· Clinical Research ·

Impact of preoperative anterior topographic parameters on effective optical zone after keratorefractive lenticule extraction and wavefront-guided LASIK

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Abstract
● **AIM:** To investigate the impact of preoperative anterior corneal topographic parameters on the morphology of the postoperative effective optical zone (EOZ) in patients undergoing keratorefractive lenticule extraction (KLEx) and wavefront-guided LASIK (WG-LASIK).

● **METHODS:** This retrospective study included 310 eyes from patients who underwent either KLEx (*via* small incision lenticule extraction, 171 eyes) or WG-LASIK (139 eyes). Patients were stratified into subgroups based on the median values of spherical equivalent (SE) and anterior corneal topographic parameters. Postoperative EOZ parameters were measured 1mo after surgery and compared across subgroups. Correlation analysis and multivariable linear regression analysis were performed to explore the associations between preoperative anterior corneal topographic parameters and EOZ parameters.

● **RESULTS:** A total of 310 eyes were included (KLEx: 171 eyes from 88 patients; WG-LASIK: 139 eyes from 82 patients). The mean age was 30.65±5.67y in the KLEx cohort and 29.06±5.94y in the WG-LASIK cohort. In the KLEx cohort, SE, preoperative mean keratometry (Km), steep keratometry (K2), and anterior corneal astigmatism (K2-K1) were positively correlated with the postoperative optical zone reduction ratio (RR=EOZ/planned optical zone ×100%; all $P<0.01$). Multivariable regression identified SE [β=0.027, 95% confidence interval (CI): 0.022-0.032, $P<0.001$], Km (β=0.009, 95%CI: 0.002-0.016, P=0.014), and anterior corneal astigmatism (β=0.031, 95%CI: 0.013-0.049, $P<0.001$) as significant predictors of RR (R^2=0.456, $P<0.001$). In the WG-LASIK cohort, SE was positively correlated with RR ($P<0.01$); K2 and anterior corneal astigmatism were positively correlated with both RR ($P<0.05$) and EOZ eccentricity ($P<0.01$). Multivariable regression showed SE (β=0.015, 95%CI: 0.007-0.023, $P<0.001$) and anterior corneal astigmatism (β=0.029, 95%CI: 0.012-0.047, P=0.001) were significant predictors of RR (R^2=0.121, $P<0.001$).

● **CONCLUSION:** Preoperative anterior corneal topographic parameters, particularly anterior corneal astigmatism, significantly affect postoperative EOZ morphology in both KLEx and WG-LASIK. Additionally, Km is a predictor of EOZ reduction specifically in KLEx.

● **KEYWORDS:** keratorefractive lenticule extraction; wavefront-guided LASIK; anterior corneal topography; effective optical zone; optical zone reduction ratio
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INTRODUCTION
Currently, two popular corneal refractive surgery techniques, keratorefractive lenticule extraction (KLEx) and wavefront-guided laser *in situ* keratomileusis (WG-LASIK), are widely used to safely and effectively correct myopia. Both procedures aim not only to correct refractive errors but also to provide superior visual quality[1]. The effective optical zone (EOZ), also known as the functional optical zone, is a critical concept in corneal refractive surgery, contributing to the postoperative visual quality. It refers to the corneal area that provides functional, high-quality vision following surgery[2]. A smaller or decentered EOZ has been

shown to be associated with increased postoperative higher-order aberrations, more frequent night vision disturbances, and reduced contrast sensitivity[3-10]. Thus, identifying preoperative factors that influence the morphology of the postoperative EOZ is crucial for optimizing patient outcomes.

While several studies have investigated the relationship between preoperative factors such as spherical equivalent (SE), sphere, and cylinder correction with postoperative EOZ[4,11-14], there was limited research examining the influence of anterior topographic parameters like keratometry and corneal asphericity (Q-value)[9,13,15-16]. Therefore, the aim of this study is to comprehensively explore the impact of anterior topographic parameters on postoperative EOZ in patients undergoing KLEx and WG-LASIK.

PARTICIPANTS AND METHODS

Ethical Approval The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB No.202401177B0) and adhered to the principles outlined in the Declaration of Helsinki (2024). As this was a retrospective study that involved the review of existing clinical records and imaging data, the requirement for written informed consent was waived by the IRB. No monetary compensation was provided to participants.

Study Population This study consecutively enrolled patients who underwent KLEx surgeries with small incision lenticule extraction or WG-LASIK for myopia or myopic astigmatism performed by a single experienced refractive surgeon (Sun CC) between 2018 and 2022. Exclusion criteria were: 1) less than one-month postoperative follow-up; 2) incomplete medical records; 3) severe dry eye, glaucoma, ocular inflammation, or retinal diseases; 4) autoimmune disorders; 5) prior ocular surgeries. To examine the impact of baseline SE, anterior keratometry, and Q-value on postoperative outcomes, eyes were stratified by these preoperative variables at the cohort-specific median (The median SE, K1, K2, Km and Q-value were -6, 42.65, 44.2, 43.45 D and -0.35 in the KLEx cohort, while the median values of SE, K1, K2, Km, and Q-value in the WG-LASIK cohort were -6.5, 42.6, 44.3, 43.3 D and -0.32, respectively).

Ophthalmologic Examinations and EOZ Measurement Comprehensive ophthalmologic evaluations were conducted preoperatively and at one month postoperatively. These included a thorough history taking, manifest refraction, non-contact intraocular pressure measurement, slit-lamp examination, fundoscopic examination, and corneal tomography using the Pentacam HR (Oculus, Wetzlar, Germany). Anterior topographic parameters-flat keratometry (K1), steep keratometry (K2), and mean keratometry (Km)-were recorded within a 3 mm zone centered on the corneal vertex, along with the Q-value for corneal asphericity, measured within an 8 mm zone, all using the Pentacam.

EOZ at one-month postoperatively was derived from the tangential curvature difference map (TCDM) of the Pentacam and was defined as the zero-curvature difference contour line on the TCDM. Three investigators (Hsu JH, Tsai TH, and Lin ET) independently assessed EOZ size, decentration, and eccentricity using Image J software (version 1.54; National Institutes of Health, Bethesda, MD, USA). First, a color threshold was applied to highlight the EOZ, and the images were then converted to binary format. Using the relevant Image J tools, several EOZ parameters were extracted. Because the sizes of the planned optical zone (POZ) were not consistent, we expressed postoperative EOZ size as the optical-zone-reduction ratio (RR), calculated as EOZ/POZ×100%. For decentration, the absolute value of decentration (mm), as well as the absolute decentration in both x- and y-axes (mm), was calculated, with the EOZ centroid being compared to the corneal vertex from Pentacam data. Eccentricity was derived from the ratio of the major axis to the minor axis, indicating how much the EOZ deviated from a circular EOZ.

Surgical Technique All KLEx surgeries were performed using the VisuMax 500kHz laser system (Carl Zeiss Meditec AG, Germany) with a pulse energy of 140 nJ. The cap diameter ranged from 7.0 to 8.0 mm, with a cap thickness of 100 to 120 μm, and a POZ of 6.0 to 7.0 mm. A precise 3.0 mm incision was made at the 11 o'clock position. Preoperative triple marking centration at 0°, 180° and 270° was done in all KLEx cases to mitigate the effect of cyclotorsion. For WG-LASIK, preoperative ablation calculations were performed using a Hartmann-Shack aberrometer (iDesign; J&J Vision, Santa Ana, CA, USA), and flaps were created using a 60-kHz intralase femtosecond laser (iFS, J&J Vision, Santa Ana, CA, USA). The flaps had a superior hinge, with a diameter of 9.0 mm and thickness between 100 and 120 μm. After flap creation, the ablation was carried out using the Star S4IR excimer laser (J&J Vision, Santa Ana, CA, USA) with a POZ of 6.0 to 7.5 mm and an ablation zone of 8.0 mm. X-Y-Z tracking and iris registration for torsional tracking were performed in all cases. Postoperatively, patients were prescribed a two-week course of 1% prednisolone acetate ophthalmic suspension (Prednicone; Winston, Taiwan, China) and 0.5% levofloxacin ophthalmic solution (Cravit; Santen, Japan).

Statistical Analysis The Kolmogorov-Smirnov test was used to assess data distribution, revealing a non-parametric distribution on both surgery cohorts. Continuous variables were expressed as mean±standard deviation. Differences in continuous variables between the high- and low-SE subgroups, as well as between the subgroups stratified by anterior topographic parameters, were compared with the Mann-Whitney *U* tests. Spearman's correlation analysis

Table 1 Preoperative patient characteristics subcategorized by anterior topographic parameters

Parameters	*n*	Age, y	SE, D	Pupil size, mm	Angle kappa, mm	POZ, mm
KLEx						
Overall	171	30.65±5.67	-6.33±2.24	6.64±0.67	0.20±0.11	6.56±0.29
K1, D						
>42.65 D	85	30.84±5.88	-6.33±2.16	6.61±0.64	0.19±0.11	6.56±0.32
≤42.65 D	86	30.48±5.52	-6.33±2.35	6.68±0.72	0.20±0.11	6.56±0.27
P		0.691	0.695	0.471	0.501	0.564
K2, D						
>44.2 D	87	30.66±5.72	-6.31±2.20	6.60±0.61	0.19±0.11	6.55±0.31
≤44.2 D	84	30.66±5.69	-6.35±2.32	6.70±0.74	0.21±0.11	6.57±0.27
P		0.889	0.806	0.446	0.167	0.975
Km, D						
>43.45 D	85	30.92±5.87	-6.21±2.12	6.61±0.63	0.19±0.11	6.57±0.30
≤43.45 D	86	30.40±5.52	-6.44±2.39	6.68±0.72	0.20±0.11	6.55±0.28
P		0.531	0.811	0.562	0.524	0.512
Q value						
>-0.35	95	31.54±6.26	-6.41±2.32	6.58±0.73	0.19±0.10	6.56±0.26
≤-0.35	76	29.55±4.69	-6.23±2.17	6.73±0.60	0.21±0.12	6.56±0.33
P		0.07	0.596	0.108	0.484	0.846
WG-LASIK						
Overall	139	29.06±5.94	-6.34±1.65	6.63±0.65	0.20±0.10	6.87±0.23
K1, D						
>42.6 D	71	30.82±6.62	-6.29±1.61	6.64±0.65	0.20±0.11	6.88±0.21
≤42.6 D	68	27.22±4.55	-6.40±1.71	6.62±0.66	0.21±0.10	6.86±0.25
P		0.002	0.683	0.74	0.415	0.931
K2, D						
>44.3 D	70	30.49±6.66	-6.50±1.60	6.64±0.68	0.20±0.11	6.86±0.22
≤44.3 D	69	27.61±4.78	-6.18±1.71	6.63±0.63	0.20±0.09	6.88±0.24
P		0.028	0.211	0.667	0.923	0.392
Km, D						
>43.3 D	71	30.52±6.74	-6.30±1.64	6.64±0.65	0.20±0.11	6.88±0.22
≤43.3 D	68	27.53±4.60	-6.39±1.68	6.63±0.66	0.21±0.09	6.87±0.25
P		0.022	0.763	0.765	0.766	0.916
Q value						
>-0.32	73	29.66±5.15	-6.35±1.60	6.65±0.65	0.20±0.10	6.88±0.22
≤-0.32	66	28.39±6.72	-6.34±1.73	6.61±0.67	0.21±0.11	6.87±0.25
P		0.116	0.931	0.667	0.594	0.998

Continuous variables are expressed as mean±standard deviation. KLEx: Keratorefractive lenticule extraction; WG-LASIK: Wavefront-guided laser *in situ* keratomileusis; SE: Spherical equivalent; K1: Flat keratometry; K2: Steep keratometry; Km: Mean keratometry; POZ: Planned optical zone.

was conducted to explore the relationships between SE, anterior topographic parameters (K1, K2, Km, anterior corneal astigmatism, Q value), and EOZ, with correlation coefficient (r) ≥0.2 regarded as meaningful correlation. Linear regression analyses were conducted with postoperative EOZ parameters as dependent variables, while age and any covariate showing an absolute correlation coefficient of ≥0.2 served as independent predictors. P<0.05 was considered statistically significant. The minimum sample size was calculated from the planned multivariable regression of preoperative predictors against EOZ outcomes. For a regression model designed to detect an R^2≥0.10 at a significance level of 0.05 and a power of 0.80, a minimum sample size of 75 eyes was required for each procedure group. All statistical analyses were performed with SPSS version 29.0.2.0.

RESULTS

Preoperative Patient Characteristics A total of 310 eyes were included in our study (KLEx: 171 eyes from 88 patients; WG-LASIK: 139 eyes from 82 patients). Baseline patient characteristics were demonstrated in Table 1. The average age was 30.65±5.67y in the KLEx cohort and 29.06±5.94y in the WG-LASIK cohort. For KLEx patients, the average

Table 2 Preoperative patient characteristics subcategorized by spherical equivalent

Parameters	*n*	Age, y	Pupil size, mm	K1, D	K2, D	Km, D	Q value	Angle kappa, mm	POZ, mm
KLEx									
Overall	171	30.65±5.67	6.64±0.67	42.78±1.49	44.24±1.60	43.50±1.51	-0.34±0.11	0.20±0.11	6.56±0.29
SE, D									
>-6 D	81	29.70±5.17	6.58±0.63	42.74±1.47	44.24±1.62	43.49±1.51	-0.35±0.10	0.19±0.12	6.73±0.17
≤-6 D	90	31.51±6.02	6.70±0.72	42.81±1.53	44.25±1.62	43.51±1.53	-0.34±0.12	0.20±0.10	6.41±0.29
P		0.069	0.386	0.854	0.897	0.995	0.367	0.225	<0.001
WG-LASIK									
Overall	139	29.06±5.94	6.63±0.65	42.57±1.45	44.37±1.61	43.44±1.49	-0.33±0.11	0.20±0.10	6.87±0.23
SE, D									
>-6.5 D	68	29.29±5.70	6.64±0.65	42.70±1.46	44.35±1.68	43.51±1.53	-0.33±0.10	0.19±0.10	7.02±0.14
≤-6.5 D	71	28.83±6.23	6.63±0.66	42.44±1.46	44.38±1.57	43.38±1.47	-0.33±0.12	0.22±0.10	6.73±0.22
P		0.67	0.955	0.479	0.657	0.929	0.963	0.092	<0.001

Continuous variables are expressed as mean±standard deviation. KLEx: Keratorefractive lenticule extraction; WG-LASIK: Wavefront-guided laser *in situ* keratomileusis; SE: Spherical equivalent; K1: Flat keratometry; K2: Steep keratometry; Km: Mean keratometry; POZ: Planned optical zone.

SE, K1, K2, Km, Q-value, and angle kappa were -6.33±2.24, 42.78±1.49, 44.24±1.60, 43.50±1.51 D, -0.34±0.11, and 0.20±0.11 mm, respectively. In the WG-LASIK cohort, these values were -6.34±1.65, 42.57±1.45, 44.37±1.61, 43.44±1.49 D, -0.33±1.11, and 0.20±0.10 mm, respectively.

Across both surgical cohorts, eyes in the higher myopia (more-negative SE) subgroup were assigned a significantly smaller POZ (*P*<0.001). Within the WG-LASIK cohort, patients with steeper corneas (higher K1, K2, and Km) were older (*P*=0.002, 0.028, and 0.022, respectively). No other baseline demographic differences were observed (Table 2).

EOZ Parameters One Month after KLEx and WG-LASIK Table 3 summarizes the comparisons of EOZ parameters between subgroups. Among KLEx patients, the RR was significantly lower in those with a more-negative SE compared to those with SE>-6 D, with values of 66.6%±7.2% and 75.8%±9.9%, respectively (*P*<0.001). Similarly, patients with lower K1 (K1≤42.65 D) had a lower RR than those with higher K1 (K1>42.65 D), showing values of 69.4%±9% and 72.5%±10.3%, respectively (*P*=0.032). For K2, a lower RR was observed in patients with lower K2 (K2≤44.2 D) compared to those with higher K2 (K2>44.2 D), with respective values of 68.9%±9.2% and 73.0%±9.9% (*P*=0.005). Additionally, lower Km (Km≤43.45 D) was associated with a significantly lower RR than higher Km (Km>43.45 D), with values of 69.1%±9.0% and 72.8%±10.2%, respectively (*P*=0.012).

In the WG-LASIK cohort, patients with SE≤-6.5 D also had a significantly lower RR compared to those with SE>6.5 D, with values of 70.9±7.7% and 73.9±8.5%, respectively (*P*=0.027). Similarly, patients with lower K2 (K2≤44.3 D) exhibited a lower RR compared to those with higher K2 (K2>44.3 D), with respective values of 70.8%±8.1% and 73.9%±8.1% (*P*=0.007). Patients with lower K2 (K2≤44.3 D) exhibited less eccentricity compared to those with higher K2 (K2>44.3 D), with respective values of 1.12±0.09 and 1.15±0.07 (*P*=0.018).

Correlation and Linear Regression Between SE, Anterior Topographic Parameters, and EOZ Correlation analysis demonstrated significant positive correlations with *r*≥0.2 between SE, K2, Km, anterior corneal astigmatism (K2-K1), and RR in KLEx patients (*P*<0.01). A similar positive association was found between K2 and eccentricity (*P*<0.01). In WG-LASIK patients, significant positive correlations with *r*≥0.2 were observed between SE, K2, anterior corneal astigmatism, and RR (*P*<0.05), with comparable correlations between K2, anterior corneal astigmatism, and eccentricity (*P*<0.01). Detailed results are presented in Table 4.

Multivariable regression analysis as shown in Table 5 included significant variables with *r*≥0.2 from the correlation analysis. In the KLEx cohort, SE (*β*=0.027, 95%CI: 0.022-0.032, *P*<0.001), anterior corneal astigmatism (*β*=0.031, 95%CI: 0.013-0.049, *P*<0.001), and Km (*β*=0.009, 95%CI: 0.002-0.016, *P*=0.014) emerged as significant predictors of RR (R^2=0.456, *P*<0.001). Similarly, in the WG-LASIK cohort, SE (*β*=0.015, 95%CI: 0.007-0.023, *P*<0.001) and anterior corneal astigmatism (*β*=0.029, 95%CI: 0.012-0.047, *P*=0.001) were significant predictors of RR (R^2=0.121, *P*<0.001). Additionally, anterior corneal astigmatism (*β*=0.064, 95%CI: 0.050-0.079, *P*<0.001) was a significant predictor of eccentricity in WG-LASIK patients (R^2=0.355, *P*<0.001).

DISCUSSION

In this study, we identified the impact of preoperative SE and anterior topographic parameters on EOZ morphology following KLEx and WG-LASIK procedures. In the KLEx cohort, preoperative SE, Km, and anterior corneal astigmatism were predictive of RR. In the WG-LASIK cohort, only SE and anterior corneal astigmatism were predictive of RR. Additionally, we observed that anterior corneal astigmatism was predictive of eccentricity in WG-LASIK patients. This

Table 3 EOZ parameters at one-month postoperatively

Parameters	*n*	RR, %	Decentration, mm	Absolute X-decentration, mm	Absolute Y-decentration, mm	Eccentricity
KLEx						
Overall	171	71.0±9.7	0.32±0.17	0.17±0.12	0.23±0.18	1.11±0.07
SE, D						
>-6	81	75.8±9.9	0.31±0.16	0.17±0.11	0.23±0.18	1.11±0.08
≤-6	90	66.6±7.2	0.32±0.18	0.17±0.13	0.24±0.18	1.10±0.08
P		<0.001	0.909	0.777	0.697	0.1
K1, D						
>42.65	85	72.5±10.3	0.33±0.18	0.16±0.12	0.26±0.20	1.11±0.07
≤42.65	86	69.4±9.0	0.3±0.15	0.18±0.12	0.21±0.15	1.10±0.08
P		0.032	0.28	0.195	0.139	0.472
K2, D						
>44.2	87	73.0±9.9	0.32±0.18	0.15±0.11	0.24±0.20	1.11±0.07
≤44.2	84	68.9±9.2	0.31±0.15	0.18±0.13	0.22±0.16	1.10±0.08
P		0.005	0.965	0.117	0.715	0.086
Km, D						
>43.45	85	72.8±10.2	0.32±0.18	0.15±0.11	0.25±0.20	1.11±0.07
≤43.45	86	69.1±9.0	0.31±0.16	0.19±0.12	0.21±0.16	1.10±0.08
P		0.012	0.711	0.052	0.291	0.274
Q-value						
>-0.35	95	70.8±9.6	0.32±0.16	0.16±0.11	0.24±0.18	1.11±0.08
≤-0.35	76	71.2±10.0	0.31±0.18	0.17±0.12	0.22±0.18	1.10±0.07
P		0.858	0.567	0.572	0.274	0.574
WG-LASIK						
Overall	139	72.4±8.2	0.39±0.22	0.25±0.17	0.25±0.22	1.14±0.08
SE, D						
>-6.5	68	73.9±8.5	0.42±0.22	0.26±0.17	0.27±0.23	1.13±0.09
≤-6.5	71	70.9±7.7	0.37±0.22	0.24±0.18	0.22±0.22	1.14±0.08
P		0.027	0.09	0.289	0.144	0.807
K1, D						
>42.6	71	72.9±8.1	0.41±0.23	0.25±0.18	0.28±0.23	1.13±0.07
≤42.6	68	71.8±8.3	0.37±0.21	0.25±0.17	0.21±0.21	1.14±0.09
P		0.294	0.266	0.878	0.101	0.876
K2, D						
>44.3	70	73.9±8.1	0.40±0.23	0.26±0.18	0.25±0.22	1.15±0.07
≤44.3	69	70.8±8.1	0.38±0.22	0.24±0.17	0.24±0.22	1.12±0.09
P		0.007	0.61	0.504	0.537	0.018
Km, D						
>43.3	71	73.2±8.1	0.41±0.23	0.25±0.18	0.27±0.23	1.13±0.07
≤43.3	68	71.5±8.3	0.37±0.21	0.25±0.17	0.22±0.21	1.14±0.09
P		0.118	0.399	0.861	0.141	0.943
Q-value						
>-0.32	73	71.7±8.2	0.41±0.23	0.26±0.18	0.26±0.24	1.13±0.07
≤-0.32	66	73.1±8.3	0.37±0.21	0.23±0.17	0.23±0.21	1.14±0.09
P		0.271	0.229	0.186	0.649	0.692

Continuous variables are expressed as mean±standard deviation. KLEx: Keratorefractive lenticule extraction; WG-LASIK: Wavefront-guided laser *in situ* keratomileusis; SE: Spherical equivalent; K1: Flat keratometry; K2: Steep keratometry; Km: Mean keratometry; RR (%): Optical-zone-reduction ratio (EOZ/POZ); EOZ: Effective optical zone; POZ: Planned optical zone.

is the first study to comprehensively examine the impact of baseline anterior topographic parameters in both surgeries.

Preoperatively, there were no significant differences in age, pupil size or angle kappa between subgroups with high and low SE or anterior topographic parameters in the KLEx cohort. However, in the WG-LASIK cohort, older age was

Table 4 Correlation analysis of preoperative SE and anterior topographic parameters with EOZ

Parameters	SE	K1	K2	Km	K2-K1	Q value
KLEx						
RR	0.62[b]	0.19[a]	0.27[b]	0.24[b]	0.29[b]	0.04
Decentration	0.01	0.08	0.04	0.05	-0.10	0.06
Absolute X-decentration	-0.04	-0.15	-0.15[a]	-0.16[a]	-0.03	-0.04
Absolute Y-decentration	-0.01	0.13	0.10	0.11	-0.08	0.11
Eccentricity	0.14	0.04	-0.17[a]	0.11	0.39[b]	0.02
WG-LAIK						
RR	0.22[b]	0.10	0.21[a]	0.16	0.20[a]	-0.05
Decentration	0.17[a]	0.10	0.08	0.09	-0.04	0.06
Absolute X-decentration	0.12	-0.02	0.02	0.01	0.09	0.04
Absolute Y-decentration	0.13	0.19[a]	0.12	0.16	-0.08	0.04
Eccentricity	-0.02	0.01	0.30[b]	0.16	0.64[b]	-0.06

[a]Correlation is significant at the 0.05 level (2-tailed); [b]Correlation is significant at the 0.01 level (2-tailed). KLEx: Keratorefractive lenticule extraction; WG-LASIK: Wavefront-guided laser *in situ* keratomileusis; SE: Spherical equivalent; K1: Flat keratometry; K2: Steep keratometry; Km: Mean keratometry; RR (%): Optical-zone-reduction ratio (EOZ/POZ); EOZ: Effective optical zone; POZ: Planned optical zone.

Table 5 Multivariable linear regression of SE and anterior topographic parameters as predictors of EOZ

Variables	Unstandardized *B*	95%CI	*P*	Adjusted R^2	Model *P* value
KLEx					
RR					
SE	0.027	0.022; 0.032	<0.001	0.456	<0.001
K2-K1	0.031	0.013; 0.049	<0.001		
Km	0.009	0.002; 0.016	0.014		
WG-LASIK					
RR					
SE	0.015	0.007; 0.023	<0.001	0.121	<0.001
K2-K1	0.029	0.012; 0.047	0.001		
Eccentricity					
K2-K1	0.064	0.050; 0.079	<0.001	0.355	<0.001

KLEx: Keratorefractive lenticule extraction; WG-LASIK: Wavefront-guided laser *in situ* keratomileusis; SE: Spherical equivalent; K1: Flat keratometry; K2: Steep keratometry; Km: Mean keratometry; RR (%): Optical-zone-reduction ratio (EOZ/POZ); EOZ: Effective optical zone; POZ: Planned optical zone; CI: Confidence interval.

significantly associated with higher K1, K2, and Km values. This finding is consistent with previous reports in the general population[17-18]. Nonetheless, the age difference across these subgroups was approximately 3y, which may not be clinically significant. In both cohorts, the POZ was significantly smaller in patients with higher refractive errors, which aligns with the Munnerlyn *et al*[19] formula for a fixed ablation depth. Our cohort reflects real-world data, as POZ size was limited in high myopic patients to preserve residual corneal thickness. To address this variability in the patient demographics, we evaluated postoperative changes in optical zone size as a percentage (RR, %), eliminating the potential bias caused by differences in POZ.

As a result, postoperative RR was lower in subgroups with a more-negative preoperative SE in both cohorts. This is consistent with previous findings that higher myopic corrections are associated with greater postoperative optical zone reduction following both KLEx[12-14,20] and LASIK[3-4]. These results may be attributed to increased postoperative wound healing reactions caused by the higher laser energy required for correcting high myopia[21]. Consequently, patients with high myopia may experience both a smaller POZ and greater postoperative optical zone reduction. Surgeons should exercise caution when planning such procedures, as a smaller EOZ can negatively impact visual quality[10,22-24].

In the current study, we observed the impact of preoperative anterior corneal contour on postoperative EOZ reduction after two refractive procedures. In KLEx cohort, we found that patients with flatter K1, K2, and Km exhibited significantly lower RR. This is consistent with other studies that also reported a positive correlation between the anterior corneal curvature and postoperative EOZ[13,15]. Chan *et al*[9] suggested that mismatched contact surfaces between the patient's cornea and the contact cone may affect the EOZ after KLEx surgery. Wang and Xia[15] further proposed that postoperative EOZ might be influenced by the discrepancy between the patient's steep keratometry and the curvature of the contact cone during the KLEx procedure. Additionally, we found that other than anterior keratometry, anterior corneal astigmatism, was positively correlated with RR, in line with previous studies[7,20,25]. Ding *et al*[7] reported that larger corneal volume reduction was found in lower astigmatism patients, which could result in greater corneal biomechanical change and remodeling in the peripheral corneal stroma, leading to a smaller EOZ.

In the WG-LASIK cohort, we also found a positive association between anterior corneal astigmatism and RR. This is consistent with previous findings that higher corneal cylinder correction is associated with a larger and more elliptical postoperative EOZ[14]. Huang *et al*[26] similarly proposed that, as with the KLEx procedure, higher astigmatism is linked to a larger EOZ due to better preservation of corneal contour And since excimer laser ablation in WG-LASIK does not require a patient interface intraoperatively, there is no interaction between the cone and the anterior corneal surface, which could otherwise affect the EOZ. Therefore, we propose that corneal astigmatism, rather than anterior keratometry values, is the key variable influencing postoperative EOZ reduction in WG-LASIK. Nonetheless, a significantly lower RR was observed only in the flatter K2 subgroup, but not in the K1 or Km subgroups, unlike in the KLEx cohort. We hypothesize that the increase in anterior corneal astigmatism may be partially driven by the increase in K2, which explains the similar positive correlations between K2 and RR.

Previous studies have shown that a greater change in postoperative Q-value is associated with a smaller EOZ in patients undergoing both KLEx and LASIK[7,13,26-27]. The KLEx procedure has been observed to induce less change in Q-value compared to LASIK, which may contribute to a larger postoperative EOZ area[16,27]. Our study also observed similar trends. RR was negatively correlated with both postoperative Q-value (KLEx: r=-0.693, P<0.001; WG-LASIK: r=-0.360, P<0.001) and the change between preoperative and postoperative Q-value (KLEx: r=-0.721, P<0.001; WG-LASIK: r=-0.338, P<0.001). However, while previous studies primarily investigated changes in Q-value or postoperative Q-value as predictors of EOZ[7,13,26-27], our analysis focused on whether preoperative Q-value could predict postoperative EOZ reduction. We found no significant difference in RR when stratified by preoperative corneal asphericity, nor was there a significant correlation between preoperative Q-value and RR. One possible explanation is that early epithelial and stromal remodeling likely mediates much of the observed EOZ change[27], weakening the contribution of initial Q value. These findings suggest that preoperative corneal asphericity alone may not be an effective predictor of postoperative EOZ reduction, regardless of the surgical technique used. Additionally, we found that EOZ eccentricity after both procedures may be influenced by anterior corneal parameters, particularly corneal astigmatism. This could be due to the shape of the optical zone in astigmatism correction, which tends to be more elliptical after refractive surgery[14]. Deviations from a circular optical zone may ultimately contribute to increased eccentricity.

To better identify preoperative predictors of postoperative EOZ parameters, we performed multivariable regression analyses. In both cohorts, the magnitude of refractive errors had the largest impact on EOZ reductions. In the KLEx cohort, anterior corneal astigmatism and mean keratometry were also significant predictors of postoperative EOZ change, reaffirming that EOZ size in KLEx can be affected by both the mismatched contact surface and the degree of astigmatism correction. In the WG-LASIK cohort, only anterior corneal astigmatism, rather than other corneal curvature parameters, significantly predicted EOZ change. This finding indicated that anterior corneal astigmatism was a primary factor influencing EOZ reduction. Similarly, anterior corneal astigmatism was the sole significant predictor of EOZ eccentricity after WG-LASIK. A study published by Song *et al*[28] as well compared EOZ behavior after SMILE and FS-LASIK in multivariable models. They showed that postoperative reductions in corneal asphericity and increases in spherical aberration were the principal drivers of EOZ shrinkage[28]. Our study extends these observations by focusing exclusively on preoperative predictors. Because these parameters are known at the initial assessment, they enable surgeons to enlarge the POZ or adjust centration before performing surgery, an advantage not afforded by models that depend on postoperative metrics. We did not analyze baseline spherical aberration, but, as with Q-value, its change rather than its preoperative magnitude is likely more informative for forecasting EOZ morphology.

Taken together, our findings suggest a practical rule: when a KLEx candidate has a steep Km—or when either procedure is planned for an eye with a very negative SE and low astigmatism—surgeons should program the POZ slightly larger than the standard nomogram, provided residual stromal thickness is adequate, to offset predictable postoperative shrinkage of optical zone and preserve visual quality. This recommendation should, however, be interpreted in light of our study's limitations. First, follow up was restricted to one month. EOZ is a dynamic metric that continues to remodel after surgery: epithelial remodeling typically stabilizes three to six months postoperatively[29]. Nevertheless, Liu *et al*[25] showed that EOZ changes beyond the first postoperative month are small compared with the pronounced early shift, suggesting that our one-month data capture the majority of clinically relevant remodeling. Further studies are needed to assess longer-term effects. Second, as a retrospective study, we did not match POZ across varying magnitudes of refractive correction. However, we aimed to present real-world data, recognizing that POZ design is often constrained by the relationship between refractive correction and corneal thickness. To minimize the impact of POZ variability, we analyzed EOZ change as a percentage of the POZ.

In conclusion, factors beyond SE can help predict EOZ morphology. In KLEx, a steeper mean keratometry and greater anterior corneal astigmatism are linked to a larger postoperative EOZ, whereas in WG-LASIK, anterior corneal astigmatism shows a positive association with both EOZ size and eccentricity.

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