Comparison of Higher Order Aberrations between Wavefront Optimized Photorefractive Keratectomy and Laser *in situ* Keratomileusis in Myopic Patients

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ABSTRACT

Objective: To compare the higher order aberrations (HOA) between wavefront optimized (WFO) laser *in situ keratomileusis* (LASIK) and photorefractive keratectomy (PRK) in myopic patients.

Study Design: Quasi-experimental study.

Place and Duration of the Study: Armed Forces Institute of Ophthalmology, Rawalpindi, Pakistan, from December 2021 to December 2022.

Methodology: Forty-four patients underwent wavefront optimized PRK and fifty-seven patients underwent wavefront optimized LASIK. All variables were recorded before the procedure and at 1, 3, 6, and 12 months postoperatively and included uncorrected visual acuity (UCVA), corrected distance visual acuity (CDVA), root mean square (RMS) of HOAs, spherical aberration (SA), and coma aberration (CA).

Results: A total of 101 eyes of 51 patients were considered in the final analysis. Patients were divided into two groups. Group A comprised of 44 (43.6%) eyes of 22 patients who underwent PRK while group B comprised of 57 (56.4%) eyes of 29 patients who underwent LASIK. UCVA significantly improved postoperatively at 3 and 6 months in both PRK and LASIK groups ($p<0.001$ for both groups). In this study, the increase in root mean square (RMS) of higher order aberrations from baseline value was 77% after PRK and 28% after LASIK, similar ratio was observed in spherical aberration (SA). The trend of rise in Coma aberrations was more in LASIK group 66.49% as compared to 46.2% in PRK group.

Conclusion: Both Wavefront Optimized PRK and LASIK are safe and have elicited comparable results of post-procedure visual recovery. There was a marked increase in RMS of HOAs in PRK group as compared to WFO LASIK group while coma aberration increased more in LASIK as compared to PRK postoperatively.

Key Words: *LASIK, PRK, RMSh, HOAs, Spherical aberration, Coma, Myopia.*

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INTRODUCTION

Corneal refractive surgery demands accurate ablation in order to achieve the desired visual outcome and perfect quality of vision. The surge in the incidence of myopia in the last few years has been anticipated to increase to 50% by the year 2050.[1] For the refractive surgical treatment of myopia and myopic astigmatism, alteration in the corneal refractive power is done by moulding the desired corneal shape using lasers. Laser *in situ keratomileusis* (LASIK) and photorefractive keratectomy (PRK) use this technique with safety along with accuracy and have comparable visual outcomes.[2]

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Conventional refractive surgical procedures increase the problems of glare, halos, and night vision quality, which are a result of induced higher-order aberrations (HOAs).[3] The subjective refraction and expected amount of spherical aberration (SA) induced after conventional laser refractive procedure is the basis of wavefront optimized (WFO) ablation profile. This technique implies larger amount of tissue ablation in periphery (approximately 35% more) thus preserving the asphericity of cornea.[4,5]

A change in paradigm has occurred with evolving technology, having different ablation profiles in excimer laser surgery including customized, aspherical, topography-guided, and wave-front optimized ablation techniques.[6,7] With increasing interest in Laser *in situ keratomileusis* (LASIK) and photorefractive keratectomy (PRK), and the introduction of wavefront optimized (WFO) technology, corneal refractive surgery field has been transmogrified because of increased precision and prognosticative potential.[8]

HOAs make about 15% of total corneal aberrations in an eye and are described in Zernike polynomials as above second order aberrations. Coma and trefoil are third order aberrations and fourth order aberrations include spherical aberrations.[9] WFO technique reshapes the cornea by using individualised ablation profile, reducing pre-existing and surgically induced aberration thus minimising postoperative HOAs.[10]

Although there have been past studies on wavefront optimized PRK and LASIK separately, but there has not been a comparison in the local population. The objective of this study was to compare the HOAs after wavefront optimized LASIK and PRK in myopic patients.

METHODOLOGY

This was a quasi-experimental study conducted in the Armed Forces Institute of Ophthalmology, from December 2020 to December 2021. The minimum sample size (n=64, 32 in each group) was calculated using WHO sample size calculator with 95% level of confidence and 10% precision. Simple consecutive sampling technique was used. In this study, 44 patients underwent PRK and 57 patients underwent LASIK. All variables were recorded before the procedure and at 1, 3, 6, and 12 months postoperatively. Both these procedures were performed by the same experienced surgeon. Ethical review committee gave the ethical approval. Written informed consent was taken from all patients. Patients aged 18 to 40 years having refractive error between -1.00 D to -10.00 D and unchanged refraction for the last 12 months were part of the study. Residual stromal thickness postoperatively not less than 280 µm was the inclusion criteria. Pregnancy and lactation, corneal ectatic diseases, ocular allergy, history of ocular surgery, trauma, and any of the active or residual ocular diseases (glaucoma, retinal disease, dry eyes) were the exclusion criteria.

Preoperative clinical ophthalmic examination constituted manifest and cycloplegic refraction, uncorrected visual acuity (UCVA), corrected distance visual acuity (CDVA), slit lamp biomicroscopic assessment of anterior and posterior segment, intraocular pressure (IOP) measurement, and dry eye assessment with tear film breakup time (TBUT). Investigations included; measurement of root mean square (RMS) of HOAs, spherical aberration (SA) and coma aberration (CA) with aberrometer (Wavelight Allegro Analyzer version 1073), corneal tomography and topography with Wavelight Oculyzer II and Wavelight Topolyzer Verio (Wavelight GmbH, Erlangen, Germany). Patients were advised to discontinue contact lens usage at least 2 weeks prior to workup.

Patients in group A who underwent PRK had epithelial removal with PRK spatula, WFO stromal ablation with excimer laser (EX-500, 1050 Hz Excimer laser, Wavelight GmbH, Erlangen, Germany) with remaining minimum stromal bed of 300 µm. About 0.02% mitomycin C was applied to stromal bed after ablation for 30-40 seconds and then cornea was cooled and washed thoroughly with the chilled balanced salt solution. Bandage contact lens was applied at the end of the procedure. WFO LASIK was performed in all patients of group B. Flap thickness was kept 100 µm and was created using a femtosecond laser (FS-200, 200 kHz Femtosecond laser, Wavelight GmbH, Erlangen, Germany). Flap was lifted with the help of flap lifter, while corneal stromal ablation was done with excimer laser (EX-500 Wavelight technologies) leaving minimum 280 µm of residual stromal bed.

Post-procedure medication included artificial tear substitutes and a combination of tobramycin and dexamethasone eye drops, each two hourly for one day and then four hourly for the next two weeks. Tobramycin and dexamethasone eye drops were discontinued in LASIK patients after two weeks while in PRK patients it was replaced by fluorometholone eye drops after four weeks which was continued eight hours for the next two months. Artificial tears were continued in both groups for six months.

Postoperative evaluation was done at 1, 3, 6, and 12 months and included UCVA, CDVA, RMS of HOAs, SA, and coma. The best of the three readings of wavefront analyzer were recorded. Constant pupil size of 6mm was taken for analysing results of aberrometery. Mean RMS values of total HOAs, spherical aberration (4^{th} order aberration) and coma (3^{rd} order aberration) were recorded.

Statistical analysis was done with the help of statistical package for social sciences (SPSS 17.0) for windows. The data was described in terms of mean ± SD (standard deviation). Visual acuity outcomes were compared in logMAR values. For comparison of LASIK and PRK groups, independent samples student's t-tests were utilised. The non-normally distributed data was analysed with repeated measures ANOVA test. A p-value of 0.05 was considered as statistically significant.

RESULTS

A total 101 eyes of 51 patients were considered in the final analysis. On the basis of refractive surgical technique used, the patients were divided into two groups. Group A comprised of 44 (43.6%) eyes of 22 patients who underwent PRK while group B comprised of 57 (56.4%) eyes of 29 patients who underwent LASIK. Out of 51 patients, there were 44 (43.6%) males and 57 (56.4%) females, with almost similar gender distribution in the two groups. The baseline clinical and demographic characteristics are given in Table I.

The visual acuity in terms of UCVA significantly improved postoperatively at 3 and 6 months in both PRK and LASIK groups ($p<0.001$ for both groups) but there was no significant difference observed in terms of CDVA values at 3 and 6-months compared with baseline in both the groups ($p=0.376$, and $p=0.915$, respectively).

Significant difference was found in the mean root mean square of high order aberrations (RMSh), mean SA and mean Coma in patients undergoing PRK and LASIK from preoperative to 3 and 6 months postoperatively as shown in Table II.

Table I: Baseline demographic and clinical characteristics compared between study groups (n=101).

	Overall Total (n = 101)	Group A PRK (n = 44)	Group B LASIK (n = 57)	p-value
Mean age	24.1±5.5 years	24.2±5.3 years	23.9±5.6 years	0.771
Gender				0.051
Male	44 (43.6%)	24 (54.5%)	20 (35.15%)	
Female	57 (56.4%)	20 (45.5%)	37 (64.9%)	
Eye involved				0.930
Right	50 (49.5%)	22 (50.0%)	28 (49.1%)	
Left	51 (50.9%)	22 (50.0%)	29 (50.9%)	
UCVA (log)	1.17±0.26	1.05±0.26	1.26±0.23	<0.001
CDVA (log)	0.023±0.121	0.002±0.013	0.04±0.160	0.117
Sphere	-3.47±2.02	-2.57±1.32	-4.17±2.19	<0.001
Cylinder	-0.60±0.62	-0.45±0.50	-0.72±0.68	0.03
MRSE	-3.78±2.09	-2.80±1.30	-4.53±2.27	<0.001

n= number, UCVA = uncorrected visual acuity, CDVA = corrected distance visual acuity, log = logMAR, PRK = photorefractive keratectomy, LASIK = laser in situ keratomileusis, p = p-value, MRSE = mean refraction spherical equivalent.

Table II: Comparison of outcome parameters preoperatively and 3, 6-months postoperatively in patients belonging to PRK and LASIK groups.

		Group A PRK (n=44)	P*	Group B LASIK (n=57)	P*
RMSh	Pre-op	0.316±0.15	<0.001	0.403±0.31	<0.001
	3-mo post-op	0.595±0.28		0.643±0.46	
	6-mo post-op	0.56±0.17		0.562±0.25	
SA	Pre-op	0.059±0.11	<0.001	0.075±0.09	<0.001
	3-mo post-op	0.331±0.18		0.270±0.14	
	6-mo post-op	0.333±0.17		0.275±0.17	
COMA	Pre-op	0.186±0.11	0.019	0.197±0.14	<0.001
	3-mo post-op	0.264±0.22		0.377±0.28	
	6-mo post-op	0.272±0.14		0.328±0.26	
UCVA (log)	Pre-op	1.054±0.26	<0.001	1.265±0.23	<0.001
	3-mo post-op	0.0150±0.02		0.045±017	
	6-mo post-op	0.004±0.01		0.047±0.17	
CDVA (log)	Pre-op	0.002±0.01	0.376	0.040±0.16	0.915
	3-mo post-op	0.002±0.01		0.040±0.16	
	6-mo post-op	0.00±0.00		0.040±0.16	

**Repeated measures ANOVA significance values, n= number, UCVA = uncorrected visual acuity, CDVA = corrected distance visual acuity, log = logMAR, PRK = photorefractive keratectomy, LASIK = laser in situ keratomileusis, p = p-value, SA = spherical aberration, RMSh = root mean square of higher order aberrations.*

The RMSh significantly increased from pre-op to 3-month follow-up (p<0.001), and decreased slightly from 3-month to 6-month follow-up with no significant difference (p=1.0) in PRK group and similar trend was observed in the LASIK group as the difference was not significant (p=0.363). Figure 1C shows the trend of mean RMSh values at pre- and postoperative time points in two study groups. The mean SA significantly increased from pre-op to 3-month post-op (p<0.001) and decreased slightly from 3-month to 6-month post-op with no significant difference (p=1.0) in PRK group. Similar trend was observed in the LASIK group, where mean SA increased significantly at 3-month post-op compared with pre-op (p<0.001) with insignificant decrease from 3-month to 6-month follow-up (p=1.0) as shown by Figure 1E. For mean Coma, there was significant difference at three time points (p=0.019), post-hoc analysis, which revealed insignificant increase from pre-op to 3-month follow-up (p=0.236), while significant increase was observed at 6-month follow-up compared with baseline (p=0.014) in the PRK group. For the LASIK group, mean Coma increased significantly at 3-month follow-up compared with pre-op (p<0.001) with insignificant decrease from 3-month to 6-month follow-up (p=0.255), as the trend shown in Figure 1D.

The intergroup comparison of outcomes at 3-months post-op follow-up for PRK and LASIK group revealed no significant differences in terms of UCVA (p=0.193), CDVA (p=0.125), RMSh (p=0.551), and SA (p=0.067). However, for Coma, there was a significant difference in mean values compared between PRK and LASIK group (p=0.034).

Similarly, the intergroup comparison of outcomes at 6-months post-op follow-up for PRK and LASIK revealed no significant differences in UCVA (p=0.108), CDVA (p=0.104), RMSh (p=0.961), SA (p=0.109), and COMA (p=0.204).

At 1-year follow-up there were 16 patients from PRK group who came for follow-up, and 25 in LASIK group, rest were lost to follow-up. At 1-year there was no significant difference in RMSh found in PRK (0.589±0.17 *vs.* 0.596±0.16, p=0.868) and LASIK group (0.66±0.47 *vs.* 0.56±0.25, p=0.174) in comparison with 6-months readings, respectively. For SA, mean values were similar in both PRK (0.319±0.17 *vs.* 0.3162±0.19, p=0.911) and LASIK (0.28±0.15 *vs.* 0.27±0.13, p=0.784) at 1 year compared with 6-month values. Similarly, for Coma, mean values were the same in both PRK (0.32±0.12 *vs.* 0.30±0.17, p=0.718) and LASIK (0.34±0.26 *vs.* 0.32±0.30, p=0.621) at 1 year compared with 6-months readings.

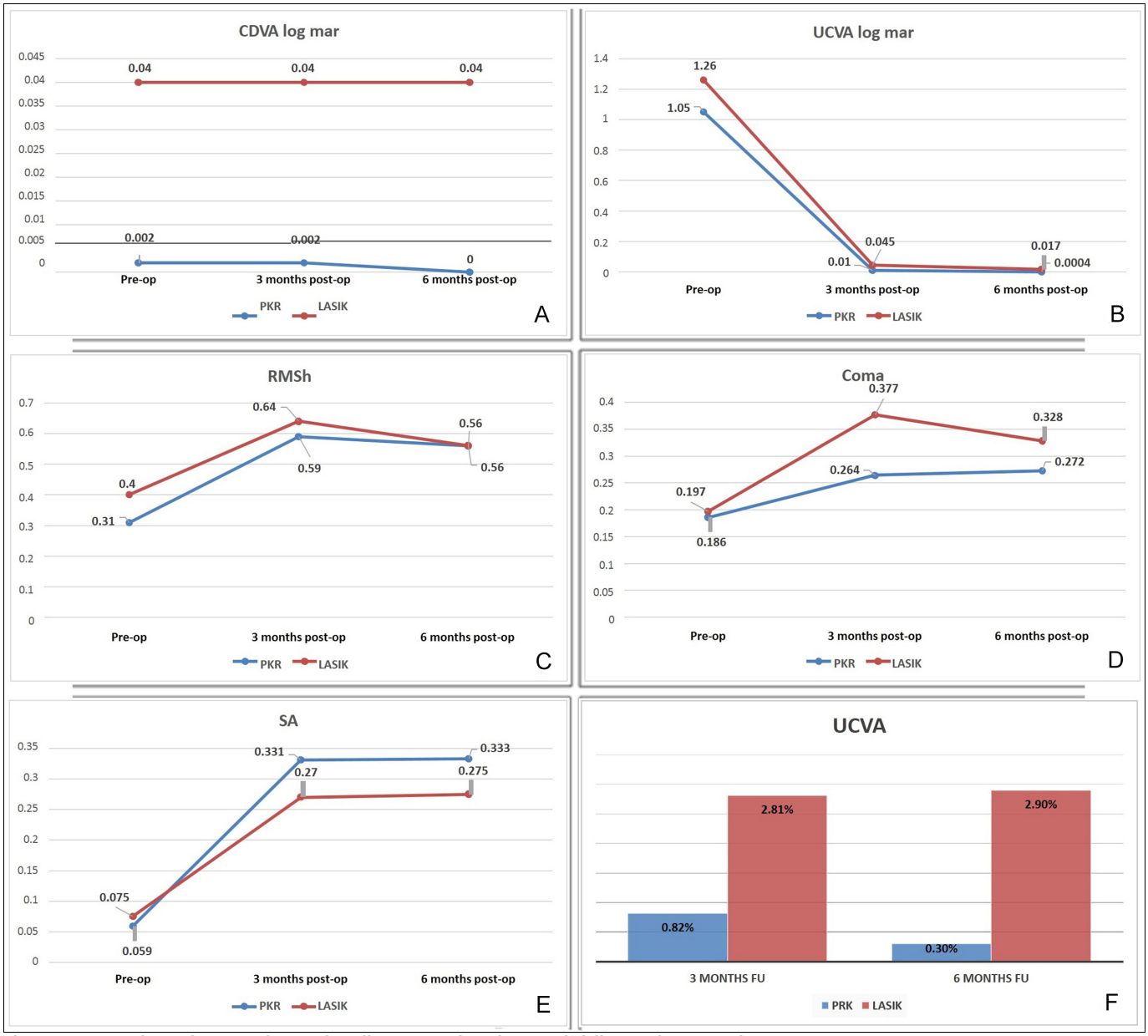

Figure 1: Comparison of mean values at baseline, 3-month and 6-month follow-up in PRK and LASIK groups.

DISCUSSION

Refractive surgery procedures are gaining fame for visual improvement and getting rid of spectacles but the decrease in vision quality and problems of halo and glare is because of alteration in the corneal asphericity thus inducing higher order aberrations.[11] In myopic patients, some parts of the laser beam are reflected (as it enters the periphery) causing the circular beam to become elliptical and as a consequence there is reduction in the effectiveness of laser energy.[12] The HOAs result from the under-ablation of the corneal periphery. The advancement in the field of refractive surgery and the advent of wavefront technology have addressed the problem of higher-order aberrations by applying extra energy to the periphery.[13] The Wavefront optimized technology secures the corneal surface asphericity by delivering more energy to the periphery of cornea and is the most common refractive surgical procedure done in USA (48%) according to a survey done in 2017.[14] This study done in past showed findings consistent with the results of Zeng *et al.*[2] that despite improvement in visual acuity, HOAs increase after wavefront optimized LASIK in myopic patients although it is less than conventional laser procedure.[15]

The current study compared the post-procedure changes in the higher-order aberrations in eyes undergoing WFO PRK and LASIK. RMSh values at 6 months postoperatively in PRK (Group A) came out to be 0.56±0.17 which was better than the results shared by Kang *et al.* (0.80±0.24) and Jun *et al.* (0.84±0.24).[12,16] In group A (PRK group), the mean spherical aberration at 6 months postoperatively was 0.33±0.17 which is better than the results of Kang *et al.* (0.51 ± 0.15)

and Jun *et al*. (0.57±0.24).[12,16] Coma aberration after 6 months in WFO PRK was reported to be 0.41±0.25, 0.39±0.21, and 0.26±0.18 by the studies of Kang *et al.*, Jun *et al.,* and Yuan *et al.,* respectively.[12,16,17] However, this study results showed a finer outcome (0.272±0.14) at 6 months postoperatively.

In LASIK group (Group B), RMSh value of 0.562±0.25 were seen 6 months post-op which was comparable to PRK group (Group A 0.56±0.17) and was found better than the results of Kim *et al.* (0.76 ± 0.38).[18] Mean spherical aberrations at 3 months in this study group were similar to the analysed data shared by Smadja *et al.* (0.27±0.14).[19] Yuan *et al.* have reported post-LASIK spherical aberration of 0.37±0.11 which is greater than this study's results of 0.275±0.17.[17] Changes in the corneal integrity that occurs while creating the flap in LASIK is thought to be the cause in increasing Coma aberrations.[20] Similar findings were observed in the current study where Coma increased from pre-op 0.197±0.14 to 0.328±0.26, six months post-LASIK which are analogus to the results of Zhang *et al.* (0.30±0.36).[2]

To date, limited studies have compared the post-procedure results of WFO PRK and LASIK. In this study, the increase in RMSh from baseline value was 77% after PRK and 28% after LASIK, similar ratio in SA. The trend of rise in coma aberrations was more in the LASIK group 66.49% as compared to 46.2% in the PRK group.

This study has a few limitations. Mainly it had a small sample size and 1 year follow-up had lesser patients (lost to follow-up) thus 6 monthly results were compared. Despite these limitations, this study is of value as it is among the first few analysis of comparison between WFO PRK and LASIK and it will provide aid to surgeons while planning patients for refractive surgery.

CONCLUSION

Both wavefront optimized PRK and LASIK profiles are safe and have elicited comparable results of post-procedure visual recovery. The overall 6 monthly post-procedure results were better than the previous studies. Moreover, there was a marked increase in RMS of HOAs in PRK group as compared to WFO LASIK group while coma aberration increased more in LASIK as compared to PRK postoperatively.

ETHICAL APPROVAL:
The study was approved by the Ethical review committee of the Armed Forces Institute of Ophthalmology, Rawalpindi, Pakistan.

PATIENTS' CONSENT:
Written informed consent was taken from all patients.

COMPETING INTEREST:
The authors declared no competing interest.

AUTHORS' CONTRIBUTION:
SH: Conception and design of the work.
AT: Drafting and data analysis.
MI: Final approval of the manuscript.
SA: Data acquisition.
All the authors have approved the final version of the manuscript to be published.

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