SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 6825-6828
Open Access. Online & Print

DOI: 10.5281/zenodo.12426702

ASSESSMENT OF INDUCED HIGH-ORDER ABERRATIONS IN PATIENTS TREATED WITH PHOTOREFRACTIVE KERATECTOMY FOR MANAGEMENT OF MYOPIA

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Received: **19/10/2025**
Accepted: **11/01/2026**

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ABSTRACT

Excimer laser is utilized in common laser eye surgery techniques including LASIK (Laser-Assisted In-Situ Keratomileusis) and PRK (Photorefractive Keratectomy). Both techniques are commonly used to correct myopia and hypermetropia; which are known as "lower order aberrations". Lower order aberrations can be corrected leaving higher-order aberrations uncorrected or inducing some higher order aberrations (HOAs) mainly spherical aberrations which are assumed to be responsible for patients' complaints of poor vision quality, even with postoperative visual acuity of 20/25 or 20/20. So, this study aimed at assessing the effect of PRK using excimer laser in induction of High Order Aberrations (HOAs) in the cornea by measuring the high order aberrations before and after PRK procedure. An interventional study was conducted at Bahgat Eye Clinic, Egypt. The participants included were patients already scheduled to undergo PRK surgery in the clinic, myopic less than 6 Diopters and including both sexes aged between 20-35 years. While those with keratoconus and previous eye surgeries were excluded. All patients underwent complete ophthalmic examination using AUTO REF device, measuring the thickness, curvature and power of the cornea by pentacam device, measuring aberrations and optical distortions using wavefront analysis, determining the appropriate laser (excimer laser) dose and applying it to the patient's cornea. Re-measurement of the thickness and dimensions of the cornea and aberration was done 6 months after the operation. Six months after PRK, there was a marked increase with statistically significant change in both spherical and cylindrical refraction. Also, statistically highly significant change in corneal thickness, K1 and K2 parameters among studied patients. There was statistically significant increase in coma and statistically significant decrease in effect blur among studied patients while there was non-significant change in spherical aberration. While PRK remains a valuable option for achieving improved visual acuity, the induction of HOAs can lead to significant visual disturbances, impacting patient satisfaction and quality of life. Our findings indicate that photorefractive keratectomy led to a significant decrease in effect blur and increase in coma-like aberrations

KEYWORDS: Ultraviolet Laser, Excimer Laser, Human Cornea, PRK, Photorefractive Keratectomy, Laser-Assisted In-Situ Keratomileusis, LASIK

1 INTRODUCTION

Photorefractive keratectomy (PRK) has emerged as a widely utilized surgical intervention for the management of myopia, offering patients a viable alternative to glasses and contact lenses. PRK is used to correct myopia by reshaping the cornea by flattening the radius of curvature of the central cornea. Despite its effectiveness in reducing refractive error, PRK can induce high-order aberrations (HOAs), which are complex distortions of the wavefront of light as it passes through the eye. These aberrations can have significant implications for visual quality, potentially leading to issues such as reduced contrast sensitivity, glare, and halos, especially under low-light conditions **(1).**

The shape of the anterior corneal surface has a significant impact on the quality of the retinal picture because the tear-air contact is the most powerful image-forming interface in the eye. Surface focusing defects on the cornea, such typical corneal astigmatism, impairs the retinal image. Astigmatism or an error in the cornea's spherical power can be readily corrected with spectacles. Corneal optical impairments like coma and distortion cannot be corrected by glasses. In addition to being common in keratoconus and after penetrating keratoplasty, these aberrations can also happen after radial keratotomy and other refractive corneal surgical procedures **(2)**.

As the demand for refractive surgery continues to rise, understanding the relationship between PRK and the induction of HOAs is crucial for optimizing surgical outcomes. It has been indicated that the extent and type of HOAs can vary significantly among individuals, influenced by factors such as the ablation profile, the degree of myopia, and the healing response of the cornea **(3)**.

Hence, this study aimed to assess the effect of PRK using excimer laser induction of High Order Aberrations (HOAs) in the cornea by measuring the high order aberrations before and after PRK procedure.

2 MATERIALS AND METHODS

This interventional study was conducted at Bahgat Eye Clinic, Egypt and included 48 consecutive patients who were scheduled for excimer laser operations from January to August of 2023 in the Egyptian Lasik Group. The study was approved by ethical committee of Faculty of Medicine, Zagazig University (IRB 380/2/June/2024). An informed written consent was obtained from all patients.

Myopic less than 6 Diopters and including both sexes aged between 20-34 years. Patients were eligible for inclusion if they had a best corrected visual acuity of 20/20. a refractive error correction between 0.0 diopters(D) and −6.0 D of sphere and between-0.5 D and -3.0 Of cylinder. While those with keratoconus and previous eye surgeries were excluded.

All patients underwent complete ophthalmic examination using AUTO REF device, measuring the thickness, curvature and power of the cornea by pentacam device, measuring aberrations and optical distortions using wavefront analysis, determining the appropriate laser (excimer laser) dose and applying it to the patient's cornea. Re-measurement of the thickness and dimensions of the cornea and aberration was done 6 months after the operation. The mean follow—up time was (3.46±0.8 1) months, ranging from 3 to 6 months.

Written informed consent was obtained from each patient after a thorough discussion of benefits and known risks of the procedure.

3 RESULTS

This study included 89 eyes from 48 patients. 40 eyes were of male patients (47.9%), 49 eyes were of female patients (52.1%), with mean age was 28.15± 3.36(20-34) years. All patients enrolled in this study were myopic with or without astigmatism and a mean spherical equivalent of −4.5± 1.16 D.

Table (1) Postoperative change in spherical and cylindrical refraction among studied patients:

	Preoperative	Postoperative	Wx	P-Value
	Median (IQR)	Median (IQR)		
Spherical	-1.65(-3.2, -0.195)	-0.08(-0.38, 0.165)	-2.471	0.006*
Cylindrical	-1.92(-2.86, -0.69)	-0.695(-0.87, -0.535)	-3.013	0.002

IQR: Interquartile range, Wx: Wilcoxon signed rank test, *p<0.05 is statistically significant

The results show that six months after PRK, there was a marked increase with statistically significant change in both spherical and cylindrical refraction among studied patients **(Table 1)**.

Table (2) Postoperative change in pentacam parameters among studied patients:

	Preoperative	Postoperative	t	P-Value
	Mean ± SD	Mean ± SD		
THX	511.13 ± 25.2	475.19 ± 20.04	5.287	<0.001**
K1	44.38 ± 1.23	42.22 ± 2.49	6.487	<0.001**
K2	45.84 ± 1.86	43.34 ± 2.71	7.729	<0.001**

t: paired sample t test, K1: flat keratometry, K2: steep keratometry**p≤0.001 is statistically highly significant

There was statistically highly significant change in corneal thickness, K1 and K2 parameters among studied patients **(Table 2)**.

Table (3) Postoperative change in corneal aberration parameters among studied patients:

	Preoperative Median (IQR)	Postoperative Median (IQR)	Wx	p
Coma	0.165(0.092 – 0.359)	0.293(0.2 – 0.467)	-2.017	0.044*
Trifoli	0.203(0.121 – 0.292)	0.2(0.158 – 0.282)	-0.569	0.569
Spherical aberration	0.082(0.046 – 0.251)	0.075(0.024 – 0.247)	-1.086	0.278
Effect blur	3.26(2.28 – 3.88)	1.07(0.69 – 1.47)	-3.516	<0.001**

IQR interquartile range, Wx : Wilcoxon signed rank test *p<0.05 is statistically significant **p≤0.001 is statistically highly significant

By examining the corneal aberrations, there was statistically significant increase in coma and statistically significant decrease in effect blur among studied patients while there was non-significant change in Trifoli and spherical aberration (**Table 3).**

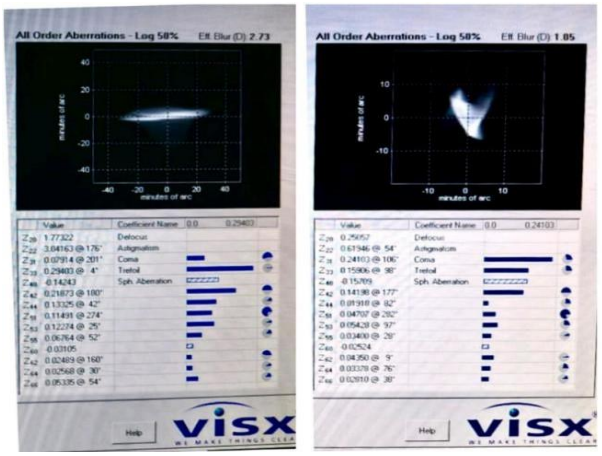

Figure: Preoperative and postoperative corneal aberration profile after PRK.

4 DISCUSSION

The current study found that six months after PRK, there was a marked increase with statistically significant change in both spherical and cylindrical refraction among studied patients.

Photorefractive keratectomy (PRK) has been shown to be an effective treatment for myopia, with significant reductions in both spherical and cylindrical refractions. **Mohammadi et al. (4)** reported that the procedure's predictability and accuracy are particularly high for mild to moderate myopia, with 96% of cases achieving final refraction within ±1D for myopia less than -6D. However **Moshirfar et al. (5)** stated that PRK induces higher-order aberrations, especially in cases of high myopia, which can affect optical quality **Oliver et al. (6)** stated these aberrations stabilize one-year post-surgery and primarily impact image quality under scotopic conditions. The keratometry and refractive regression following myopic PRK, with the rate of regression dependent on treatment magnitude and patient age. Despite these challenges, PRK remains a safe and predictable procedure for treating myopia, with most patients achieving significant improvements in visual acuity.

The present study found that there was statistically highly significant change in corneal thickness, K1 and K2 parameters among studied patients.

These results were compatible with **Ozulken and Gokce (7)** who reported that corneal changes after photorefractive keratectomy (PRK) for myopia reveal significant alterations in corneal thickness and keratometry. There was a decrease in central corneal thickness (CCT) and corneal volume (CV) following PRK, with changes correlating to the degree of myopic correction after photorefractive keratectomy (PRK) surgery**.** cleared that epithelial thickness initially decreases post-PRK but shows thickening by 3 months, influenced by the amount of myopia treated, treatment zone size, and preoperative epithelial thickness. These corneal changes do not significantly affect refractive outcomes. **Rosa et al. (8).** illustrated that stromal thickness decreases significantly after PRK and remains stable from 1 to 6 months postoperatively. Overall, PRK induces complex corneal remodeling, involving both epithelial and stromal layers, which stabilize within 3-6 months postoperatively.

Our current findings regarding postoperative change in corneal aberration clearly revealed that there was statistically significant increase in coma and statistically significant deccrease effect blur among studied patients while there was non-significant change in Trefoil and spherical aberration.

Corneal aberrations after photorefractive keratectomy (PRK) for myopia have shown mixed results. **Rosa et al. (9)** found that higher-order aberrations (HOAs) stabilized one-year post-PRK, with increased spherical aberration and coma in high myopia cases

Serrao et al. (10) reported a non-significant increase in higher-order aberrations (HOAs) and spherical aberration after PRK, while noting significant increases in vertical trefoil and coma. The same authors also observed that PRK caused a permanent increase in coma-like and spherical aberrations, although corneal power remained stable from 1 to 7 years post-surgery. Their findings further showed that spherical aberration and coma were slightly higher after PRK compared to radial keratotomy (RK), whereas overall HOAs were lower in PRK. Collectively, these studies indicate that PRK affects corneal aberrations—particularly coma and spherical

aberration—although the magnitude and clinical significance of these changes vary across studies.

Supporting this, **Shao et al. (11**) demonstrated that higher-order wavefront aberrations were nearly twice as high after RK compared to PRK at larger pupil sizes (4 and 6 mm), suggesting that PRK results in better image-forming corneal properties.

Similarly, **Tran et al. (12**) reported a significant increase in corneal spherical aberrations and coma-like aberrations following PRK. **Xi (13**) also found that total HOAs of the anterior corneal surface, as well as spherical and coma aberrations, significantly increased after Trans-PRK, while the posterior corneal HOAs remained unchanged.

5 CONCLUSION

The assessment of induced high-order aberrations (HOAs) in patients treated with photorefractive keratectomy (PRK) for myopia management highlights the complex interplay between effective refractive correction and visual quality. While PRK remains a valuable option for achieving improved visual acuity, the induction of HOAs can lead to significant visual disturbances, impacting patient satisfaction and quality of life. Our findings indicate that photorefractive keratectomy led to a significant decrease in effect blur and increase coma-like aberrations.

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