# Clinical Outcomes of Transepithelial Photorefractive Keratectomy According to Epithelial Thickness

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## ABSTRACT

**PURPOSE:** To investigate the clinical outcomes, vector parameters, and corneal aberrations of corneal wavefront-guided (CWFG) transepithelial photorefractive keratectomy (PRK), according to epithelial thickness.

**METHODS:** This retrospective, comparative case series study included 91 eyes (91 patients) that underwent CWFG transepithelial PRK for myopic astigmatism. Epithelial thickness was less than 50 $\mu$m in 48 patients and 60 $\mu$m or greater in 43 patients. Clinical outcomes, including visual acuity, manifest refraction, vector parameters, and corneal wavefront aberration, were compared between the two groups.

**RESULTS:** The mean uncorrected distance visual acuity, safety and efficacy indices, and aberrometric values were comparable between the two groups at 6 months after transepithelial PRK. The postoperative spherical equivalent was significantly different between the two groups: 0.05 ± 0.19 diopters (D) in the less than 50 $\mu$m group and -0.05 ± 0.18 D in the 60 $\mu$m or greater group ($P$ = .009). The difference between the two groups was 0.10 D, which is less than the theoretical difference because the epithelial remodeling pattern was different. There was a slight difference in slope between target induced astigmatism vector and surgically induced astigmatism vector (0.9979 in the less than 50 $\mu$m group and 0.9145 in the 60 $\mu$m or greater group; $P$ = .025).

**CONCLUSIONS:** Transepithelial PRK is an effective and safe treatment modality regardless of epithelial thickness. However, a difference in postoperative refraction is present between the two groups, and astigmatic correction may be less in patients with thick epithelium; hence, a new algorithm is needed that can be tailored in accordance with individual epithelial thickness.


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Transepithelial photorefractive keratectomy (PRK) is a procedure that consists of treating refractive error by removing the epithelium via laser phototherapeutic keratectomy and ablating the corneal stroma via PRK.[1] Recently, single-step transepithelial PRK (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany) that ablates epithelium and stroma in a single step, termed all-surface laser ablation, has become a popular treatment option in the refractive surgery field.[2-4] Epithelial ablation is performed targeting 55 µm at the center and 65 µm at the periphery, based on a previous population-based epithelial profile study,[5] after stromal ablation in a continuous profile; this approach can shorten the surgical time.[3] Furthermore, previous studies have reported that this treatment profile can reduce early postoperative pain, haze formation, and the epithelial healing period when compared with conventional and alcohol-assisted PRK.[2,3]

Although many researchers have shown the excellent efficacy and safety of transepithelial PRK,[1-4] several concerns regarding the correction of refractive errors have been raised because of the inter-individual epithelial thickness profile variability and the associated potential refractive effect.[6,7] Indeed, in a previous study, normal corneal epithelial thickness

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was 53.4 ± 4.6 μm with high variability (43.5 to 63.6 μm).[5] In other studies, mean corneal epithelial thickness was 48.0 to 59.9 μm.[8-11] Furthermore, theoretical calculation of induced refractive errors can range from -1.32 to +1.27 D, in accordance with different epithelial profiles.[7] Recently, corneal epithelial thickness measurement has become popular because of advances in imaging techniques, especially in the keratorefractive surgery field.[12] Epithelial thickness tomography can be clinically applied to screening for high-risk complications, planning treatment profiles, and understanding postoperative clinical outcomes and wound healing.

The aim of the current study was to comparatively investigate the clinical outcomes, including visual acuity, refractive error, and corneal aberrometric changes, based on epithelial thickness after transepithelial PRK.

## PATIENTS AND METHODS

### Study Design

This study comprised a retrospective, comparative, observational case series that was approved by the institutional review board of Yonsei University College of Medicine (Seoul, South Korea; IRB No. 4-2017-1077). The review board waived the requirement for informed consent from patients because of the retrospective nature of the study. The study followed the tenets of the Declaration of Helsinki. Patients enrolled in this study received treatment by corneal wavefront-guided (CWFG) transepithelial PRK from a single experienced surgeon (DSYK) at Eyereum Eye Clinic (Seoul, South Korea) between October 2014 and June 2017.

The inclusion criteria for this study were as follows: less than 10.00 diopters (D) of myopia; between 20 and 45 years of age; stable refraction for at least 1 year; corrected distance visual acuity (CDVA) of 0.8 Snellen fraction or better; and either corneal epithelial thickness less than 50 μm or 60 μm or greater. Because transepithelial PRK ablates 55 μm for the removal of corneal epithelium, we enrolled patients who had a greater than 5 μm difference, with 55 μm reference epithelial thickness, to clarify the effect of corneal epithelial thickness. The exclusion criteria for this study were presence of severe ocular surface diseases, keratoconus, or cataract, and/or history of intraocular or corneal surgery. We retrospectively reviewed the medical records of 91 patients (91 eyes) who met the inclusion and exclusion criteria. If both eyes were eligible to enroll, right or left eye data were randomly chosen using randomization tables, regardless of ocular dominance, refraction, or the presence of aberrations. Patients were divided into two groups based on epithelial thickness: less than 50 μm (48 eyes) or 60 μm or greater (43 eyes).

### Preoperative and Postoperative Assessment

Before surgery, all patients underwent a detailed ophthalmological examination that included evaluation of uncorrected distance visual acuity (UDVA) and CDVA (logMAR), manifest refraction, slit-lamp examination (Haag-Streit, Köniz, Switzerland), keratometry, and Scheimpflug-based corneal topography (Pentacam HR; Oculus Optikgeräte, Wetzlar, Germany). Epithelial thickness and central corneal thickness (CCT) were examined with spectral-domain anterior segment optical coherence tomography (SD-OCT) (RTVue; Optovue, Inc., Fremont, CA), which was performed three or more times to ensure accuracy; average values were used for evaluation. Corneal wavefront aberrations were measured using the Keratron Scout (Optikon 2000, Rome, Italy). All examinations were repeated at 1, 3, and 6 months after surgery.

### Surgical Technique

Surgeries were performed as described previously.[1] Ablation profile planning was performed using the integrated Optimized Refractive Keratectomy-Custom Ablation Manager software (version 5.1; SCHWIND eye-tech-solutions GmbH). A static cyclotorsion compensation algorithm profile was used for CWFG treatment, and dynamic cyclotorsion control was implemented automatically for all treatments. Centration on the corneal vertex was ensured by input from the topographer. The epithelium and stroma were ablated with the SCHWIND Amaris 1050RS excimer laser platform (SCHWIND eye-tech-solutions GmbH), using a single continuous profile. The ablation profiles used here were customized full CWFG ablation profiles, calculated using the ORK-CAM software module (SCHWIND eye-tech-solutions GmbH).

### Statistical Analysis

Data are expressed as mean values ± standard deviation/standard error. The Student's *t* test was used to determine significant differences between the two groups. Continuous variables were compared by linear regression analysis. Statistical analysis was performed using SPSS statistics software (version 23; IBM Corporation, Armonk, NY). A *P* value of less than .05 was considered statistically significant.

## RESULTS

This study included 48 eyes in the less than 50 μm group and 43 eyes in the 60 μm or greater group. The baseline characteristics of both groups are displayed in **Table 1**. There were no significant differences in age, sex, preoperative refractive errors, or preoperative visual acuity. Optic zone, total ablation zone, and abla-

TABLE 1
**Characteristics of Eyes That Underwent Corneal Wavefront-Guided Transepithelial Photorefractive Keratectomy, According to Epithelial Thickness[a]**

| Characteristic | < 50 $\mu$m | ≥ 60 $\mu$m | P |
|---|---|---|---|
| No. of eyes (R/L) | 48 (30/18) | 43 (20/23) | .126 |
| Sex (M/F) | 13/35 | 20/23 | .054 |
| Age, (y) | 27.42 ± 4.79 (20 to 40) | 28.86 ± 5.33 (20 to 44) | .177 |
| Refractive errors (D) | | | |
| Sphere | -4.19 ± 1.53 (-7.00 to -1.00) | -4.04 ± 1.64 (-8.50 to -0.75) | .643 |
| Cylindrical | -0.96 ± 0.74 (-2.87 to 0.00) | -1.17 ± 1.15 (-5.37 to 0.00) | .284 |
| SE | -4.68 ± 1.59 (-7.56 to -1.06) | -4.63 ± 1.80 (-9.56 to -1.00) | .896 |
| logMAR CDVA | -0.11 ± 0.07 (-0.18 to 0.05) | -0.09 ± 0.08 (-0.18 to 0.10) | .168 |
| logMAR UDVA | 1.19 ± 0.26 (0.52 to 1.52) | 1.26 ± 0.27 (0.52 to 2.00) | .180 |
| Preoperative CCT ($\mu$m) | 544.13 ± 26.02 (493 to 606) | 563.88 ± 34.71 (485 to 634) | .006[b] |
| Ablation depth ($\mu$m) | 146.50 ± 20.54 (97.20 to 189.48) | 146.94 ± 24.76 (93.86 to 193.31) | .925 |
| Optical zone (mm) | 6.70 ± 0.23 (6.3 to 7.3) | 6.74 ± 0.29 (6.0 to 7.3) | .577 |
| Total ablation zone (mm) | 8.29 ± 0.20 (7.66 to 8.65) | 8.30 ± 0.18 (7.84 to 8.63) | .684 |
| Epithelium thickness ($\mu$m) | 48.10 ± 1.12 (45 to 49) | 60.60 ± 0.93 (60 to 64) | <.001[b] |
| Stromal thickness ($\mu$m) | 496.00 ± 25.98 (444 to 558) | 503.28 ± 34.67 (425 to 574) | .257 |
| Average K (D) | 43.37 ± 1.06 (41.02 to 45.43) | 43.18 ± 1.91 (38.84 to 47.60) | .545 |
| Equivalent K (D) | 43.29 ± 1.01 (40.54 to 45.43) | 43.18 ± 1.61 (40.03 to 46.81) | .706 |

*D = diopters; SE = spherical equivalent; CDVA = corrected distance visual acuity; UDVA = uncorrected distance visual acuity; CCT = central corneal thickness; K = keratometry*
*[a]Results are expressed as mean ± standard deviation unless otherwise noted.*
*[b]Significantly different between the two groups.*

tion depth also did not differ between the two groups. Although preoperative CCT and epithelial thickness were significantly smaller in the less than 50 µm group, stromal thickness was comparable between the two groups.

### Visual Acuity, Efficacy, and Safety

The mean UDVA significantly improved after transepithelial PRK in both groups (1.19 ± 0.26 to -0.12 ± 0.06 in the less than 50 µm group and 1.26 ± 0.27 to -0.10 ± 0.07 in the 60 µm or greater group; $P$ < .001 for both groups; **Table 1, Table A**, available in the online version of this article). All eyes of the less than 50 µm group (100%), and 42 eyes of the 60 µm or greater group (98%) demonstrated 20/20 or better UDVA at 6 months after surgery (**Figure 1**). At 6 months after surgery, there was no significant difference in mean efficacy index (the ratio of postoperative UDVA to preoperative CDVA) between the less than 50 µm group and the 60 µm or greater group (1.04 ± 0.13, and 1.03 ± 0.10, respectively; $P$ = .514) and in mean safety index (the ratio of postoperative to preoperative CDVA) (1.05 ± 0.14, and 1.04 ± 0.12, respectively; $P$ = .770).

### Refraction

The mean manifest spherical equivalent refraction (SEQ) improved significantly after surgery in both groups (**Table 1**, **Table A**). All treated eyes achieved within 0.50 D of the intended value; linear regression between attempted and achieved SEQ in the less than 50 µm and 60 µm and greater groups showed that the slopes were 0.9939 and 0.9683, respectively, and that the coefficients ($R^2$) were 0.9869 and 0.9906, respectively (**Figure 1**). Although the accuracy of refractive correction was good in both groups, postoperative sphere and SEQ were significantly hyperopic in the less than 50 µm group (**Table A**, **Figure 1**).

### Astigmatism Correction

Outcomes of astigmatism correction demonstrated excellent results, with all treated eyes exhibiting postoperative cylinder of 0.50 D or less (**Figure 1**). Linear regression models of surgically induced astigmatism (SIA) versus target induced astigmatism (TIA) revealed significantly different slopes, which were 0.9979 in the less than 50 µm group and 0.9145 in the 60 µm or greater group ($P$ = .025; **Figure 1**). Further, we performed vector analysis of astigmatism in accordance with the

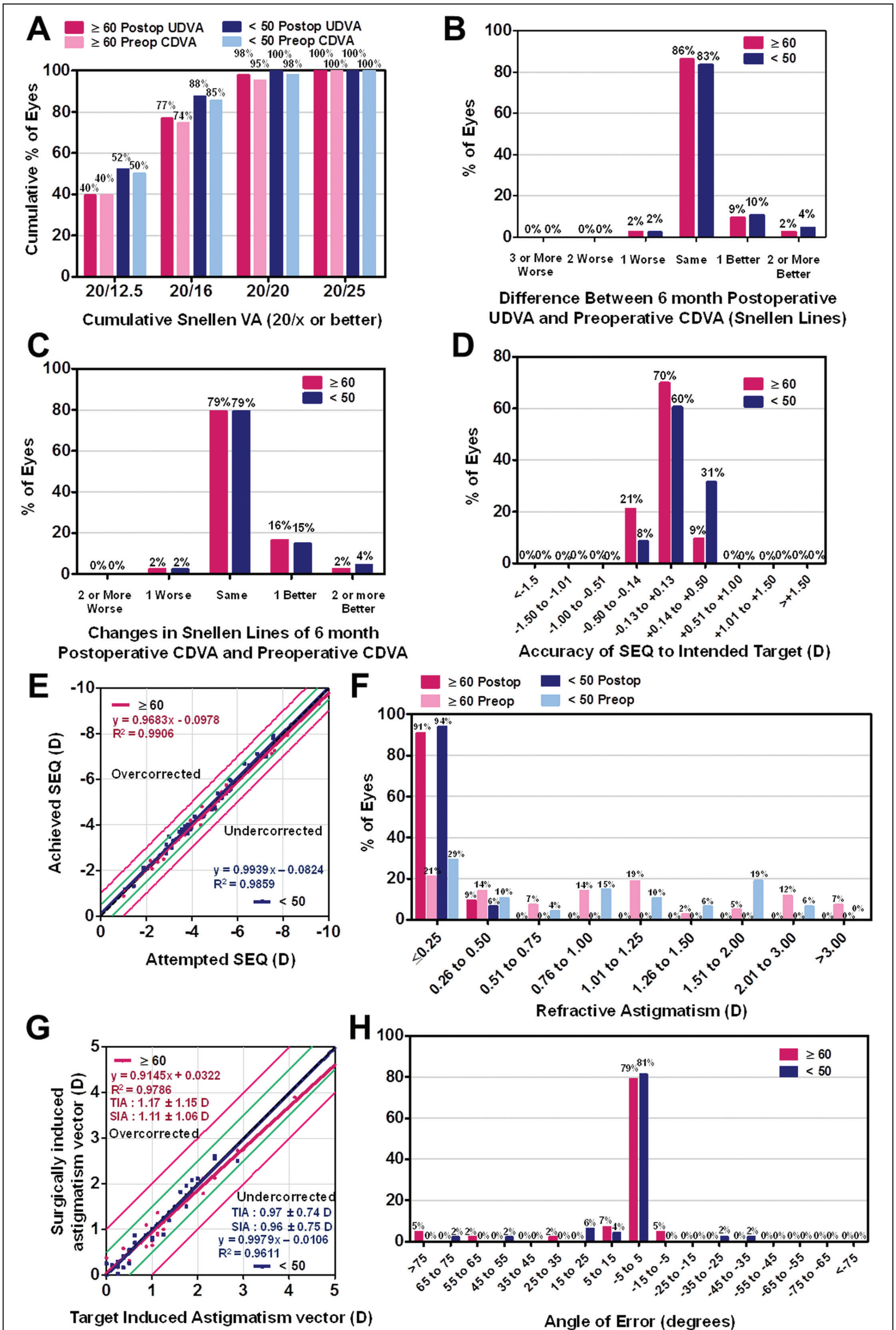


**Figure 1.** Visual outcomes after transepithelial photorefractive keratectomy according to epithelial thickness (≥ 60 $\mu$m = preoperative epithelial thickness ≥ 60 $\mu$m; < 50 = preoperative epithelial thickness < 50 $\mu$m). (A) Cumulative 6-month postoperative uncorrected distance visual acuity (UDVA) and preoperative corrected distance visual acuity (CDVA). Changes in Snellen lines of postoperative (B) UDVA and (C) CDVA, relative to preoperative CDVA. The accuracy of spherical equivalent refraction (SEQ) in relation to the (D) intended target and (E) attempted versus achieved changes in SEQ at 6 months after surgery. Comparative distribution of (F) preoperative and 6-month postoperative cylinder and (G) target induced versus surgically induced astigmatism vectors at 6 months after surgery. (H) Refractive astigmatism angle of error distribution at 6 months after surgery. D = diopters; SD = standard deviation; TIA = target induced astigmatism; SIA = surgically induced astigmatism

method of Alpins (**Table B**, available in the online version of this article).[13,14] Although most values were not significantly different between the two groups, there was a significant difference in the absolute mean values of the magnitude of error between the two groups ($P$ = .028; **Table B**). **Figure A** (available in the online version of this article) shows the polar plots of TIA, SIA, difference vector, and correction index using the same axes.

### Corneal Thickness, Epithelial Thickness, and Stromal Thickness

Preoperative CCT was greater in the 60 µm or greater group; as expected, postoperative CCT was greater in the 60 µm or greater group because of comparable ablation depth (**Table 1**). Preoperative epithelial thickness of the less than 50 µm group was thinner than that of the 60 µm or greater group; similarly, postoperative epithelial thickness of the less than 50 µm group was thinner than that of the 60 µm or greater group (**Table 1**, **Table A**). Interestingly, the less than 50 µm group exhibited increased epithelial thickness at 6 months after surgery, whereas the 60 µm or greater group exhibited decreased epithelial thickness at the same assessment. Preoperative stromal thickness was not significantly different between the two groups; however, the 6-month postoperative stromal thickness was significantly thicker in the 60 µm or greater group (**Table 1**, **Table A**), despite comparable ablation depth.

### Refractive Correction According to Preoperative Refractive Error

There was no significant correlation between SEQ error (attempted minus achieved SEQ) and attempted SEQ in the less than 50 µm group, whereas a mild but significant undercorrecting trend, in accordance with preoperative SEQ, was observed in the 60 µm or greater group (**Figure BA**, available in the online version of this article). Moreover, a significant, negative correlation was noted between TIA and magnitude of error in the 60 µm or greater group, but not in the less than 50 µm group (**Figure BB**). Although a highly linear relationship was observed between achieved SEQ and achieved keratometric changes in both groups ($R^2$ = 0.8997 and 0.8267, respectively), the slope of the less than 50 µm group was 0.9704, whereas that of the 60 µm or greater group was 0.7413; these were significantly different (**Figure BC**).

### Higher Order Aberrations

There were no significant differences between preoperative and postoperative total corneal root mean square higher order aberrations and corneal trefoil in either group (**Table C**, available in the online version of this article, **Figure 2**). In both groups, the corneal spherical aberration significantly increased and the corneal coma significantly decreased at 6 months after surgery. Notably, there were no significant differences between the two groups.

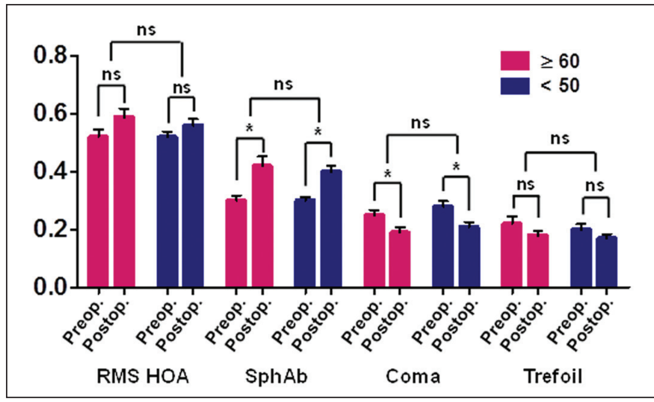


**Figure 2.** Changes in higher order aberrations (HOAs) at 6 months after transepithelial photorefractive keratectomy, according to epithelial thickness (ET) (≥ 60 = preoperative ET ≥ 60 *µ*m; < 50 = preoperative ET < 50 *µ*m). Data are presented as mean values ± standard error of the mean (SEM). RMS = root mean square; SphAb = spherical aberration; ns = not significant; * significant difference

## DISCUSSION

The visual outcomes of this study indicated that transepithelial PRK is a safe and effective modality, as previously shown in other studies,[1-3,15] regardless of preoperative epithelial thickness. However, corneal epithelial thickness varies widely among patients. Previous studies reported mean corneal epithelial thickness as 48.0 to 59.9 µm.[5-11] We undertook this study because differences in the corneal epithelium may cause differences in surgical outcomes of transepithelial PRK targeting 55 µm centrally. There were no significant differences in postoperative UDVA or the efficacy and safety indices between groups. Furthermore, analysis of higher order aberrations revealed that there were no significant differences between the two groups, although a wide optical zone may mask differences.

Although the two groups demonstrated excellent refractive outcomes, there was a significant difference in postoperative sphere and SEQ between groups. The postoperative SEQ demonstrated a mild hyperopic (0.05 D) shift in the less than 50 µm group and a slight myopic (-0.05 D) shift in the 60 µm or greater group (**Table A**). This phenomenon may be explained by less stromal ablation at the same ablation depth setting, due to a thick epithelial thickness in the 60 µm or greater group. Notably, preoperative stromal thickness was comparable between the two groups; however, postoperative stromal thickness was thicker in the 60 µm or greater group, despite comparable ablation depth.

However, we found that although a difference in epithelial thickness of 12 µm between the two groups should theoretically induce an approximately 0.80 D difference (according to analysis by the Munnerlyn formula),[16] the measured difference between the two groups in this study was only 0.10 D. This may be explained by analysis of the postoperative epithelial thickness. Postoperative epithelial thickness increased by approximately 4.3 µm in the less than 50 µm group and decreased by approximately 1.4 µm in the 60 µm or greater group. Many previous studies have reported increased epithelial thickness after keratorefractive surgery, including after transepithelial PRK,[12,17-21] but a few studies have not.[22] Notably, a previous study showed a significant negative correlation between preoperative epithelial thickness and postoperative epithelial thickening.[19] Furthermore, we noted a tendency for smaller preoperative epithelial thickness to be indicative of greater potential postoperative epithelial thickening in another study, although the authors of that study did not focus on that finding.[18] In the context of these studies, corneal epithelial proliferation after surgery may be reduced if the preoperative corneal epithelial thickness is thicker, which is consistent with our results. This phenomenon leads to a smaller refractive difference between the two groups and suggests that optimization based on individual epithelial profile is essential.

In this study, the change of epithelial thickness was 4.3 µm in the less than 50 µm group and -1.4 µm in the 60 µm or greater group, both of which were less than in previous reports. A previous study reported that epithelial thickening was 5.2 µm at 3 months after PRK,[19] whereas another study showed approximately 6 µm of epithelial thickening at 1 year after PRK.[23] In analyses of LASIK surgery, one study reported that the mean epithelial thickening at the corneal vertex was 7.41, 9.29, and 12.33 µm for low, moderate, and high myopia, respectively.[17] Another study showed that epithelial thickness increased by approximately 8 µm after LASIK.[21] Small incision lenticule extraction (SMILE) also results in epithelial thickening after treatment[24-26]; epithelial thickness was reported to increase by 6 µm in SMILE-treated eyes[24] and increased by 3.9 to 7.1 µm, in accordance with the magnitude of myopia.[25] Notably, epithelial thickening after SMILE was smaller and stabilized faster than that after femtosecond laser–assisted LASIK.[26] The thickening of the epithelium may vary depending on the surgical procedure. A single study has demonstrated the epithelial remodeling pattern of transepithelial PRK; the epithelial thickness at 6 months increased by 3.69 µm, which is smaller than the increase that occurred after other surgical techniques.[20] Taken together, our results and previous studies indicate that the epithelial thickening after transepithelial PRK may be less than after other treatments. Moreover, the magnitude of epithelial thickening is greater after small optical zone ablations.[12] Because optical zone and total ablation zone were large in our study, epithelial thickening in our patients was less than reported in other studies. Epithelial thickness may continue to change over time, and 6 months of follow-up may be insufficient for a definitive assessment of epithelial thickness outcomes. However, it has been reported that epithelial thickness does not substantially change after 3 months.[21,27,28] The CWFG profile used in this study may prevent corneal epithelial proliferation by improving smoothness of the corneal surface.

Although the relationship between attempted SEQ and SEQ errors showed a mild tendency for undercorrection in the 60 µm or greater group (**Figure BA**), undercorrection was only -0.22 D when preoperative SEQ was -10.00 D (calculated by the model formula). However, this value may not be clinically meaningful. The relationship between achieved SEQ in the corneal plane and achieved keratometric change was significantly different between the two groups (**Figure BC**). We must be cautious in our interpretation because the keratometry value was calculated with a corneal refractive index of 1.376; however, refractive index exhibits individual variability and its values in epithelium are higher than in stroma.[29] Sample size in this study was relatively small, such that one error in the measured value may have many effects.

Interestingly, although the astigmatic correction of the two groups was generally comparable, the absolute value of the magnitude of error significantly differed between the two groups (**Table B**, **Figure BB**). Further, the difference vector was smaller in the less than 50 µm group, although there was weak statistical evidence for this trend. Moreover, the slopes were significantly different between the two groups in **Figures 1G** and **BB**, which implies that the astigmatism correction in the less than 50 µm group is more substantial than in the 60 µm or greater group. This may be because the optic zone size becomes smaller when the epithelium is thicker during transepithelial PRK.[7]

The epithelial thickness profile of the peripheral cornea could influence refractive error[7]; however, we could not evaluate this parameter due to the small number of cases in the study. Toricity and cylindrical effects of corneal epithelium could influence correction of refractive error, especially in relation to astigmatism. Asymmetry and individual variability of the peripheral epithelial thickness profile may induce marginal amounts of coma and astigmatism when ablated by the symmetric epithelium ablation profile. Furthermore, depending on the particular surgeon's habits and surgical platform, ablation is typically centered on the pupil center or corneal vertex, or at a location between these two. Therefore, a discrepancy may occur between the thinnest point of epithelial thickness and the center of ablation. Toricity and asymmetry may be larger if the central epithelial thickness is large because it would exhibit more reservoirs for variation; this may contribute to reduced astigmatism correction in the 60 µm or greater epithelial thickness group.

Preoperative CCT was approximately 20 µm thicker in the 60 µm or greater group, and stromal thickness was also slightly thicker, although the statistical evidence was weak. Although thicker epithelial thickness may be associated with thicker stromal thickness and CCT, further study is needed to verify this hypothesis. Expected stromal ablation values were 98 µm in the less than 50 µm group and 86 µm in the 60 µm or greater group; however, changes in stromal thickness generally showed 6 µm overablation, which suggests that epithelial thickness is not associated with this phenomenon. Notably, it may be associated with many factors, including operation room conditions, surgical factors, errors in measurements, and inter-machinery variability.

Limitations of this study include its relatively small sample size, non-randomized retrospective design, and lack of functional visual quality evaluation. Nevertheless, this study has many implications because it is the first study to investigate the clinical outcomes of transepithelial PRK based on epithelial thickness, and may address some safety and efficacy concerns related to the fixed epithelium ablation profile in the transepithelial PRK procedure. The post-hoc power of postoperative SEQ and epithelial thickness changes was 0.731 and 1.0, respectively. Thus, the current findings provide insight regarding the proper application of transepithelial PRK in eyes with various epithelial thicknesses. The gender difference may be a confounding factor, despite its borderline significance. Patients in the 60 µm or greater group were older and had higher astigmatism and worse CDVA; however, these differences were not significant. Future studies regarding these parameters may prove useful.

Transepithelial PRK was safe and effective regardless of epithelial thickness as the postoperative epithelial profile compensated for the stromal ablation: thin preoperative epithelial thickness was associated with an increase in postoperative epithelial thickness, whereas thick preoperative epithelial thickness was associated with a decrease in postoperative epithelial thickness.

## AUTHOR CONTRIBUTIONS

Study concept and design (DSYK, EKK, KYS, TK); data collection (DSYK); analysis and interpretation of data (IJ, DSYK, SA-M, TK); writing the manuscript (IJ); critical revision of the manuscript (DSYK, SA-M, EKK, KYS, TK); statistical expertise (SA-M); supervision (TK)

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TABLE A

## Comparison of Postoperative Visual Acuity, Refractive Errors, and Epithelium Thickness of Patients Who Underwent Corneal Wavefront-Guided Transepithelial Photorefractive Keratectomy, According to Epithelial Thickness[a]

| Characteristic | < 50 μm | ≥ 60 μm | *P* |
|---|---|---|---|
| logMAR UDVA | -0.12 ± 0.06 (-0.18 to 0.00) | -0.10 ± 0.07 (-0.18 to 0.10) | .118 |
| logMAR CDVA | -0.12 ± 0.06 (-0.18 to 0.00) | -0.10 ± 0.07 (-0.18 to 0.10) | .162 |
| Sphere (D) | 0.13 ± 0.18 (-0.25 to 0.50) | 0.04 ± 0.18 (-0.25 to 0.50) | .026[b] |
| Cylindrical (D) | -0.15 ± 0.13 (-0.37 to 0.00) | -0.19 ± 0.13 (-0.50 to 0.00) | .176 |
| SE (D) | 0.05 ± 0.19 (-0.25 to 0.50) | -0.05 ± 0.18 (-0.375 to 0.375) | .009[b] |
| CCT (μm) | 444.23 ± 31.50 (379 to 513) | 469.42 ± 42.06 (387 to 550) | .002[b] |
| Δ CCT (preop vs 6 months) (μm) | 99.90 ± 26.81 (35 to 153) | 94.47 ± 28.57 (26 to 144) | .352 |
| Epithelium thickness (μm) | 52.44 ± 3.05 (44 to 59) | 59.19 ± 3.98 (49 to 69) | < .001[b] |
| Δ Epithelium thickness (preop vs 6 months) (μm) | 4.31 ± 2.89 (-3 to 10) | -1.42 ± 4.11 (-11 to 7) | < .001[b] |
| Stromal thickness (μm) | 391.79 ± 31.94 (326 to 461) | 410.21 ± 42.26 (336 to 494) | .020[b] |
| Δ Stromal thickness (preop vs 6 months) (μm) | 104.21 ± 27.44 (39 to 159) | 93.07 ± 28.89 (24 to 139) | .063 |
| Average K (D) | 38.87 ± 1.72 (35.04 to 42.79) | 39.13 ± 2.11 (33.94 to 43.30) | .524 |
| Δ K (preop vs 6 months) (D) | -4.50 ± 1.30 (-7.38 to -1.87) | -4.05 ± 1.12 (-6.08 to -1.61) | .082 |

*UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; D = diopters; SE = spherical equivalent; CCT = central corneal thickness; Δ = change; K = keratometry*

[a]*Results are expressed as mean ± standard deviation (range).*

[b]*Significantly different between the two groups.*

TABLE B

**Comparison of Vector Parameters of Patients Who Underwent Corneal Wavefront-Guided Transepithelial Photorefractive Keratectomy, According to Epithelial Thickness[a]**

| | Total Eyes | | | Right Eyes | | | Left Eyes | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | < 50 μm | ≥ 60 μm | *P* | < 50 μm | ≥ 60 μm | *P* | < 50 μm | ≥ 60 μm | *P* |
| TIA | 0.97 ± 0.74 (0.00 to 2.87) | 1.17 ± 1.15 (0.00 to 5.37) | .314 | 0.87 ± 0.59 (0.00 to 2.00) | 1.24 ± 1.12 (0.00 to 4.12) | .142 | 1.14 ± 0.93 (0.00 to 2.87) | 1.12 ± 1.19 (0.00 to 5.37) | .966 |
| SIA | 0.96 ± 0.75 (0.00 to 2.62) | 1.11 ± 1.06 (0.00 to 5.08) | .443 | 0.84 ± 0.61 (0.00 to 2.11) | 1.17 ± 1.02 (0.12 to 3.90) | .165 | 1.15 ± 0.92 (0.00 to 2.62) | 1.05 ± 1.12 (0.00 to 5.08) | .763 |
| DV | 0.14 ± 0.13 (0.00 to 0.37) | 0.19 ± 0.13 (0.00 to 0.50) | .125 | 0.13 ± 0.13 (0.00 to 0.37) | 0.19 ± 0.12 (0.00 to 0.37) | .086 | 0.17 ± 0.13 (0.00 to 0.37) | 0.18 ± 0.14 (0.00 to 0.50) | .761 |
| CI | 0.98 ± 0.26 (0.10 to 1.80) | 0.92 ± 0.19 (0.51 to 1.58) | .208 | 0.96 ± 0.28 (0.10 to 1.80) | 0.91 ± 0.22 (0.51 to 1.58) | .590 | 1.03 ± 0.23 (0.71 to 1.64) | 0.92 ± 0.16 (0.62 to 1.26) | .097 |
| IOS | 0.25 ± 0.40 (0.00 to 2.08) | 0.18 ± 0.21 (0.00 to 1.00) | .344 | 0.27 ± 0.45 (0.00 to 2.08) | 0.17 ± 0.19 (0.00 to 0.68) | .438 | 0.22 ± 0.27 (0.00 to 1.00) | 0.19 ± 0.23 (0.00 to 1.00) | .683 |
| AofE | 2.81 ± 14.84 (-44 to 66) | 6.58 ± 20.49 (-10 to 87) | .314 | 0.80 ± 13.88 (-44 to 46) | 11.95 ± 27.98 (-6 to 87) | .067 | 6.17 ± 16.15 (-4 to 66) | 1.91 ± 8.74 (-10 to 35) | .287 |
| \|AofE\| | 6.69 ± 13.51 (0 to 66) | 8.26 ± 19.86 (0 to 87) | .658 | 6.40 ± 12.29 (0 to 46) | 12.95 ± 27.50 (0 to 87) | .257 | 7.17 ± 15.71 (0 to 66) | 4.17 ± 7.87 (0 to 35) | .430 |
| MofE | -0.01 ± 0.15 (-0.36 to 0.25) | -0.07 ± 0.18 (-0.35 to 0.37) | .114 | -0.03 ± 0.12 (-0.25 to 0.20) | -0.07 ± 0.21 (-0.35 to 0.37) | .427 | 0.01 ± 0.19 (-0.36 to 0.25) | -0.07 ± 0.17 (-0.33 to 0.25) | .132 |
| \|MofE\| | 0.10 ± 0.11 (0.00 to 0.36) | 0.15 ± 0.12 (0.00 to 0.37) | .028[b] | 0.08 ± 0.09 (0.00 to 0.25) | 0.17 ± 0.12 (0.00 to 0.37) | .004[b] | 0.13 ± 0.13 (0.00 to 0.36) | 0.13 ± 0.12 (0.00 to 0.33) | .875 |

*TIA = target induced astigmatism; SIA = surgically induced astigmatism; DV = difference vector; CI = correction index; IOS = index of success; AofE = angle of error; MofE = magnitude of error*

[a]*Results are expressed as mean ± standard deviation (range).*

[b]*Significantly different between the two groups.*

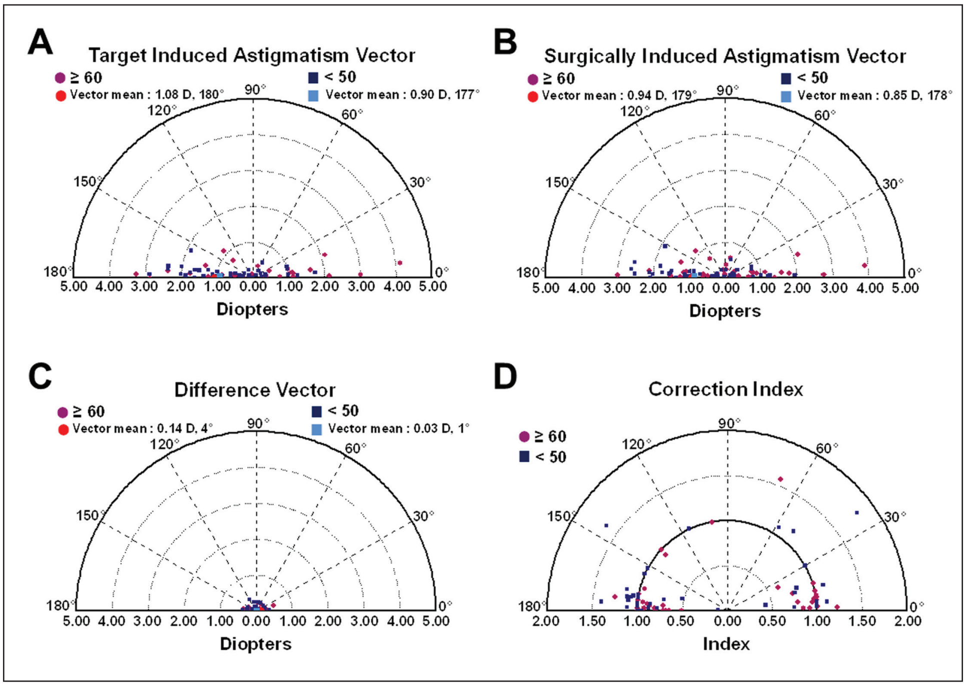


**Figure A.** Single-angle polar plots of (A) target induced astigmatism vector, (B) surgically induced astigmatism vector, (C) difference vector, and (D) correction index at 6 months after transepithelial photorefractive keratectomy, according to epithelial thickness (ET) (≥ 60 = preoperative ET ≥ 60 $\mu$m; < 50 = preoperative ET < 50 $\mu$m). D = diopters

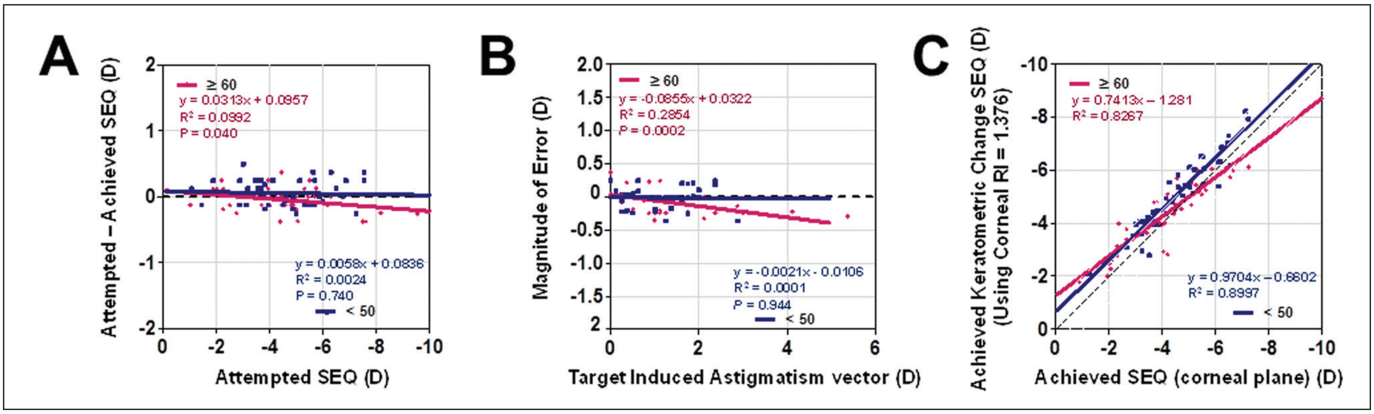


**Figure B.** (A) Spherical equivalent refraction (SEQ) error versus attempted SEQ at 6 months after surgery. (B) Magnitude of error versus target induced astigmatism vector at 6 months after surgery. (C) Achieved SEQ versus achieved keratometric change at the keratometric level, 6 months after surgery. SEQ = spherical equivalent; D = diopters

TABLE C

**Comparison of Corneal Aberrations of Patients Who Underwent Corneal Wavefront-Guided Transepithelial Photorefractive Keratectomy, According to Epithelial Thickness[a]**

| | RMS HOA | | | Spherical Aberration | | | Coma | | | Trefoil | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | < 50 μm | ≥ 60 μm | *P* | < 50 μm | ≥ 60 μm | *P* | < 50 μm | ≥ 60 μm | *P* | < 50 μm | ≥ 60 μm | *P* |
| Preoperative | 0.52 ± 0.13 (0.30 to 0.80) | 0.52 ± 0.15 (0.33 to 1.26) | .861 | 0.30 ± 0.10 (0.13 to 0.61) | 0.30 ± 0.12 (0.04 to 0.62) | .951 | 0.28 ± 0.13 (0.07 to 0.52) | 0.25 ± 0.12 (0.07 to 0.58) | .197 | 0.20 ± 0.13 (0.03 to 0.54) | 0.22 ± 0.17 (0.04 to 0.99) | .572 |
| 6 months postoperative | 0.56 ± 0.15 (0.32 to 0.86) | 0.59 ± 0.19 (0.21 to 1.06) | .376 | 0.40 ± 0.15 (0.15 to 0.75) | 0.42 ± 0.21 (0.00 to 0.84) | .727 | 0.25 ± 0.12 (0.02 to 0.57) | 0.19 ± 0.12 (0.03 to 0.52) | .560 | 0.17 ± 0.10 (0.01 to 0.54) | 0.18 ± 0.12 (0.02 to 0.60) | .682 |
| *P* (vs preoperative) | .183 | .063 | | < .001[b] | .001[b] | | .002[b] | .030[b] | | .136 | .177 | |
| Δ (preoperative vs 6 months postoperative) | 0.04 ± 0.18 (-0.38 to 0.46) | 0.07 ± 0.25 (-0.93 to 0.69) | .414 | 0.11 ± 0.16 (-0.23 to 0.49) | 0.12 ± 0.21 (-0.44 to 0.63) | .709 | -0.07 ± 0.16 (-0.43 to 0.28) | -0.06 ± 0.16 (-0.33 to 0.30) | .564 | -0.03 ± 0.16 (-0.53 to 0.21) | -0.04 ± 0.21 (-0.93 to 0.45) | .828 |

*RMS = root mean square; HOA = higher order aberrations*

[a]*Results are expressed as mean ± standard deviation (range).*

[b]*Significant.*