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Original Article

Higher-order aberrations following wavefront-guided photorefractive keratectomy and laser in situ keratomileusis

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ABSTRACT

Background: We aimed to evaluate higher-order aberrations (HOAs) following wavefront-guided photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) in patients with myopia and myopic astigmatism.
Methods: This retrospective observational case-control study included patients who underwent wavefront-guided PRK (40 eyes of 20 patients) or LASIK (40 eyes of 20 patients) between August 2018 and November 2018 at the refractive surgery unit of Kayseri City Hospital Eye Clinic, Turkey. The corrected distance visual acuity (CDVA), manifest refraction, corneal topography, and HOAs were evaluated preoperatively and 3 months postoperatively in all patients.
Results: The mean age ± standard deviation (SD) was 27.13 ± 5.54 years and 29.10 ± 4.38 years in the PRK and LASIK groups, respectively (P = 0.06). Both groups had a mean CDVA of 1.00. The mean ± SD of spherical and spherical equivalent values was -2.09 ± 1.56 diopter (D) and -3.03 ± 1.72 D in the PRK group and -2.23 ± 1.69 D and -3.35 ± 1.71 D in the LASIK group, respectively (P = 0.58). When the preoperative and postoperative HOAs and root mean square (RMS) values (for a 6-mm pupil diameter) were compared in the PRK group, a significant difference was found in vertical coma and total RMS values (P = 0.003 and P < 0.001, respectively); in the LASIK group, there was a significant difference in preoperative and postoperative vertical coma and total RMS values (P = 0.0.001 and P < 0.001, respectively). There was no significant difference in preoperative and postoperative vertical coma values between the two groups (P = 0.735 and P = 0.583, respectively).
Conclusions: In terms of HOAs, total RMS values decreased significantly and vertical coma values increased significantly at 3 months postoperatively in both PRK and LASIK groups. However, there were no differences between the two groups.

KEY WORDS

high-order aberrations, HOAs, corneal wavefront aberrations, laser in situ keratomileusis, LASIK, photorefractive keratectomy, PRK, vertical coma, root mean square, RMS, postoperative

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INTRODUCTION

Keratorefractive surgery can successfully reduce spherocylindrical refractive defects, but may impair visual quality [1, 2]. In modern corneal surgery, new surgical procedures have been developed using rapidly developing technologies. The central corneal shape is modified (straightened to correct myopia and steepened to correct hyperopia) in surgical procedures such as photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK), both of which are commonly used [3]. These surgical procedures affect the optical quality of the cornea and give rise to aberrations that distort the images [4]. Studies have shown that an increase in total higher-order aberrations (HOAs), especially coma and spherical aberrations, can be induced after PRK and LASIK [5, 6]. The PRK technique is older than the LASIK technique, but still in use. In PRK, stromal ablation is required after epithelial peeling without corneal flap formation. On the contrary, conventional LASIK involves flap formation using a mechanical microkeratome. Two other techniques, which are now used routinely, have been developed to avoid HOAs, especially spherical aberrations. These techniques, called femtosecond laser- and wavefront-guided ablation, improve visual quality by significantly lower induction of total HOAs against mechanical microkeratome LASIK [7, 8]. HOAs can be affected by several factors, including the optical zone, flap formation, and decentralized ablation [9-11]. The femtosecond laser is a solid-state laser that has been shown to reduce the incidence of flap complications and flap-related aberrations by creating flaps of desired thickness and smoothness [10]. Wavefront-guided ablation is an ablation technique that uses objective refractive information obtained from the aberrometer as opposed to the standard excimer laser using subjective refraction information [3].

This study aimed to compare the effect of the wavefront-guided PRK technique with that of the wavefront-guided LASIK technique on HOAs in patients with myopia and myopic astigmatism.

METHODS

This retrospective, observational, case-control study was conducted at the refractive surgery unit of Kayseri City Hospital Eye Clinic, Turkey. Before initiating the study, ethics committee approval was obtained from the Institutional Review Board of Erciyes University (no. 2020/102, date: 12.02.2020). The study was conducted in accordance with the principles of the Declaration of Helsinki. Patients who underwent wavefront-guided PRK (40 eyes of 20 patients) or LASIK (40 eyes of 20 patients) for myopia and myopic astigmatism between August 2018 and November 2018 were included, and their files were retrospectively reviewed. Patients were included in the study if they had undergone complete ophthalmologic examinations, including corrected distance visual acuity (CDVA), manifest refraction, biomicroscopic anterior segment, and dilated fundus examinations; intraocular pressure measurements with Goldmann applanation tonometry; and corneal topography (Pentacam HR; Oculus, Wetzlar, Germany) and wavefront analyses (iDesign Advanced WaveScan Studio™ System; Johnson & Johnson Vision, Inc., Santa Ana, CA, USA) preoperatively and at 3 months postoperatively. Spherical, coma, and trefoil HOAs were evaluated based on Zernike pyramid analysis for a pupil diameter of 6 mm. Patients were excluded from the study if they had any ocular disease, wound healing disorder, connective tissue disorder, or postoperative complications such as keratitis, corneal haze, and flap-related complications; required retreatment; had undergone previous corneal and intraocular surgery; or had a postoperative residual corneal thickness less than 400 µm.

For the surgical procedure, flaps were prepared using the AMO IntraLase FS60 femtosecond laser platform (IntraLase Group, Abbott Medical Optics Inc., Irvine, CA, USA). Both PRK and LASIK techniques were performed by the same surgeon (ND). For PRK, 0.5% proparacaine hydrochloride eye drops (Alcaine; Alcon Laboratories, Inc, Fort Worth, Texas, USA) were applied twice at 10-min intervals before applying the excimer laser. Then, 20% alcohol was dropped into an 8.5-mm ring. After standing for 15 s, a standard epithelial defect was formed, and the alcohol was rinsed with 30 mL of a balanced saline solution (BSS). Next, the epithelium was removed with a spatula. Excimer laser surface ablation was performed using the VISX STAR S4 IR excimer laser platform (Abbott Medical Optics Inc., Santa Ana, CA, USA). Mitomycin C (0.02%) was applied for 40 s and washed with 30 mL of BSS. A drop of 0.5% moxifloxacin (Vigamox 0.5%; Alcon Laboratories Inc., Fort Worth, TX, USA) was then instilled directly onto the cornea. For LASIK, topical 0.5% proparacaine hydrochloride eye drops (Alcaine; Alcon Laboratories, Inc, Fort Worth, TX, USA) were applied twice at 10-min intervals before applying the excimer laser. A corneal flap was then created using femtosecond laser technology. Excimer laser surface ablation was performed using the VISX STAR S4 IR excimer laser platform (Abbott Medical Optics, Inc., Santa Ana, CA, USA). A drop of 0.5% moxifloxacin (Vigamox 0.5%; Alcon Laboratories Inc., Fort Worth, TX, USA) was then instilled directly onto the cornea.

In the postoperative period, the following drops were applied topically: 0.5% moxifloxacin drops four times a day; 0.1% fluorometholone drops (FML; Allergan, Istanbul, Turkey) four times a day; and a preservative-free combination of sodium hyaluronate 0.15% and trehalose 3% (Thealoz Duo®, Thea Pharma Ltd, UK) two times a day. The 0.1% fluorometholone drops were discontinued in both groups after 1 month by reducing the dosage by one drop each week. All patients were evaluated on day 1 following surgery as well as on month 1 and 3 postoperatively. Ocular aberrations were evaluated at month 3 postoperatively (due to the longer recovery period in the PRK group).

Analysis performed using IBM SPSS Statistics for Windows, version 21 (IBM Corp., Armonk, NY, USA). Continuous numerical variables are presented as means ± standard deviations (SDs), and categorical variables are presented as percentages and numbers. Normality of data distribution was examined using the Kolmogorov–Smirnov test. Preoperative and postoperative numerical data were analyzed using Student's t-test if they were normally distributed or using the Mann–Whitney U test if they were not normally distributed. The relationship between aberrations and corneal refractive power was evaluated using Pearson's linear correlation test. Statistical significance was set at $P < 0.05$.

RESULTS

The mean age ± SD was 27.13 ± 5.54 years and 29.10 ± 4.38 years in the PRK and LASIK groups, respectively ($P = 0.06$). The mean of logarithm of the minimum angle of resolution (logMAR) of CDVA was 1.00 in both groups. The mean ± SD of spherical and spherical equivalent values was -2.09 ± 1.56 diopters (D) and -3.03 ± 1.72 D in the PRK group and -2.23 ± 1.69 D and -3.35 ± 1.71 D in the LASIK group, respectively ($P > 0.05$ in both). Preoperative and postoperative maximum keratometry readings (K-max) and central corneal thickness (CCT) values in both groups are shown in Table 1. The preoperative and postoperative total HOAs and RMS values are shown in Table 2. When the preoperative and postoperative vertical coma, horizontal coma, and trefoil aberrations and RMS values (for a 6-mm pupil diameter) were compared within the PRK group, significant reductions were found in terms of vertical coma and total RMS values ($P = 0.003$ and $P < 0.001$, respectively); in the LASIK group, there was a significant difference in vertical coma and total RMS values ($P = 0.001$ and $P < 0.001$, respectively) (Table 2). There was no significant difference between the preoperative vertical coma values ($P = 0.73$) and postoperative vertical coma values ($P = 0.58$) between the two groups.

There was no correlation between the change in K-max after laser surgery and the change in spherical aberrations in the LASIK group (r = -0.009, $P = 0.96$); however, a weak negative correlation was found in the PRK group (r = -0.46, $P = 0.006$). There was no correlation between the change in K-max after laser surgery and the change in vertical coma aberrations in the PRK group (r = 0.19, $P = 0.27$); however, a weak positive correlation was found in the LASIK group (r = 0.46, $P = 0.01$). There was no correlation between the change in K-max after laser surgery and the change in horizontal coma aberrations in the PRK group (r = 0.01, $P = 0.93$) and the LASIK group (r = -0.03, $P = 0.85$). There was no correlation between the change in K-max after laser surgery and the change in trefoil aberrations in the PRK group (r = 0.10, $P = 0.55$) and the LASIK group (r = - 0.14, $P = 0.44$). There was no correlation between the change in K-max after laser surgery and the change in total RMS value in the PRK group (r = 0.31, $P = 0.07$), whereas there was a strong positive correlation in the LASIK group (r = 0.93, $P < 0.001$) (Table 3).

Table 1. Preoperative and postoperative values of the maximum keratometry reading and CCT in both study groups.

Variable	PRK group		LASIK group	
	Preoperative	Postoperative	Preoperative	Postoperative
K-max (D), mean ± SD	43.42 ± 1.38	41.24 ± 1.73	43.69 ± 1.06	40.72 ± 1.00
CCT (µm), mean ± SD	535.76 ± 41.45	482.38 ± 53.12	525.70 ± 95.03	465.76 ± 39.47

Abbreviations: CCT, central corneal thickness; D, diopter; K-max, keratometry reading; LASIK, laser in situ keratomileusis; PRK, photorefractive keratectomy; SD, standard deviation

Table 2. Comparison between preoperative and three-month postoperative total HOAs and RMS values in both study groups.

Group	HOAs	Preoperative	Postoperative	*P*-value
PRK group, µm mean ± SD	Spherical	-0.008 ± 0.133	0.012 ± 0.172	0.41
	Horizontal coma	-0.014 ± 0.074	0.00 ± 0.163	0.64
	Vertical coma	0.181 ± 0.183	0.074 ± 0.129	**0.003**
	Trefoil	0.007 ± 0.096	-0.003 ± 0.146	0.65
	RMS	4.149 ± 1.809	1.201 ± 0.593	**<0.001**
LASIK group, µm mean ± SD	Spherical	-0.005 ± 0.093	-0.003 ± 0.103	0.92
	Horizontal coma	0.002 ± 0.094	0.038 ± 0.104	0.15
	Vertical coma	0.167 ± 0.131	-0.001 ± 0.221	**0.001**
	Trefoil	0.024 ± 0.140	0.012 ± 0.074	0.63
	RMS	5.396 ± 1.567	1.366 ± 0.583	**<0.001**

Abbreviations: HOA, higher-order aberration; LASIK, laser in situ keratomileusis; PRK, photorefractive keratectomy; RMS, root mean square; SD, standard deviation. $P < 0.05$ is considered statistically significant

Table 3. Correlation between the change in K-max after Keratorefractive surgery and the change in HOAs in both study groups

Group	HOAs	r	*P*-value
PRK group	Spherical	-0.46	**0.006**
	Horizontal coma	+0.01	0.93
	Vertical coma	+0.19	0.27
	Trefoil	+0.10	0.55
	RMS	+0.31	0.07
LASIK group	Spherical	-0.009	0.96
	Horizontal coma	-0.03	0.85
	Vertical coma	+0.46	**0.01**
	Trefoil	-0.14	0.44
	RMS	+0.93	**< 0.001**

Abbreviations: K-max, keratometry reading; HOA, higher-order aberration; r, correlation co-efficient; LASIK, laser in situ keratomileusis; PRK, photorefractive keratectomy; RMS, root mean square; SD, standard deviation. $P < 0.05$ is considered statistically significant

DISCUSSION

This study evaluated the visual outcomes of wavefront-guided PRK and LASIK and investigated their effect on HOAs. In terms of HOAs, total RMS and vertical coma values decreased significantly at 3 months postoperatively in both groups. However, there were no differences between the two groups. In addition, there was no difference in the visual outcomes. With the exception of a weak positive correlation with vertical coma, along with a strong positive correlation with total RMS values in the LASIK group only, no significant correlation was found between K-max and other HOAs in either study group.

Aberrations cause visual distortion and decrease the visual quality [12]. HOAs such as coma, spherical, trefoil, and tetrafoil aberrations account for 15% of the average wavefront defects [13]. The wavefront profile of the cornea provides important information related to the visual quality. Studies have shown that wavefront-guided PRK and LASIK provide better visual outcomes than conventional PRK and LASIK do [14, 15]. Moshirfar et al. showed that wavefront-guided PRK induces fewer HOAs against wavefront-guided LASIK at six months follow-up [16]. However, Hosseini et al. showed that both PRK and LASIK induce HOAs for a 6-mm pupil diameter, with no difference between the two groups [17]. In our study, no significant increase in HOAs was observed in either group, but there was a significant decrease in vertical coma and RMS values in both groups. However, there was no significant difference between the groups. A study by Manche et al. showed that LASIK was superior to PRK in the first postoperative month in terms of HOAs, but there was no difference in the third month; as they noted similar results at 3 months postoperatively [11]. However, we did not record the HOAs at 1 month postoperatively because of late recovery following PRK.

Hosseini et al. showed that spherical aberration was induced significantly in eyes treated with LASIK, but not in eyes treated with PRK [17]; however, in our study, no significant change was observed in spherical aberrations. However, in their study, the preoperative spherical values were -3.26 ± 1.43 D and -3.57 ± 1.75 D in the PRK and LASIK groups, respectively, and the preoperative values in our study were -2.09 ± 1.56 D and -2.23 ± 1.69 D, respectively. In our study, vertical coma values were significantly altered in both groups, but Hosseini et al. found no difference between the two groups. They found that the LASIK group induced more total HOAs compared with the PRK group, yet no statistically significant difference was observed between the two groups. In both groups, vertical coma was directed from negative to positive values, with no significant difference between the two groups [17].

RMS, which is an expression of the physical surface or shape of the wavefront map, represents the deflection on the perfect wavefront. Although the RMS value for total HOAs varies with pupil diameter, when we evaluated HOAs for a 6-mm pupil diameter, it decreased in both groups, yet no difference was found between the groups. In another study, the RMS of the total HOA value decreased or remained unchanged in the PRK group compared with the LASIK group, and they have argued that these findings are caused by aberrations induced by LASIK flap formation using a microkeratome [11]. In contrast, in our study, femtosecond technology was used for flap reconstruction. Perhaps, in our study, a properly formed flap did not pose any risk of aberrations.

Hosseini et al. showed that changes in total HOA RMS and its preoperative values had a significant correlation, whereby a higher increase in the postoperative value correlated with a lower preoperative HOA RMS [17]. They argued that this could either reflect the effect of different ablation depths on HOAs or the success of personalized ablation. Wavefront-guided ablation corrects some old HOAs while inducing a new set of HOAs. As in our study, coma aberrations were induced, while other HOAs did not change. Hosseini et al. found that in multiple regression analyses, preoperative spherical and cylindrical values, and optical zone only could predict 51% and 42% of the variance of alterations in total HOA RMS following PRK and LASIK for a 6-mm pupil diameter, respectively [17]. Decentered ablation, flap reconstruction, wound healing, and epithelial hyperplasia could be among the other influential factors [17]. In our study, the properly formed flap using femtosecond technology may explain the lack of a significant difference between the two groups.

Although comparing pre- and postoperative values of HOAs in PRK and LASIK groups using wavefront-guided technology is one of the strengths of this study, the lack of longer postoperative follow-up with multiple measurements is a limitation. Conducting future studies with multiple postoperative visits and longer follow-ups, in addition to the recruitment of patients with higher refractive error values, can provide a broad horizon for accurately determining the effect of refractive surgery on the patient's quality of vision.

CONCLUSIONS

Wavefront-guided PRK and LASIK have been successful in reducing HOAs in patients with myopia and myopic astigmatism. Although the PRK method is now an old method, its success in improving visual acuity and quality is comparable to that of femtosecond-assisted LASIK—a newer, more advanced technology.

ETHICAL DECLARATIONS

Ethical approval: Ethics committee approval was obtained from the Institutional Review Board of Erciyes University (no.: 2020/102, date: 12.02.2020). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Conflict of interest: None.

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REFERENCES

1. Farjo AA, Sugar A, Schallhorn SC, Majmudar PA, Tanzer DJ, Trattler WB, et al. Femtosecond lasers for LASIK flap creation: a report by the American Academy of Ophthalmology. Ophthalmology. 2013;120(3):e5-e20. doi: 10.1016/j.ophtha.2012.08.013 pmid: 23174396
2. Agarwal S, Thornell E, Hodge C, Sutton G, Hughes P. Visual Outcomes and Higher Order Aberrations Following LASIK on Eyes with Low Myopia and Astigmatism. Open Ophthalmol J. 2018;12:84-93. doi: 10.2174/1874364101812010084 pmid: 29997707
3. Chalita MR, Chavala S, Xu M, Krueger RR. Wavefront analysis in post-LASIK eyes and its correlation with visual symptoms, refraction, and topography. Ophthalmology. 2004;111(3):447-53. doi: 10.1016/j.ophtha.2003.06.022 pmid: 15019317
4. Oshika T, Miyata K, Tokunaga T, Samejima T, Amano S, Tanaka S, et al. Higher order wavefront aberrations of cornea and magnitude of refractive correction in laser in situ keratomileusis. Ophthalmology. 2002;109(6):1154-8. doi: 10.1016/s0161-6420(02)01028-x pmid: 12045059
5. Ivarsen A, Hjortdal J. Seven-year changes in corneal power and aberrations after PRK or LASIK. Invest Ophthalmol Vis Sci. 2012; 53(10):6011-6. doi: 10.1167/iovs.12-10208 pmid: 22879417
6. Moreno-Barriuso E, Lloves J, Marcos S, Navarro R, Llorente L, Barbero S. Ocular aberrations before and after myopic corneal refractive surgery: LASIK-induced changes measured with laser raytracing Invest Ophthalmol VisSci. 2001 42(6):1396-403.
7. Sales CS, Manche EE. One-year eye-to-eye comparison of wavefront-guided versus wavefront-optimized laser in situ keratomileusis in hyperopes. Clin Ophthalmol. 2014;8:2229-38. doi: 10.2147/OPTH.S70145 pmid: 25419115
8. Padmanabhan P, Mrochen M, Basuthkar S, Viswanathan D, Joseph R. Wavefront-guided versus wavefront-optimized laser in situ keratomileusis: contralateral comparative study. J Cataract Refract Surg. 2008;34(3):389-97. doi: 10.1016/j.jcrs.2007.10.028 pmid: 18299062
9. Endl MJ, Martinez CE, Klyce SD, McDonald MB, Coorpender SJ, Applegate RA, et al. Effect of larger ablation zone and transition zone on corneal optical aberrations after photorefractive keratectomy. Arch Ophthalmol. 2001;119(8):1159-64. doi: 10.1001/archopht.119.8.1159 pmid: 11483083
10. Waheed S, Chalita MR, Xu M, Krueger RR. Flap-induced and laser-induced ocular aberrations in a two-step LASIK procedure. J Refract Surg. 2005;21(4):346-52. pmid: 16128331
11. Manche EE, Haw WW. Wavefront-guided laser in situ keratomileusis (Lasik) versus wavefront-guided photorefractive keratectomy (Prk): a prospective randomized eye-to-eye comparison (an American Ophthalmological Society thesis). Trans Am Ophthalmol Soc. 2011;109:201-20. pmid: 22253488
12. Applegate R, Hilmanted G, Thibos L. Assesment of visual performance (chapter 7). In: Kruger R, Applegate R, Macrae S, editors. Wavefront customized visual correction: the quest for super vision. 2nd ed. New Jersey Slack: Inc; 2004. p. 65-76.
13. Rabinowitz YS. The genetics of keratoconus. Ophthalmol Clin North Am. 2003;16(4):607-20, vii. doi: 10.1016/s0896-1549(03)00099-3 pmid: 14741001
14. Wigledowska-Promienska D, Zawojska I. Changes in higher order aberrations after wavefront-guided PRK for correction of low to moderate myopia and myopic astigmatism: two-year follow-up. Eur J Ophthalmol. 2007;17(4):507-14. doi: 10.1177/112067210701700405 pmid: 17671923
15. Zhang J, Zhou YH, Wang NL, Li R. Comparison of visual performance between conventional LASIK and wavefront-guided LASIK with iris-registration. Chin Med J (Engl). 2008;121(2):137-42. pmid: 18272040
16. Moshirfar M, Schliesser JA, Chang JC, Oberg TJ, Mifflin MD, Townley R, et al. Visual outcomes after wavefront-guided photorefractive keratectomy and wavefront-guided laser in situ keratomileusis: Prospective comparison. J Cataract Refract Surg. 2010;36(8):1336-43. doi: 10.1016/j.jcrs.2010.02.012 pmid: 20656157
17. Jahadi Hosseini SH, Abtahi SM, Khalili MR. Comparison of Higher Order Aberrations after Wavefront-guided LASIK and PRK: One Year Follow-Up Results. J Ophthalmic Vis Res. 2016;11(4):350-7. doi: 10.4103/2008-322X.194069 pmid: 27994802