ARTICLE

Comparison of postoperative higher-order aberrations and contrast sensitivity: Tissue-saving versus conventional photorefractive keratectomy for low to moderate myopia

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PURPOSE: To assess the efficacy, predictability, safety, contrast sensitivity, higher-order aberrations (HOAs), and patient satisfaction after tissue-saving photorefractive keratectomy (PRK) and conventional PRK.

SETTING: Department of Ophthalmology, Farabi Eye Hospital, Tehran Medical University, Tehran, Iran.

DESIGN: Comparative case series.

METHODS: This prospective study evaluated eyes with low to moderate myopia that had PRK with a Technolas 217z excimer laser. Patients were randomly assigned to have surgery using a conventional algorithm (PlanoScan) or a tissue-saving algorithm (Zyoptix). Contrast sensitivity, HOAs, and patient satisfaction were analyzed preoperatively and 1, 3, and 6 months postoperatively.

RESULTS: The conventional group comprised 42 eyes (21 patients) and the tissue-saving group, 62 eyes (31 patients). At 6 months, all eyes in both groups were within ±0.50 diopter of the attempted correction and had an uncorrected distance visual acuity of 20/25 or better. However, the tissue-saving group had a statistically significantly greater increase in the mean root mean square of total HOAs and more induced spherical aberration than the conventional group ($P<.05$). There was no significant difference between the 2 groups in mesopic or photopic contrast sensitivity. The level of satisfaction after surgery was the same in the 2 groups.

CONCLUSIONS: Although the conventional and tissue-saving algorithms for PRK were both safe and effective in treating low to moderate myopia, tissue-saving PRK induced a greater increase in HOAs than conventional PRK; this may be because of the smaller blend zone of the tissue-saving algorithm. Contrast sensitivity and patient satisfaction were comparable between the 2 methods.

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Photorefractive keratectomy (PRK) is one of the most commonly performed ablative refractive surgeries worldwide, and recently there has been an increasing trend toward the use of surface ablation. The renewed interest in this refractive technique is the result of the advent of new flying-spot excimer lasers, adjuvant application of mitomycin-C, new generations of therapeutic contact lenses, the lower risk for intraoperative and postoperative complications, and good outcomes and safety, particularly in myopic eyes. In addition, surface ablation can now be performed in eyes with a thin central cornea and using higher limits of stromal ablation.[1–4]

Tissue-saving algorithms have been developed to increase the limits of myopic refractive correction, in particular to avoid postoperative keratectasia in laser

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in situ keratomileusis (LASIK) candidates with borderline residual stromal bed (RSB) thickness. Tissue-saving ablation patterns can also be used for PRK in eyes with a relatively thin cornea. These algorithms ablate less stromal tissue to achieve the desired correction and shorten the ablation time by decreasing the ablation stages of the excimer laser, leading to better patient cooperation.[5–9]

However, a recent study[10] found a greater increase in higher-order aberrations (HOAs) after tissue-saving LASIK than after conventional LASIK using an excimer laser. This increase can affect the quality of vision by inducing significant reductions in contrast sensitivity under mesopic conditions and cause adverse postoperative symptoms, such as glare and halos.[11–15] The aim of this randomized prospective study was to compare the efficacy, predictability, safety, stability, contrast sensitivity, HOAs, and satisfaction of patients who had PRK with a tissue-saving algorithm or a conventional algorithm over a follow-up of 6 months.

PATIENTS AND METHODS

This study evaluated eyes with low to moderate myopia that had excimer laser PRK between October 2008 and February 2009 at Farabi Eye Hospital. The study followed the tenets of the Declaration of Helsinki, and the Institutional Review Board, Tehran University of Medical Sciences, approved the study. All patients provided written informed consent. Surgery was performed in both eyes during the same session.

Patients selected for the study met the following criteria: age 20 years or older, documented stable refraction for at least 1 year, central corneal thickness 480 µm or thicker, spherical equivalent (SE) refraction −5.00 diopters (D) or lower of myopia, refractive astigmatism 2.00 D or lower, and corrected distance visual acuity (CDVA) 20/20 or better. Exclusion criteria were a history of refractive or cataract surgery, keratoconus, collagen vascular disease, and diabetic retinopathy. Soft contact lenses and rigid gas-permeable contact lenses were removed for a minimum of 2 weeks and 4 weeks, respectively, before the preoperative examination.

Preoperative Assessment

The preoperative ophthalmic examination included visual acuity measurement with a Snellen E chart, manifest and cycloplegic refractions, slitlamp microscopy, applanation tonometry, and indirect ophthalmoscopy. Corneal topography (Orbscan IIz, Bausch & Lomb) and wavefront Hartmann-Shack aberrometry measurements (Zywave II, Bausch & Lomb) were performed. All measurements were under mesopic conditions (3 candelas [cd]/m^2). If the manifest pupil was smaller than 6.0 mm, pharmaceutical agents were used to achieve a 6.0 mm pupil. All wavefront maps were standardized for a 6.0 mm pupil. The pupil diameter was also measured using a wavefront sensor.

Excimer Laser and Ablation Algorithms

Surgery was performed using a Technolas 217z100 excimer laser system (Bausch & Lomb), which has 4 software programs. In this study, patients were randomized (random number sheet) to have PRK using the PlanoScan algorithm software for conventional treatment or the Zyoptix tissue-saving algorithm software, in which less corneal tissue is removed than in conventional treatments because of the small blend zone.

In all cases, the optical zone was 6.0 mm and the primary goal was emmetropia. The programming for all treatments was based on the manifest refraction. No nomogram adjustments were made.

Surgical Technique

After topical tetracaine 0.5% drops were administered to anesthetize the eye, an eyelid speculum was inserted. The surface corneal epithelium in a 9.0 mm diameter area was loosened using a 20% alcohol solution and a blunt spatula and then discarded. The ocular surface was irrigated with a balanced salt solution and the cornea dried with a polyvinyl alcohol sponge (Merocel). An Acuvue Advance HydraClear soft contact lens with a base curve of 8.4 mm, diameter of 14.0 mm, DK/t value of 86, and oxygen flux of 97% (Johnson & Johnson Vision Care, Inc.) was placed over the cornea at the end of procedure. Mitomycin-C was not used after the laser ablation.

Postoperative Protocol

After surgery, patients were given chloramphenicol 0.5% drops 4 times a day for 5 days and diclofenac sodium 0.1% 4 times a day for the first day. The contact lens was removed when reepithelialization was complete (between 3 days and 5 days postoperatively). Betamethasone 0.1% drops were applied 4 times a day for 3 weeks and then changed to fluorometholone 0.1% drops 4 times a day, after which the drops were tapered over 8 weeks depending on the eye's clinical appearance and refraction. Preservative-free hypromellose 0.32% artificial tears (Artelac) were prescribed 4 times a day for 3 weeks and then tapered over 8 weeks.

Postoperative follow-up was every day for the first 5 days. Patients then had a complete ophthalmic evaluation at 1, 3, and 6 months.

Outcome Measures

Postoperative parameters included efficacy, stability, predictability, safety, and HOAs. Safety was evaluated by the number of eyes that lost 2 or more lines of CDVA at 6 months. The safety index[16] was defined as the mean postoperative CDVA/mean preoperative CDVA. Predictability was evaluated at 6 months using the mean cycloplegic SE. Efficacy was

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evaluated by the uncorrected distance visual acuity (UDVA) at 6 months. The efficacy index[16] was calculated as the postoperative UDVA/the preoperative CDVA. Stability was measured by comparing the postoperative cycloplegic SE at 3 and 6 months.

Contrast sensitivity was measured preoperatively and 1, 3, and 6 months postoperatively using a CSV-1000E device (VectorVision) under photopic and mesopic conditions as described by Quesnel et al.[17] The luminance at the patient's eye was approximately 75 cd/m^2 for photopic conditions and 3 cd/m^2 for mesopic conditions. Dark adaptation was a minimum of 5 minutes in all cases. Because residual refractive error can modify contrast sensitivity,[18] all contrast sensitivity measurements were performed with best distance correction.

At 3 months, patients were asked to complete a previously validated questionnaire.[19] Before responding to the questionnaire, patients were informed that cooperation was voluntary and that the results would be confidential and would not affect their postoperative care. The patients completed the questionnaires themselves without help (eg, of a research assistant). However, a research assistant was available to answer questions.

The questionnaire was a 14-item self-report instrument that mainly assessed the patients' postoperative overall satisfaction and visual symptoms, such as glare and halo (Supplement A, available at http://jcrsjournal.org). Patients were asked to rate the quality of their distance vision and to grade their level of satisfaction on a scale of 1 to 5 (1 = very unsatisfied; 5 = very satisfied). They were also asked to evaluate their symptoms of glare and halos on a scale of 0 to 5 (0 = none; 1 = very low; 2 = low; 3 = moderate; 4 = high; 5 = very high). Patients were asked whether they would recommend their surgery to others with the same refractive error and whether, based on their experience, they would choose to have the same surgery if they had not had it previously.

Statistical Analysis

Data analysis was performed using SPSS for Windows software (version 13.0, SPSS, Inc.). A paired-sample *t* test was used for preoperative to postoperative comparisons and an independent-sample *t* test for comparisons between the conventional ablation group and the tissue-saving ablation group. Correlations were determined using the Pearson correlation coefficient (*r*). A *P* value less than 0.05 was considered statistically significant.

RESULTS

Twenty-one patients (42 eyes) were treated with the conventional algorithm and 31 patients (62 eyes) with the tissue-saving algorithm. Table 1 shows the patients' demographic and pretreatment data. There was no statistically significant difference between the 2 groups in mean age (*P* = .67), mean sphere (*P* = .41), mean cylinder (*P* = .45), mean SE (*P* = .21), or mean pupil diameter for treatment (*P* = .57). The percentages of eyes with low myopia (≤−3.00 D) and with moderate myopia (>−3.00 D) were similar in the 2 groups. The mean predicted ablation depth was statistically significantly greater in the conventional group than in the tissue-saving group (*P* = .04).

Table 1. Demographic and preoperative information.

Parameter	Group	
	Conventional	Tissue Saving
Patients (n)	21	31
Eyes (n)	42	62
Age (y)		
Mean ± SD	26.2 ± 4.6	26.6 ± 4.3
Range	20 to 35	20 to 35
Sphere (D)		
Mean ± SD	−2.50 ± 0.54	−2.63 ± 0.79
Range	−1.00 to −3.50	−1.25 to −4.00
Cylinder (D)		
Mean ± SD	−0.56 ± 0.46	−0.59 ± 0.49
Range	0.00 to −2.00	0.00 to −2.00
SE (D)		
Mean ± SD	−2.77 ± 0.51	−2.93 ± 0.79
Range	−1.50 to −3.62	−1.50 to −4.50
Pupil diameter (mm)		
Mean ± SD	7.12 ± 0.78	7.03 ± 0.71
Range	6.00 to 8.50	6.02 to 8.50
Level of myopia, n (%)		
High (>3.00 D)	14 (33.3)	24 (38.7)
Low (≤3.00 D)	28 (66.7)	38 (61.3)
Predicted ablation depth (μm)		
Mean ± SD	53.1 ± 15.4	42.4 ± 9.9
Range	30 to 95	26 to 70

SE = spherical equivalent

All patients completed the 1-month and 3-month follow-up examinations. Thirty eyes (71%) in the conventional group and 38 eyes (61%) in the tissue-saving group had a 6-month follow-up examination. The patients missing at 6 months were excluded from that analysis. They were called again, however, and all reported stable or improved visual acuity compared with the 3-month follow-up and said they were completely satisfied with the outcomes of the surgery.

Stability

At 3 months, the mean SE was −0.020 D ± 0.18 (SD) (range −0.88 to 0.38 D) in the conventional group and −0.008 ± 0.15 D (range −0.38 to +0.62 D) in the tissue-saving group. At 6 months, the mean was 0.030 ± 0.15 D (range −0.25 to +0.38 D) and −0.030 ± 0.12 D (range −0.50 to 0.25 D), respectively. The change in SE between 3 months and 6 months was not statistically significant in either group (*P* = .09).

Table 2. Root mean square of HOAs and selected single Zernike coefficients preoperatively and postoperatively group.

				Postoperative								
	Preoperative			1 Month			3 Months			6 Months		
RMS (μm)	Conv	TS	*P*	Conv	TS	*P*	Conv	TS	*P*	Conv	TS	*P*
Total HOAs												
Mean ± SD	0.31 ± 0.09	0.3 ± 0.14	.53	0.43 ± 0.16	0.47 ± 0.14	.15	0.40 ± 0.12	0.47 ± 0.16	.07	0.39 ± 0.13	0.44 ± 0.14	.19
Range	0.11–0.53	0.12–0.88		0.17–1.03	0.18–0.84		0.13–0.65	0.17–0.88		0.15–0.65	0.17–0.74	
Total 3rd order												
Mean ± SD	0.47 ± 0.19	0.44 ± 0.26	.52	0.58 ± 0.28	0.58 ± 0.24	.9	0.51 ± 0.25	0.57 ± 0.26	.33	0.50 ± 0.20	0.56 ± 0.24	.32
Range	0.09–0.98	0.11–1.49		0.08–1.40	0.05–1.21		0.05–1.07	0.16–1.21		0.18–0.89	0.11–1.21	
Trefoil-x Z(−3,3)												
Mean ± SD	0.10 ± 0.08	0.09 ± 0.07	.49	0.12 ± 0.10	0.10 ± 0.07	.22	0.12 ± 0.08	0.10 ± 0.07	.14	0.09 ± 0.06	0.09 ± 0.08	.64
Range	0.00–0.34	0.00–0.32		0.01–0.41	0.00–0.28		0.00–0.32	0.00–0.32		0.00–0.29	0.00–0.38	
Coma-x Z(−1,3)												
Mean ± SD	0.09 ± 0.08	0.07 ± 0.06	.07	0.12 ± 0.11	0.16 ± 0.13	.13	0.12 ± 0.10	0.16 ± 0.14	.11	0.14 ± 0.10	0.18 ± 0.15	.24
Range	0.00–0.37	0.00–0.27		0.01–0.54	0.01–0.57		0.01–0.44	0.00–0.55		0.03–0.41	0.01–0.60	
Coma-y Z(1,3)												
Mean ± SD	0.13 ± 0.11	0.13 ± 0.11	.87	0.19 ± 0.14	0.17 ± 0.14	.7	0.15 ± 0.13	0.19 ± 0.14	.29	0.14 ± 0.12	0.17 ± 0.13	.36
Range	0.00–0.37	0.00–0.47		0.00–0.58	0.00–0.55		0.00–0.46	0.00–0.58		0.00–0.43	0.01–0.51	
Trefoil-y Z(3,3)												
Mean ± SD	0.12 ± 0.09	0.13 ± 0.12	.6	0.13 ± 0.10	0.12 ± 0.13	.86	0.11 ± 0.09	0.11 ± 0.11	.91	0.12 ± 0.09	0.10 ± 0.08	.3
Range	0.00–0.34	0.01–0.62		0.00–0.55	0.00–0.70		0.00–0.40	0.00–0.58		0.00–0.35	0.00–0.33	
Total 4th order												
Mean ± SD	0.23 ± 0.11	0.24 ± 0.11	.69	0.40 ± 0.16	0.47 ± 0.16	.03	0.32 ± 0.11	0.41 ± 0.17	.09	0.34 ± 0.14	0.42 ± 0.15	.14
Range	0.08–0.55	0.04–0.64		0.14–0.85	0.14–0.84		0.12–0.72	0.14–0.81		0.09–0.69	0.10–0.74	
SA Z(0,4)												
Mean ± SD	0.08 ± 0.07	0.09 ± 0.07	.86	0.19 ± 0.12	0.25 ± 0.13	.02	0.17 ± 0.11	0.23 ± 0.14	.04	0.16 ± 0.12	0.22 ± 0.11	.05
Range	0.00–0.30	0.00–0.31		0.01–0.53	0.01–0.62		0.03–0.43	0.01–0.58		0.00–0.50	0.04–0.49	

Conv = conventional algorithm group; HOA = higher-order aberration; *P* = *P* value; RMS = root mean square SA = spherical aberration; TS = tissue-saving algorithm group

Safety

At 6 months, the mean CDVA was −0.04 ± 0.04 logMAR (range −0.10 to 0.00 logMAR) in the conventional group and −0.02 ± 0.04 logMAR (range −0.10 to 0.00 logMAR) in the tissue-saving group. The difference between the groups was not statistically significant (95% confidence interval [CI], −0.04 to 0.00; *P* = .06). No eye lost more than 1 line of CDVA. The safety index was 1.08 in the conventional group and 1.05 in the tissue-saving group.

Efficacy

At 6 months, the mean UDVA was −0.02 ± 0.04 logMAR (range −0.10 to 0.00 logMAR) in the conventional group and −0.01 ± 0.05 logMAR (range −0.10 to 0.10 logMAR) in the tissue-saving group. The difference between groups was not statistically significant (95% CI, 0.040 to 0.007; *P.17* =). The UDVA was 20/16 or better in 9 eyes (30%) and 20/20 or better in 30 eyes (100%) in the conventional group. It was 20/16 or better in 8 eyes (21.1%), 20/20 or better in 35 eyes (92.1%), and 20/25 or better in 38 eyes (100%) in the tissue-saving group. The efficacy index was 1.05 in the conventional group and 1.03 in the tissue-saving group.

Predictability

At 6 months, the mean SE was 0.03 ± 0.15 D (range −0.25 to +0.38 D) in the conventional group and −0.03 ± 0.12 D (range −0.50 to +0.25 D) in the tissue-saving group. The difference between the 2 groups was not statistically significant (95% CI, 0.005 to 0.130; *P* = .07). At 6 months, all eyes in both groups were within ±0.50 D of the attempted correction.

Higher-Order Aberrations

Table 2 shows the root mean square (RMS) of HOAs and selected single Zernike coefficients and Table 3, the absolute changes over time. The RMS of total HOAs was not significantly different between the 2 groups preoperatively (*P* = .53). Six months after

Table 3. Absolute change in magnitude of higher-order Zernike from preoperatively to postoperatively.

	Absolute Change (μm)								
	1 Month Postop			3 Months Postop			6 Months Postop		
RMS	Conv	TS	P	Conv	TS	P	Conv	TS	P
Total HOAs									
Mean ± SD	0.11 ± 0.14	0.18 ± 0.17	.04	0.08 ± 0.10	0.16 ± 0.20	.09	0.08 ± 0.11	0.16 ± 0.16	.02
Range	−0.16 to 0.62	−0.25 to 0.51		−0.11 to 0.24	−0.28 to 0.59		−0.20 to 0.28	−0.31 to 0.51	
Total 3rd order									
Mean ± SD	0.11 ± 0.30	0.15 ± 0.32	.5	0.01 ± 0.22	0.12 ± 0.34	.33	0.02 ± 0.22	0.12 ± 0.28	.04
Range	−0.46 to 1.02	−0.83 to 0.83		−0.39 to 0.39	−0.83 to 0.84		−0.51 to 0.36	−0.35 to 0.76	
Trefoil-x Z(−3,3)									
Mean ± SD	0.02 ± 0.11	0.01 ± 0.08	.7	0.01 ± 0.08	0.00 ± 0.09	.56	0.00 ± 0.08	0.01 ± 0.08	.45
Range	−0.22 to 0.40	−0.16 to 0.24		−0.11 to 0.31	−0.19 to 0.19		−0.19 to 0.18	−0.16 to 0.35	
Coma-x Z(−1,3)									
Mean ± SD	0.03 ± 0.13	0.09 ± 0.15	.03	0.00 ± 0.13	0.08 ± 0.15	.01	0.04 ± 0.12	0.11 ± 0.17	.04
Range	−0.19 to 0.44	−0.17 to 0.5		−0.24 to 0.34	−0.19 to 0.53		−0.17 to 0.29	−0.16 to 0.55	
Coma-y Z(1,3)									
Mean ± SD	0.05 ± 0.16	0.04 ± 0.16	.9	0.00 ± 0.11	0.05 ± 0.16	.2	−0.01 ± 0.11	0.04 ± 0.14	.1
Range	−0.21 to 0.57	−0.33 to 0.51		−0.24 to 0.34	−0.33 to 0.48		−0.25 to 0.22	−0.22 to 0.35	
Trefoil-y Z(3,3)									
Mean ± SD	0.00 ± 0.12	0.00 ± 0.13	.79	−0.01 ± 0.07	−0.01 ± 0.10	.99	0.00 ± 0.08	−0.01 ± 0.07	.68
Range	−0.02 to 0.47	−0.27 to 0.65		−0.21 to 0.15	−0.28 to 0.31		−0.19 to 0.15	−0.18 to 0.13	
Total 4th order									
Mean ± SD	0.16 ± 0.14	0.22 ± 0.18	.06	0.14 ± 0.14	0.17 ± 0.19	.11	0.13 ± 0.11	0.19 ± 0.13	.07
Range	−0.22 to 0.48	−0.42 to 0.56		−0.24 to 0.35	−0.21 to 0.54		−0.19 to 0.36	−0.05 to 0.49	
SA Z(0,4)									
Mean ± SD	0.10 ± 0.10	0.16 ± 0.14	.01	0.10 ± 0.09	0.18 ± 0.15	.02	0.10 ± 0.10	0.15 ± 0.12	.05
Range	−0.19 to 0.33	−0.21 to 0.44		−0.09 to 0.25	−0.17 to 0.48		−0.09 to 0.26	−0.12 to 0.42	

Conv = conventional algorithm group; HOA = higher-order aberration; *P* = *P* value; RMS = root mean square SA = spherical aberration; TS = tissue-saving algorithm group

surgery, there was a statistically significant increase over preoperatively in the mean RMS of total HOAs in the conventional group (factor increase 1.3) and in the tissue-saving group (factor increase 1.78) ($P<.001$). The increase was statistically significantly greater in the tissue-saving group than in the conventional group ($P = .02$).

The increase in total HOA RMS values was correlated with the manifest refraction SE (MRSE) treated ($r^2 = 0.27$, $P<.001$) and with the ablation depth ($r^2 = 0.30$, $P<.001$) in the tissue-saving group but not in the conventional group. The increase was not correlated with scotopic pupil size or total preoperative HOA in either group.

A significant increase in 3rd-order aberrations was observed in both conventional and tissue-saving groups 1 month after surgery compared with preoperative values ($P<.001$). The magnitude of postoperative increase of 3rd-order aberrations at 6 months was significantly greater in the tissue-saving group ($P = .04$). The magnitude of postoperative increase of 3rd-order horizontal coma aberration was also significantly higher in the tissue-saving group (Table 3).

Spherical aberration and total 4th-order aberrations was significantly increased in both groups in all postoperative follow-ups ($P<.001$). The magnitude of postoperative increase of 4th-order aberrations was not significantly different between the 2 groups. However, the spherical aberration increased significantly more in the tissue-saving group than in the conventional group at 6 months ($P = .05$) (Table 3). The postoperative increase in spherical aberration correlated strongly with ablation depth ($r^2 = 0.19$, $P<.001$) and MRSE ($r^2 = 0.16$, $P = .001$) in the tissue-saving group. It did not correlate with scotopic pupil size and total preoperative HOAs in both groups.

Despite the increase in mean HOAs, 8 eyes (26.7%) in the conventional group and 4 eyes in the tissue-saving group had a decrease in total HOAs at 6 months ($P = .08$). The increase in postoperative HOAs was inversely correlated with preoperative HOA in the tissue-saving group ($r^2 = 0.22$, $P = .002$). In both

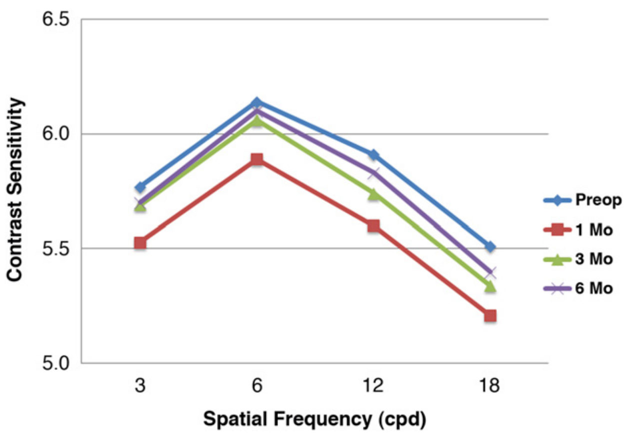

Figure 1. Mesopic contrast sensitivity sensitivity over time in the conventional group (cpd = cycles per degree).

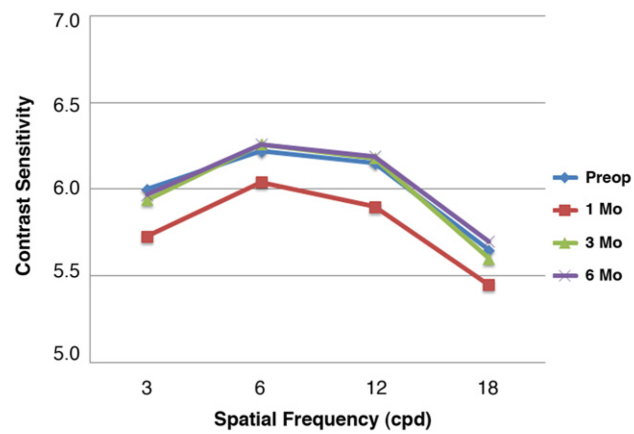

Figure 2. Mesopic contrast sensitivity over time in the tissue-saving group (cpd = cycles per degree).

groups, there was no statistically significant change in the mean RMS of the total, 3rd-order, and 4th-order aberrations from 1 month to 6 months postoperatively.

Contrast Sensitivity

There were no significant differences in mesopic and photopic contrast sensitivity between the conventional group and the tissue-saving group preoperatively or at any postoperative examination. The mesopic contrast sensitivity at all spatial frequencies decreased significantly from preoperatively to 1 month postoperatively in both groups. However, the difference between preoperatively and 3 and 6 months postoperatively was not significant (Figures 1 and 2).

At 1 month, there was a significant decrease in photopic contrast sensitivity at 3 cycles per degree (cpd), 12 cpd, and 18 cpd in the conventional group and at 3 cpd and 18 cpd in the tissue-saving group. However, photopic contrast sensitivity returned to preoperative values at 3 months in both groups. Photopic contrast sensitivity values increased at some spatial frequencies in both groups at 6 months; however, the difference was not significant (Figures 3 and 4).

Patient Satisfaction

Three months after surgery, all patients in both groups said they were satisfied or very satisfied with the surgical outcomes. Five patients (23.8%) in the conventional group and 8 patients in the tissue-saving group (25.8%) had night-vision problems. The mean glare score was 1.8 $\pm$ 0.7 in the conventional group and 2.1 $\pm$ 1.1 in the tissue-saving group and the mean halo score, 1.4 $\pm$ 1.2 and 1.8 $\pm$ 1.7, respectively. The difference between the 2 groups in the mean glare score and mean halo score was not statistically significant (P = .27 and P = .42, respectively). All patients in both groups said they would be willing to have PRK again and would recommend it to others.

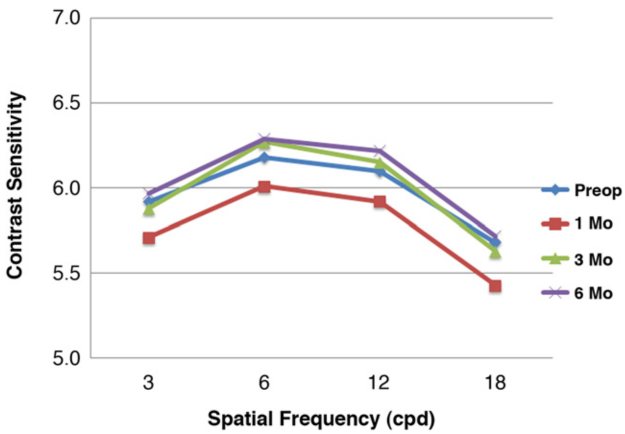

Figure 3. Photopic contrast sensitivity over time in the conventional group (cpd = cycles per degree).

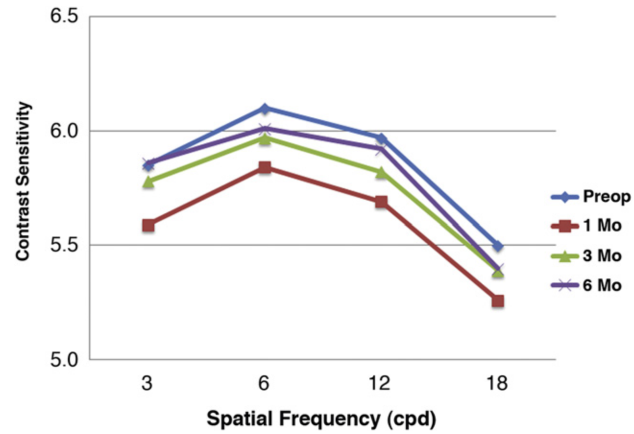

Figure 4. Photopic contrast sensitivity over time in the tissue-saving group (cpd = cycles per degree).

Complications

There were no intraoperative or postoperative complications in either group. No eye had clinically significant haze on slitlamp microscopy during the postoperative follow-up.

DISCUSSION

Post-LASIK ectasia is a rare but significant complication of ablative refractive surgery performed with an excimer laser. One of the main ways to prevent it is to leave as much RSB as possible. Although the minimum safe RSB in LASIK is usually considered to be 250 μm, there is no clearcut threshold to ensure uneventful refractive surgery that lasts throughout the patient's life. The 2 major measures to preserve a thicker RSB are to perform surface ablation, which does not require creation of a stromal LASIK flap, and to apply ablation algorithms with a lower ablation depth. Each has drawbacks and benefits.

The tissue-saving algorithm we used (Zyoptix) was designed to ablate less corneal stroma and is different from the conventional algorithm (PlanoScan) in laser-beam application and in the diameter of the blend zone. In the tissue-saving algorithm, a combination of a 1.0 mm and a 2.0 mm truncated Gaussian beam is used; the conventional algorithm uses a single 2.0 mm flat-topped beam. Furthermore, the angle of the laser's impact on the cornea is optimized in the tissue-saving algorithm because the actual keratometry (K) value of the cornea is used rather than a standard K value of 43.30 in the conventional algorithm. Another difference is the size of the blend zone, which is smaller with the tissue-saving algorithm.[10] These features were incorporated into the tissue-saving algorithm to improve the effectiveness of the laser ablation and to ablate less corneal stroma. However, tissue-saving algorithms might affect the quality of vision by inducing HOAs and decreasing contrast sensitivity, which may decrease patient satisfaction postoperatively.[5–9]

To our knowledge, this is the first prospective comparative study evaluating wavefront HOAs, contrast sensitivity visual performance, and patient satisfaction after myopic PRK with the Zyoptix tissue-saving algorithm and PRK with the conventional PlanoScan algorithm. We found both algorithms to be safe and effective in treating low to moderate myopia. By 6 months postoperatively, no eye in either group had lost more than 1 line of CDVA and all eyes in both groups were within ±0.50 D of the attempted correction and had a UDVA of 20/25 or better. The results were stable in both groups over the 6-month follow-up. Although eyes in the tissue-saving group had statistically significantly higher HOAs, contrast sensitivity and patient satisfaction were comparable between the 2 methods, with no clinically or statistically significant difference. Although the RMS of total, 3rd- and 4th-order aberrations increased significantly in both groups, the magnitude of increase in total and 3rd-order aberrations was significantly greater in the tissue-saving group than in the conventional group, and the increases from preoperatively in the tissue-saving group was statistically significant. These findings are compatible with those in a similar study of LASIK,[10] which found a significantly greater increase in the RMS of total, 3rd-, and 4th-order aberrations after tissue-saving LASIK than after conventional LASIK.

In our study, the total RMS HOA values were increased by a factor of 1.30 after conventional PRK and by a factor 1.78 after tissue-saving PRK, which agrees with results in studies of LASIK[10,20] (factor increase 1.49 after conventional LASIK and 1.84 after tissue-saving LASIK using a Technolas laser and Zywave aberrometer). However, Mastropasqua et al.[21] report a factor increase of 1.54 after conventional PRK.

There was a significant postoperative reduction in total HOAs in 26.7% of eyes after conventional PRK and in 10.5% of eyes after tissue-saving PRK. However, the preoperative HOAs in these eyes were significantly higher than in eyes that had an increase in HOAs postoperatively. Our results are consistent with those of Mastropasqua et al.,[21] who found an 8% decrease in HOAs in patients with preoperative total HOAs greater than 0.28 μm who had wavefront PRK using the tissue-saving algorithm. This indicates that custom PRK in eyes with high total HOAs might lead to a reduction in aberrations postoperatively.

Although the ablation depth was significantly less in the tissue-saving group, the amount of increase in HOAs was greater in this group. The role of the optical zone in increasing HOAs is well known.[4–6] Higher-order aberrations usually cause significant night-vision problems, especially in patients with a large pupil that exceeds the size of the optical zone. We used the same optical zone in both groups, so this was not the cause of the increase in HOAs. However, when the blending zone is small and the gradient of changes in refractive power of the cornea is high, it may increase HOAs, especially under scotopic conditions. In the conventional algorithm, an additional nonadjustable blend zone with a 3.0 mm diameter surrounds the optical zone. In tissue-saving treatments, the blend zone is considerably smaller. As a result, less tissue is removed with the tissue-saving algorithm than with the conventional algorithm. However, as Kirwan and O'Keefe report,[10] the smaller blend zone in tissue-saving treatments could result in a greater increase in HOAs postoperatively than with conventional treatments.

We found a significant decrease in contrast sensitivity at all spatial frequencies in both groups 1 month after surgery. The decrease was more significant under mesopic conditions than under photopic conditions and was clearly correlated with the increase in HOAs at 1 month. After 6 months, although the HOAs did not change significantly from the 1-month values, mesopic contrast sensitivity returned to preoperative values and photopic contrast sensitivity was better than preoperatively at some frequencies; however, the difference was not significant. These findings are comparable with those of Kim et al.,[22] who report that although wavefront-guided LASIK reduced the increase in HOAs resulting from LASIK, the mesopic contrast sensitivity in the wavefront-treated eyes was not significantly better than that in conventionally treated eyes. Moreover, other studies[23,24] found an increase in contrast sensitivity after wavefront-guided LASIK, despite an increase in HOAs. Haze can attenuate contrast sensitivity after PRK[25]; however, no eye in our study had clinically significant haze on slitlamp microscopy.

We believe that laser-induced microirregularities in corneal stroma and their effect on optical quality in the first months after surgery could have been the cause of the decrease in contrast sensitivity in our study. Over time, epithelial and stromal remodeling produces a smoother refracting surface, improving contrast sensitivity and the quality of vision. A study by Gandolfi et al.[26] found a small learning effect with the CSV-1000 contrast sensitivity test (VectorVision). This might also have affected our results and explain some of the improvement in contrast sensitivity after 3 months and 6 months.

Sharma et al.[27] report that postoperative increases in total HOAs can be associated with an increased risk for postoperative symptoms. Although the increase in postoperative total HOAs was more significant in our tissue-saving group, the percentage of patients who reported night-vision symptoms, such as halo and glare, was similar in the 2 groups.

The present study had limitations. The follow-up rate was relatively short, and some patients did not complete the 6-month follow-up examinations (71% of eyes in the conventional group and 61% in the tissue-saving group completed the follow-up). All patients had low to moderate myopia or myopic astigmatism. The risk for night-vision symptoms increases with higher levels of preoperative refractive error.[28] Further studies with larger groups of patients, a longer follow-up, and different degrees of myopia are recommended to compare the results of conventional PRK and tissue-saving PRK.

In conclusion, in this study both conventional PRK and tissue-saving PRK were safe, effective, and predictable for treating low to moderate myopia. Contrast sensitivity and patient satisfaction were comparable, with no significant difference between these 2 methods. However, tissue-saving PRK induced a greater increase in HOAs than conventional PRK as a result of the smaller blend zone in the tissue-saving algorithm.

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