Changes in stereopsis after photorefractive keratectomy

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PURPOSE: To evaluate the effects of photorefractive keratectomy (PRK) on the stereopsis of myopic and hyperopic patients.

SETTING: Farabi Eye Hospital, Tehran, Iran.

DESIGN: Prospective case series.

METHODS: This study included patients having PRK to achieve emmetropia. The patients were divided into the following 3 groups: low myopia (<−6.0 diopters [D]), high myopia (>−6.0 D), and hyperopia (<+4.0 D). Near stereoacuity was measured using the Randot test under photopic conditions (with corrective glasses) at 40 cm preoperatively (with corrective glasses) and 1, 3, and 12 months postoperatively. Repeated-measure analysis of variance was used to assess changes in stereopsis over time in the 3 groups.

RESULTS: Each group comprised 60 patients. The mean preoperative stereoacuity was 121.16 seconds of arc (arcsec) ± 149.92 (SD), improving to 83.66 ± 75.84 arcsec 1 month postoperatively and 80.66 ± 64.31 arcsec at 3 months (both $P < .001$). It remained unchanged (83.33 ± 75.01 arcsec) at 12 months ($P = .610$). Patients with high myopia had the greatest improvement in stereopsis after PRK compared with low myopic and hyperopic patients ($P < .001$). The improvement in stereoacuity was significantly higher in the severe anisometropic group; the lowest improvement was in the group without anisometropia.

CONCLUSION: Photorefractive keratectomy could result in an improvement in stereopsis. Patients with high myopia benefitted most from PRK in terms of improvement in stereopsis.

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Stereoacuity is the highest level of binocular function to distinguish a subtle depth difference between 2 objects based on geometric and retinal disparity. Factors that degrade stereopsis include aniseikonia, refractive error, reduced contrast sensitivity, heterophoria, and age.[1]

Usually, stereoacuity is not evaluated thoroughly during preoperative and postoperative visits in patients having refractive surgery. Photorefractive keratectomy (PRK) may improve stereoacuity by correcting anisometropia or eliminating the magnification or minification and prismatic effects of glasses or reduce stereoacuity by decreasing contrast sensitivity, changing the location of the nodal point, or increasing optical aberrations, especially in a decentered ablation.[2,3]

Changes in the optics of the eye after refractive surgery have been widely studied; however, few studies have assessed stereopsis after refractive surgery. To our knowledge, no study has compared stereopsis before and after PRK.[4]

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This study was performed to determine the effects of preoperative refractive error and anisometropia on the postoperative stereoacuity and changes in stereoacuity over time after PRK.

PATIENTS AND METHODS

This prospective study included patients with myopia or hyperopia having PRK to achieve emmetropia. The Institutional Review Board, Farabi Eye Hospital, Tehran, Iran, granted ethics clearance. The tenets of the Declaration of Helsinki were followed. All patients signed an informed consent form before study enrollment.

The exclusion criteria were as follows: contraindications to refractive surgery, history of any ocular disease or surgery, hyperopia greater than 4.0 D, myopia greater than 9.0 D (sphere part of the refraction after transposing to minus cylinder form), corrected distance visual acuity worse than 5/10, and ocular misalignment, such as distant or near heterophoria (>5.0 prism diopters [Δ] horizontally or >1.0 Δ vertically) determined by the alternating cover test with corrective lenses.

The patients were consecutively recruited into 3 groups according to spherical equivalent refraction as follows: low myopia (<−6.0 diopters [D]), high myopia (>−6.0 D), and hyperopia (< +4.0 D). If both eyes of a patient were in different groups, the patient was placed in the group based on the eye with the more negative refraction.

Myopic patients were further divided into 3 groups based on their cycloplegic anisometropia as follows: no anisometropia, less than 1.0 D; mild anisometropia, between 1.0 D and 3.0 D; and severe anisometropia, greater than 3.0 D.

Patient Assessment

After the medical and ocular histories were recorded, all patients had an ophthalmic evaluation, including visual acuity testing, slitlamp biomicroscopy, and measurement of refraction and stereoacuity. A trained optometrist performed all stereoacuity measurements. Stereoacuity was measured using the Randot test under photopic conditions with corrective lenses at 85 candelas/m^2 and 40 cm preoperatively and 1, 3, and 12 months postoperatively. To reduce the learning effect to the test, patients were trained and provided enough time to become familiar with the test before having the assessment. To avoid recall bias, correct answers were not provided to the patients.

Surgical Technique

All surgeries were performed by the same surgeon (H.H.) using a Technolas 217z laser platform (Bausch & Lomb) with a 6.3 mm optical zone. Wavefront-guided treatment was performed in all cases.

Statistical Analysis

Statistical analysis of the data was performed with SPSS software (version 16, SPSS, Inc.) by a biostatistician who remained blind to the patient groups. Standard descriptive statistics were used to describe quantitative variables. The Kolmogorov-Smirnov test was applied to evaluate normal distribution of data. When appropriate, the chi-square and analysis-of-variance (ANOVA) tests were used to evaluate the differences between the groups. Repeated-measures ANOVA with Greenhouse-Geisser correction was used to determine the effect of time on stereoacuity and the correlation between time and patient groups. Post hoc analysis was performed using the Scheffé test. Linear regression was used to assess the adjusted effect of patient groups on stereoacuity. A P value less than 0.05 was considered significant.

RESULTS

The study evaluated 180 patients, 60 in each group. The median patient age was 26 years (range 18 to 39 years). Table 1 shows the baseline characteristics of the patients. No significant differences in sex or age were observed between the 3 patient groups ($P > .05$). However, patients with high myopia had higher values of stereoacuity and anisometropia at baseline than the 2 other groups ($P < .001$).

Table 2 shows the means and standard errors of stereoacuity in the 3 groups before surgery and during the follow-up period. Repeated-measures ANOVA showed significant effects of time on the reduction in stereoacuity after PRK ($P < .001$) (Figure 1). Further analysis using the Scheffé post hoc test indicated that

Table 1. Baseline patient characteristics.

Characteristic	All Patients (n = 180)	Low Myopia (n = 60)	High Myopia (n = 60)	Hyperopia (n = 60)	*P* Value
Sex, n (%)					.09
Female	106 (58.9)	36 (60.0)	41 (68.3)	29 (48.3)	
Male	74 (41.1)	24 (40.0)	19 (31.7)	31 (51.7)	
Mean age (y)	26.6 ± 5.0	26.4 ± 5.2	26.9 ± 4.8	26.4 ± 4.9	.78
Mean SE (D)					
Right eye	−3.1 ± 4.7	−3.3 ± 1.5	−8.5 ± 1.4	2.5 ± 0.9	<.001
Left eye	−3.3 ± 4.9	−3.6 ± 2.2	−8.6 ± 1.7	2.3 ± 2.1	<.001
Mean anisometropia (D)	1.46 ± 1.06	1.40 ± 1.17	2.32 ± 0.92	1.66 ± 1.06	<.001
Mean stereoacuity (arcsec)	121.2 ± 149.9	95.0 ± 95.1	187.0 ± 222.0	81.5 ± 56.3	<.001

Means ± SD
SE = spherical equivalent

Table 2. Changes in stereoacuity from preoperatively to postoperatively by groups.

	Mean Change (Arcsec) ± Standard Error			
		Postoperatively		
Group	Baseline	1 Month	3 Months	12 Months
Hyperopia 0.0 to 4.0 D	81.5 ± 7.27	70.5 ± 5.82	68.5 ± 5.84	68.5 ± 5.57
Myopia 0.0 to −6.0 D	95.0 ± 12.27	65.0 ± 6.42	66.0 ± 5.87	71.0 ± 8.73
Myopia >−6.0 D	187.0 ± 28.65	115.5 ± 13.76	107.5 ± 11.05	110.5 ± 12.58

patients had significantly lower stereoacuity at the 1-month, 3-month, and 12-month follow-up visits than at baseline (all $P < .001$) (Figure 1). Figure 2 shows the correlation between the 3 groups and stereoacuity after PRK. Repeated-measures ANOVA showed a significant correlation between a reduction in stereoacuity and time ($P = .001$). The Scheffé post hoc test showed that the significant correlation was driven by the differences between patients with high myopia and low myopia as well as between patients with high myopia and hyperopia (both $P = .001$). Multivariate linear regression analysis showed that the patient groups independently predicted stereoacuity 12 months postoperatively after adjustments for sex, age, and age = sex ($P = .002$).

Myopic patients were further divided into 3 groups based on their cycloplegic anisometropia: (1) non-anisometropia: less than 1.0 D, (2) mild anisometropia: between 1.0 D and 3.0 D, and (3) severe anisometropia: greater than 3.0 D.

Table 3 shows the results of the 1-way ANOVA of the significance of differences in postoperative stereoacuity changes in myopic eyes in the 3 anisometropia subgroups. The improvement in stereoacuity was significantly different between 3 groups. The greatest improvement was in the severe anisometropic group, and the least improvement was in the no-anisometropia group ($P = .001$).

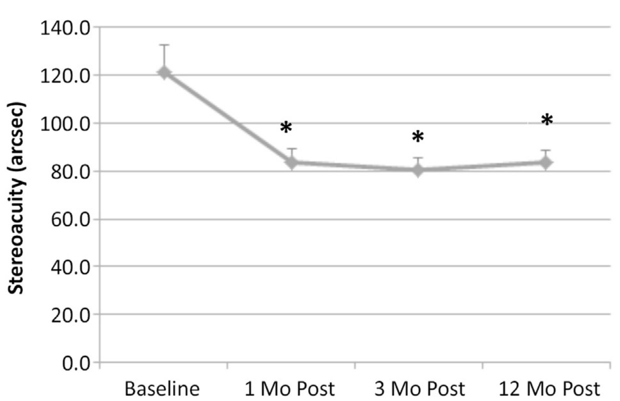

Figure 1. Stereoacuity in patients (N = 180) at baseline and 1, 3, and 12 months postoperatively. Error bars represent the standard error of the mean (* = $P < .001$ in comparison with baseline values; Post = postoperatively).

DISCUSSION

Stereopsis is the perception of depth generated by binocular retinal disparity along the horizontal meridian. High stereoacuity is required for many tasks, including intraocular surgery.[4–6] Because stereopsis has a significant influence on daily life, it is imperative to evaluate the effects of refractive surgery on the improvement in stereoacuity. In this study, the mean preoperative stereoacuity improved 1 month and 3 months after surgery and remained unchanged at the 12-month visit.

The overall improvement in stereoacuity after refractive procedures has been confirmed.[3,4] In the present

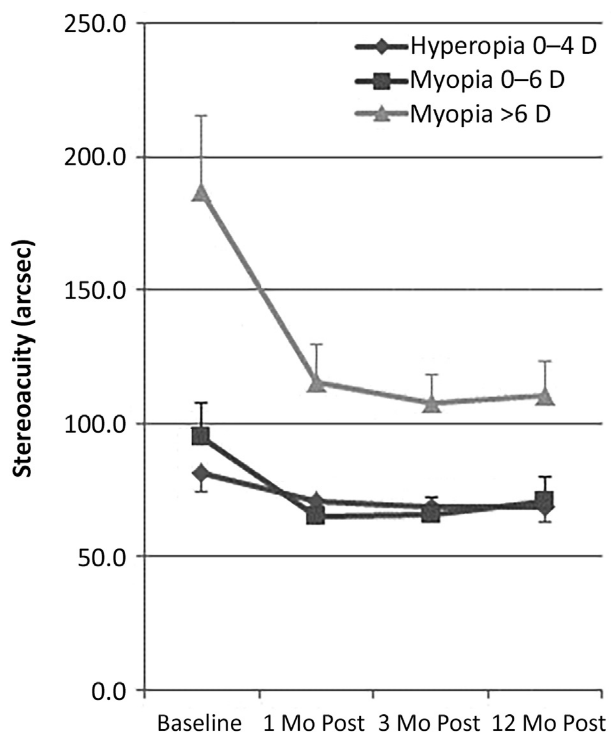

Figure 2. Stereoacuity in patients with high myopia (n = 60), low myopia (n = 60), and hyperopia (n = 60) at baseline and 1, 3, and 12 months postoperatively. Error bars represent the standard error of the mean (Post = postoperatively).

Table 3. Stereopsis changes after PRK in myopic eyes groups by amount of anisometropia ($P = .001$, ANOVA).

		Mean Stereoacuity (Arcsec) ± SD		
Myopia Group	n	Preop	1 year Postop	Improvement
No anisometropia (<1.0 D)	63	48.57 ± 19.74	42.86 ± 14.96	5.71 ± 15.10
Mild anisometropia (1.0 to 3.0 D)	50	205.20 ± 164.47	123.00 ± 61.88	82.20 ± 126.09
Severe anisometropia (>3.0 D)	7	514.28 ± 322.84	291.43 ± 181.42	222.85 ± 188.83

study, patients with high myopia (>6.0 D) and patients with higher levels of anisometropia had the most significant improvement in stereopsis after PRK compared with patients with low myopia or hyperopia.

Various factors affecting stereopsis include anisometropia, aniseikonia, reduced contrast sensitivity, strabismus, and age.[7] In addition, low levels of uncorrected refractive errors can potentially reduce binocular vision in adults.[6]

Anisometropia is a difference in refraction between 2 eyes. Liu et al.[3] reported that treating anisometropia restored stereoacuity and binocular interaction. Foveal suppression in the defocused eye is associated with the level of anisometropia[8] and might be responsible for the loss of stereopsis.[6] In the present study, patients with higher anisometropia showed higher levels of improvement in stereoacuity. Refractive surgery has the potential to improve stereoacuity by eliminating anisometropia.

In the present study, preoperative stereoacuity was measured with spectacle correction so patients who might have had aniseikonia preoperatively had improvement postoperatively. In binocular aniseikonia, there is a difference in the retinal image size between the 2 eyes. This causes difficulty in image fusion and formation of a single vision. If the binocular aniseikonia difference exceeds the maximum range of the retinal fusion, it will make stereopsis decrease or disappear. Binocular aniseikonia can increase or decrease after refractive surgery depending on the difference between the axial length between the 2 eyes.[3] For high-resolution stereopsis, clear bifoveal images are required and using glasses in anisometropia can cause magnification and minification effects on the retinal images; this can adversely affect stereopsis, which can be prevented by performing refractive surgery.[7]

The correlation between the degree of stereopsis and anisometropia might explain why in the present study the group with high myopia, which had higher preoperative anisometropia, showed greater improvement in stereoacuity after PRK.

Contrast sensitivity testing is not commonly performed in clinical settings; however, it can reflect how well a patient sees everyday objects and performs visual tasks. There have been mixed reports in the literature about postoperative contrast sensitivity. Previous studies of photopic contrast sensitivity after nonwavefront-guided laser in situ keratomileusis (LASIK) have reported a decrease in or a subtle change from preoperative levels. On the other hand, studies of wavefront-guided LASIK report improved contrast sensitivity.[9] A reduction in contrast sensitivity under mesopic conditions has been reported after refractive surgery despite a normal photopic contrast sensitivity function. Improvement in contrast sensitivity function has an effect on stereoacuity improvement after surgery.[9] Stereopsis loss with aging is strongly associated with a loss of contrast sensitivity.[1] Therefore, if we expect contrast sensitivity to improve after wavefront-guided PRK, some changes in stereoacuity would be expected, as shown in our results.

Furthermore, dry-eye syndrome is common in more than one half of patients having laser refractive eye surgery.[10] Dry-eye syndrome after refractive surgery is transient, but it significantly deteriorates the quality of vision. This might be the reason for improved stereopsis 3 months after surgery when the dry-eye symptoms are suppressed.

In the present study, we found improvement in stereoacuity after PRK in all 3 groups. The results in this study confirm that PRK contributes to the preservation of good stereopsis after surgery and that patients with high myopia and anisometropia might benefit the most from this surgery.

WHAT WAS KNOWN

- Stereoacuity improves in some patients after LASIK.

WHAT THIS PAPER ADDS

- Stereoacuity improved after PRK in patients with different refractive errors. Patients with higher degrees of myopia and patients with anisometropia might benefit the most from this surgery.

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