Intraocular Straylight and Contrast Sensitivity After Contralateral Wavefront-guided LASIK and Wavefront-guided PRK for Myopia

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ABSTRACT

PURPOSE: To compare intraocular straylight measurements and contrast sensitivity after wavefront-guided LASIK (WFG LASIK) in one eye and wavefront-guided photorefractive keratectomy (WFG PRK) in the fellow eye for myopia and myopic astigmatism correction.

METHODS: A prospective, randomized study of 22 eyes of 11 patients who underwent simultaneous WFG LASIK and WFG PRK (contralateral eye). Both groups were treated with the NIDEK Advanced Vision Excimer Laser System, and a microkeratome was used for flap creation in the WFG LASIK group. High and low contrast visual acuity, wavefront analysis, contrast sensitivity, and retinal straylight measurements were performed preoperatively and at 3, 6, and 12 months postoperatively. A third-generation straylight meter, C-Quant (Oculus Optikgeräte GmbH), was used for measuring intraocular straylight.

RESULTS: Twelve months postoperatively, mean uncorrected distance visual acuity was -0.06 ± 0.07 logMAR in the WFG LASIK group and -0.10 ± 0.10 logMAR in the WFG PRK group. Mean preoperative intraocular straylight was 0.94 ± 0.12 log s for the WFG LASIK group and 0.96 ± 0.11 log *s* for the WFG PRK group. After 12 months, the mean straylight value was 1.01 ± 0.1 log *s* for the WFG LASIK group and 0.97 ± 0.12 log s for the WFG PRK group. No difference was found between techniques after 12 months (P=.306). No significant difference in photopic and mesopic contrast sensitivity between groups was noted.

CONCLUSIONS: Intraocular straylight showed no statistically significant increase 1 year after WFG LASIK and WFG PRK. Higher order aberrations increased significantly after surgery for both groups. Nevertheless, WFG LASIK and WFG PRK yielded excellent visual acuity and contrast sensitivity performance without significant differences between techniques. [*J Refract Surg.* 2009;xx:xxx-xxx.] doi:10.3928/1081597X-

Disability glare is one of the side effects of refractive surgery.[1,2] It is due to light scatter in the optic media of the eye, which results in a veil of straylight over the retinal image. Intraocular straylight causes reduction in the contrast of the retinal image, thus decreasing quality of vision[3] and patients may experience blinding from oncoming traffic lights at night.

In an ideal eye there would be no light scattering at all, but the eye media are not optically ideal. Some of the rays entering the eye are dispersed by optical imperfections of the refracting elements. These dispersed rays spread over the retina with decreasing densities at distances farther away from the focal point of the eye.

One major source that contributes to the total amount of intraocular straylight is the cornea.[4,5] Unlike the lens, corneal light scatter is constant during one's lifetime.[6,7] However, previous studies in eyes with corneal diseases found a straylight increase due to corneal opacities and irregularities.[8]

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This study was supported by a postgraduate fellowship from Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) to Dr Barreto and graduate fellowships from FAPESP to Drs Barboni and Feitosa-Santana (07/55125-1 and 05/53974-6, respectively), and a postdoctoral fellowship from NIH to Dr Feitosa-Santana (NIH EY-04802). Dr Ventura is a CNPq research fellow, and Dr Feitosa-Santana is an IMB (University of Chicago) research fellow. The remaining authors have no proprietary interest in the materials presented herein.

The authors thank Marcos Lago, MSc, for helpful discussions throughout the project, and Emilia Longhi, MSci, for her collaboration with the C-Quant use and measurements.

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Received: January 22, 2009; Accepted: September 3, 2009

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TABLE 1

Visual Acuity and Refraction for 22 Eyes 12 Months After Simultaneous Wavefront-guided LASIK and Wavefront-guided PRK

	Preoperative	12 Months Postoperative
UDVA (logMAR)		
WFG LASIK	0.75±0.35	−0.06±0.07
WFG PRK	0.80±0.30	−0.10±0.10
P Value	.068	.038*
CDVA (logMAR)		
WFG LASIK	−0.06±0.05	−0.11±0.06
WFG PRK	−0.06±0.05	−0.14±0.07
P Value	.593	.180
SE (D)		
WFG LASIK	−2.50±0.99	−0.05±0.40
WFG PRK	−2.35±0.93	−0.19±0.42
P Value	.262	.678

0.0 logMAR = 20/20 Snellen, UDVA = uncorrected distance visual acuity, CDVA = corrected distance visual acuity, WFG = wavefront-guided, PRK = photorefractive keratectomy, SE = spherical equivalent refraction
**After Bonferroni correction, P<.003125 should be considered.*

Corneal light scatter may increase after refractive surgery, mainly after surface ablation, due to the healing process.[9-12]

This study compares intraocular straylight and contrast sensitivity after wavefront-guided LASIK (WFG LASIK) and wavefront-guided photorefractive keratectomy (WFG PRK) 12 months after surgery.

PATIENTS AND METHODS

This prospective, randomized, masked study included 22 eyes of 11 patients (6 men, 5 women; mean age: 33.8±4.8 years, range: 25 to 39 years) with myopic astigmatism who underwent simultaneous WFG LASIK in one eye and WFG PRK in the fellow eye. Complete ophthalmologic examination, topography, pachymetry, wavefront analysis, and contrast sensitivity assessment were performed. Exclusion criteria were patients aged <21 or >40 years, corrected distance visual acuity (CDVA) worse than 0.0 logMAR (Snellen 20/20) in both eyes, spherical equivalent refraction (SE) >−5.00 diopters (D), estimated ablation depth <60 µm, preexisting ocular pathology, and previous surgery. The study was approved by the Ethics Committee of the University of São Paulo Medical School, and all patients provided informed consent.

All surgeries were wavefront-guided using the Optimized Path Difference Customized Aspheric Treatment platform (OPDCAT; NIDEK Co Ltd, Gamagori, Japan) with a 5.0-mm optical zone and an additional 3.5-mm transition zone. The OPDCAT delivers an aspheric ablation to the total 8.5-mm ablation zone and treats the ocular higher order aberrations, up to the 8th Zernike order. Patients were randomized to receive LASIK in one eye and PRK in the contralateral eye. The LASIK flap was created using an MK2000 microkeratome (NIDEK Co Ltd) with a 160-µm head with diameter of 9.0 mm. In the PRK group, the epithelium was removed mechanically using a blunt blade; no mitomycin C was used.

All patients underwent wavefront analysis using the Optical Path Difference Scanning system (OPD-Scan, NIDEK Co Ltd). Measurements were performed 30 minutes after instillation of one drop each of 1% tropicamide and 1% cyclopentolate. The following data were evaluated: total higher order aberration root-mean-square from the third to the eighth radial orders, third order coma (Z_3^1, Z_3^{-1}), and fourth order spherical aberration (Z_4^0) in microns.

Intraocular straylight was measured as the straylight parameter *s* and expressed in log *s*[13] using the C-Quant straylight meter (Oculus Optikgeräte GmbH, Wetzlar, Germany). The C-Quant assesses the amount of light scattered towards the retina by a psychophysical approach called the compensation comparison method.[13,14] Straylight measurements were taken with undilated photopic pupils. At least two reliable measurements were obtained from each eye of all participants, and the variance component was calculated. The measurement with a lower standard deviation was chosen for comparing pre- and postoperative ocular straylight.

Contrast sensitivity was evaluated using the VCTS 6500 (Vistech Consultants Inc, Dayton, Ohio), which presents sine-wave gratings with spatial frequencies ranging from 1.5 to 18 cycles per degree. Contrast measurements were obtained under photopic (85 cd/m^2) and mesopic (6 cd/m^2) conditions.

Statistical analysis was carried out using a nonparametric test, the Wilcoxon signed rank test, due to the sample size and data distribution. The significance level (type I error) was set at 5%.

RESULTS

Twenty-two myopic eyes of 11 patients with a mean age of 33.8±4.8 years (range: 25 to 39 years) were enrolled in this study. Seven left eyes and 4 right eyes received WFG PRK. Mean preoperative SE was −2.50±0.99 D in the WFG LASIK group and −2.35±0.93 D in the WFG PRK group. All patients

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TABLE 2

Wavefront Analysis for a 6-mm Pupil for 22 Eyes 12 Months After Simultaneous Wavefront-guided LASIK and Wavefront-guided PRK

	Preop	1 Month	3 Months	6 Months	12 Months
Total higher order aberrations (μm)					
WFG LASIK	0.38±0.10	0.50±0.11	0.48±0.12	0.51±0.14	0.53±0.32
WFG PRK	0.37±0.12	0.46±0.11	0.44±0.11	0.43±0.11	0.40±0.09
P Value	.575	.476	.593	.241	.313
Coma (μm)					
WFG LASIK	0.14±0.08	0.26±0.13	0.25±0.14	0.23±0.13	0.22±0.09
WFG PRK	0.17±0.08	0.20±0.12	0.23±0.11	0.18±0.10	0.21±0.08
P Value	.286	.476	.858	.284	.767
Spherical aberration (μm)					
WFG LASIK	0.17±0.05	0.27±0.11	0.26±0.10	0.25±0.12	0.21±0.11
WFG PRK	0.15±0.06	0.20±0.08	0.20±0.09	0.19±0.06	0.19±0.17
P Value	.373	.154	.091	.074	.213

WFG = wavefront-guided, PRK = photorefractive keratectomy

completed 12 months of follow-up and all eyes had a preoperative CDVA of 0.0 logMAR or better. Two eyes presented with grade 0.5 to 1 haze, according to the scale by Fantes et al,[15] 40 days after surgery, which decreased thereafter. No other adverse event occurred.

At 12 months postoperatively, uncorrected distance visual acuity (UDVA) showed improvement in all eyes. Postoperative UDVA was significantly better in WFG LASIK eyes (P=.038). However, after Bonferroni correction, no significant difference was found. The mean postoperative CDVA also improved in both groups without significant difference between groups. After 12 months, mean postoperative SE was −0.05±0.40 D in WFG LASIK eyes and −0.19±0.42 D in WFG PRK eyes (Table 1).

Total higher order aberrations increased after surgery (P<.05). However, no difference was found between groups. Mean coma (Z_3^1, Z_3^{-1}) and mean spherical aberration (Z_4^0) also increased without significant difference between WFG LASIK and WFG PRK (Table 2).

Straylight values did not change significantly during follow-up (Table 3, Fig 1). Test-retest variability was higher for the preoperative measurements (average: 0.13±0.22) than for the 12-month follow-up (average: 0.06±0.08), but there was no statistical difference between preoperative and 12 months (P>.05) for the LASIK and PRK results. Three eyes (one WFG LASIK and two WFG PRK eyes) had straylight increase of more than 0.20 log *s* at 3 months and one WFG PRK eye at 3 and 6 months, but all declined thereafter (see Fig 1). Postoperative straylight measurements were similar in both groups after 12 months.

TABLE 3

Straylight Values of 22 Eyes 12 Months After Simultaneous Wavefront-guided LASIK and Wavefront-guided PRK

	Straylight (log *s*)		
	WFG LASIK	WFG PRK	*P* Value
Preop	0.94±0.12	0.96±0.11	.398
3 months	1.08±0.24	1.06±0.27	.173
6 months	1.15±0.33	1.03±0.14	.173
12 months	1.01±0.10	0.97±0.12	.306

WFG = wavefront-guided, PRK = photorefractive keratectomy

Photopic and mesopic contrast sensitivity results are shown in Figures 2 and 3, respectively. No statistically significant improvement was noted in photopic and mesopic contrast sensitivity between preoperative and 12 months postoperative. Twelve months after surgery, eyes that received WFG PRK showed similar (P>.05) photopic and mesopic contrast sensitivity compared with WFG LASIK eyes (see Figs 2 and 3).

DISCUSSION

In this prospective study, no statistically significant increase in intraocular straylight occurred in eyes with WFG PRK after 1-year follow-up. Previous studies re-

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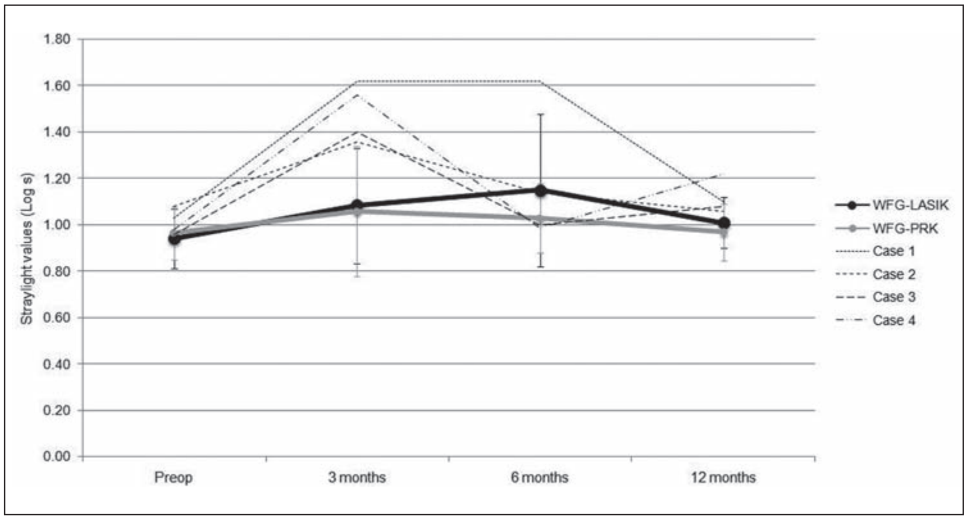

Figure 1. Straylight values expressed by the straylight parameter log *s* (mean±standard deviation) for wavefront-guided LASIK (WFG-LASIK) (black line) and wavefront-guided photorefractive keratectomy (WFG-PRK) (gray line) at 12 months postoperative (*P*=.306). Individual lines (cases 1 to 4) refer to the eyes that showed transient elevations of more than 0.2 log units.

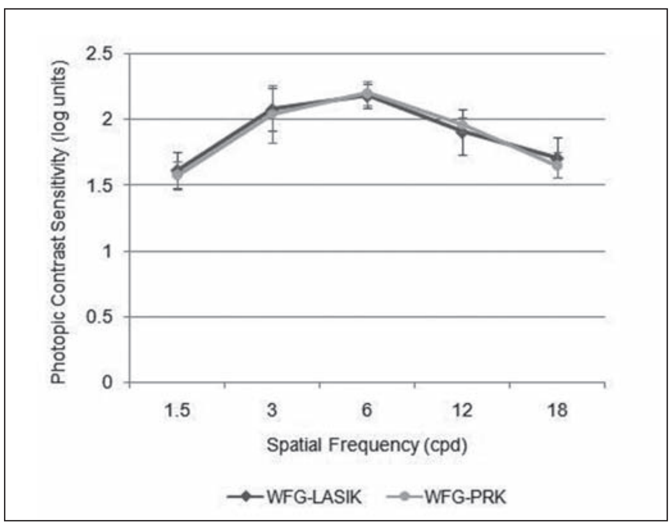

Figure 2. Postoperative photopic contrast sensitivity in wavefront-guided LASIK (WFG-LASIK) (black line) and wavefront-guided photorefractive keratectomy (WFG-PRK) (gray line). Bars around data points correspond to standard deviations. Cpd = cycles per degree

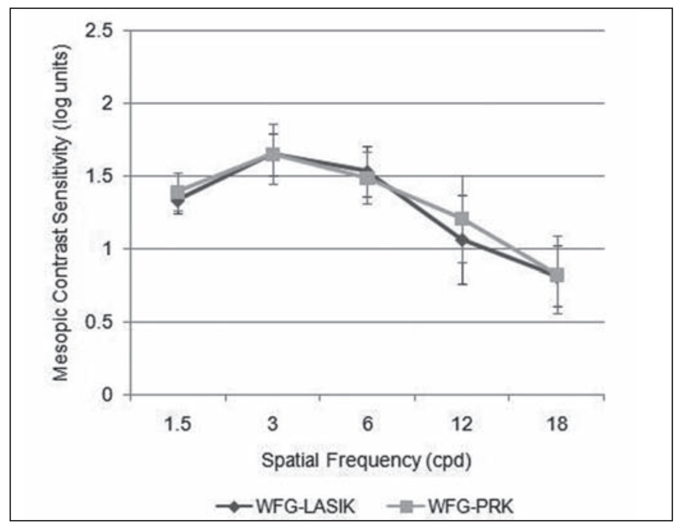

Figure 3. Postoperative mesopic contrast sensitivity in wavefront-guided LASIK (WFG-LASIK) (black line) and wavefront-guided photorefractive keratectomy (WFG-PRK) (gray line). Bars around data points correspond to standard deviations. Cpd = cycles per degree

ported both an increase and no increase of intraocular straylight after PRK.[16-19] However, measurements were obtained 1 month after surgery[16,17] and corneal backscattering of light, which correlates with the observation that visible haze usually develops 1 month after PRK, reaches a peak at 3 months, and then decreases at 6 months.[18,19] In the present study, two eyes had grade 0.5 to 1 haze and an increase of >0.20 log *s* at 3 months. By 6 months postoperative, haze had disappeared and intraocular straylight decreased as expected.

In the WFG LASIK eyes, similar straylight values were found. Two eyes had an increase of >0.20 log *s* between the third and sixth month. However, no microstriae or any flap-related defects were found in either eye and no night vision disturbances were reported. After 12 months, straylight values declined spontaneously in these eyes. In a previous study, two eyes with microstriae in the flap and increased straylight (>0.20 log *s*) were reported.[17] One eye had night vision disturbance and the other eye was asymptomatic. Such reports warn that potential straylight elevation must be considered after LASIK. In the present study, the finding of straylight elevation in 4 of 11 patients agrees with previous data and also confirms that transitory straylight elevations may persist for months.

Wavefront-guided ablation results in a lower amount of higher order aberration induction than conventional surgery.[20-22] Despite the lower magnitude of induction, higher order aberrations may also have a negative impact on visual quality,[23-25] especially under low light conditions. This must be taken into account when assessing patient visual complaints. In this

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study, there was an increase of higher order aberrations for both groups but no significant difference between groups (Table 2). According to Wallau and Campos,[26] eyes that underwent PRK with mitomycin C had less higher order aberrations and better contrast sensitivity postoperatively compared with LASIK eyes. In our study, similar photopic and mesopic contrast sensitivities were reported for WFG PRK and WFG LASIK eyes (see Figs 2 and 3). However, the poor test-retest repeatability of the Vistech charts[27-31] used in our study could obscure subtle differences between normal and abnormal performance, leading to these negative findings, mainly in a small group. Furthermore, mitomycin C, a pharmacological approach for modulating the stromal healing process, was not used in our study. Its benefits in reducing biological diversity in variables such as epithelial hyperplasia and stromal remodeling that often tend to mask attempts at custom ablation, could also improve contrast sensitivity after WFG PRK.[32]

A limitation of this study is the small number of patients evaluated, which may lead to a failure in detecting small differences. A larger number of patients would be needed to ascertain the importance of individual increased straylight values and wavefront aberrations after LASIK and surface ablations.

Undoubtfully, both the flap formation during LASIK and the wound healing process after surface ablations contribute to the final optical properties of the eye. Both situations may interfere with the intraocular straylight and the final amount of higher order aberrations. During our 12-month follow-up, similar straylight results were found after WFG PRK and WFG LASIK, but larger series are needed. Further comprehension of these factors and anatomical limitations of the eye and retina and their ability to transmit an image to the brain are fundamental to understand visual quality.

AUTHOR CONTRIBUTIONS

Study concept and design (J.B., J.R.S., S.J.B., M.R.A.); data collection (J.B., M.B., C.F.S.); interpretation and analysis of data (J.B., D.F.V., M.R.A.); drafting of the manuscript (J.B., M.B., D.F.V.); critical revision of the manuscript (J.B., C.F.S., J.R.S., S.J.B., D.F.V., M.R.A.); statistical expertise (J.R.S.); obtained funding (J.B., C.S.F., D.F.V.); administrative, technical, or material support (S.J.B.); supervision (S.J.B., M.R.A.)

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