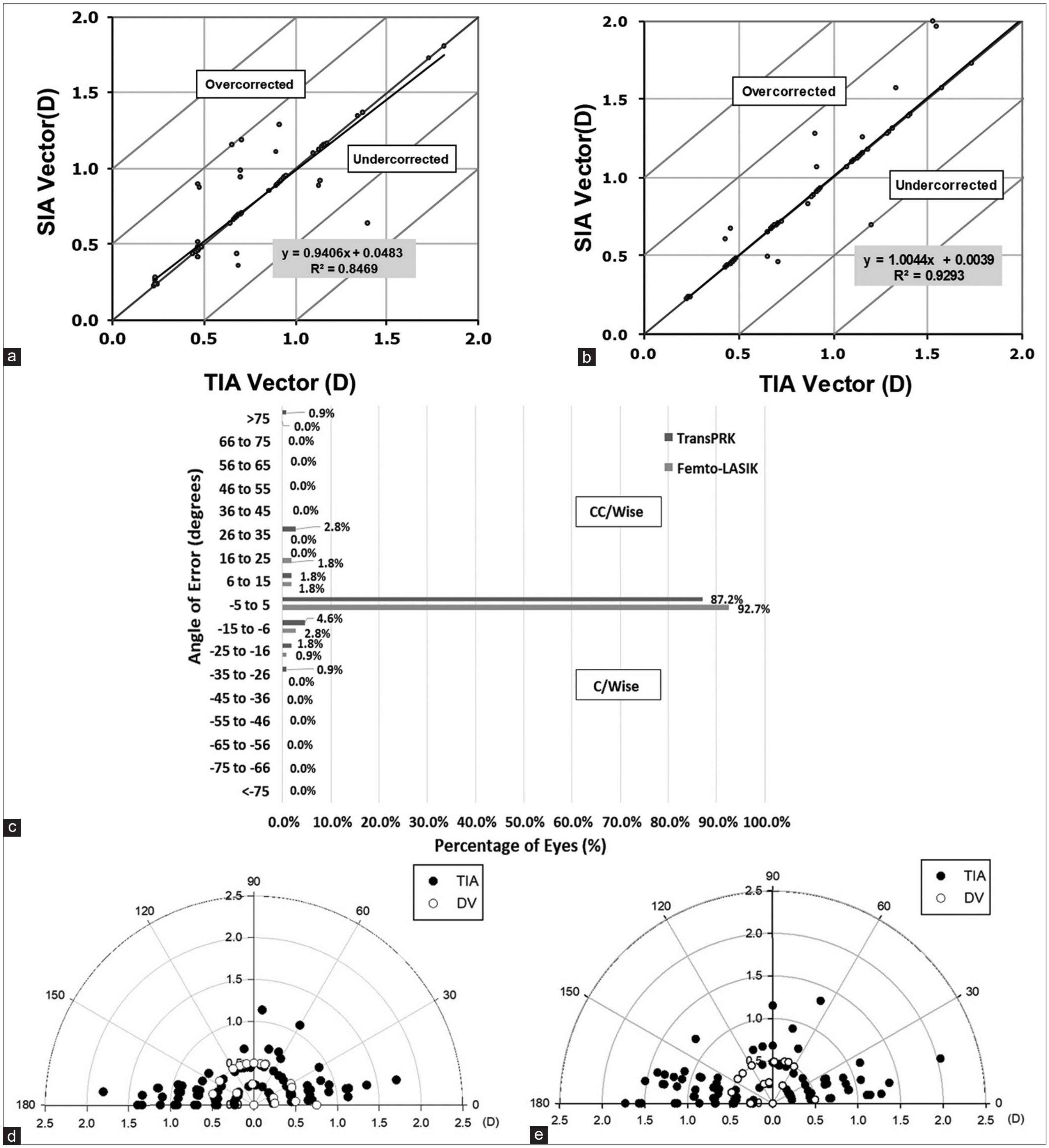

Figure 2: Postoperative vector analysis for transepithelial photorefractive keratectomy (TransPRK) and femtosecond-assisted laser *in-situ* keratomileusis (Femto-LASIK). Linear regression analysis of target-induced astigmatism (TIA) versus surgically induced astigmatism (SIA) after (a) TransPRK and (b) Femto-LASIK. (c) Postoperative distribution of the angle of error (AE). Postoperative polar scatter graphs for TIA and DV. (d) TransPRK; (e) Femto-LASIK

Femto-LASIK. Besides, the astigmatism vector analysis does not fully describe the visual quality of the patients. It should be combined with a subjective visual quality questionnaire and the aberrations of the entire eye to enrich the analysis in future studies.

Conclusion

In summary, this study revealed that TransPRK provides similar astigmatic treatment outcomes to Femto-LASIK for eyes with low to moderate astigmatism. Astigmatism is both slightly overcorrected after TransPRK and Femto-LASIK.

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Conflicts of interest

There are no conflicts of interest.

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