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ORIGINAL ARTICLE

Accommodative Changes After Photorefractive Keratectomy in Myopic Eyes

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ABSTRACT

Purpose. To determine the changes of amplitude of accommodation (AA) and facility of accommodation (FA) in myopic patients after photorefractive keratectomy (PRK).

Methods. Using Technolas 217Z excimer laser, 160 myopic eyes of 80 patients underwent PRK. The patients were categorized into two age groups: <30 and ≥ 30 years. Changes in AA and FA were observed before PRK and at 2 weeks, 1 month, and 3 months after PRK. The role of preoperative AA, FA, refractive spherical equivalent, age, and sex on postoperative AA and FA was evaluated.

Results. In younger patients, the preoperative AA and FA values 7.77 ± 1.75 D and 7.75 ± 3.97 cpm changed to 8.36 ± 1.26 D and 11.57 ± 4.20 cpm ($p < 0.001$), respectively, at 3 months after PRK. In older patients, the preoperative AA and FA values 6.66 ± 1.41 D and 5.05 ± 3.26 cpm changed to 6.72 ± 1.26 D ($p = 1.000$) and 9.58 ± 4.29 cpm ($p < 0.001$), respectively. Two weeks after surgery, preoperative AA and spherical equivalent had a significant effect on postoperative AA, whereas preoperative AA and age had a significant effect on postoperative AA after 3 months ($p < 0.001$). Postoperative FA was positively related to preoperative FA and female sex ($p < 0.05$).

Conclusions. This study suggests that some of the near-vision problems in younger myopes in early postoperative days after PRK might be due to decrease in AA and FA, which will eventually increase. However, in older patients, despite increase in FA, AA did not change.

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Key Words: accommodation, amplitude of accommodation, facility of accommodation, photorefractive keratectomy, PRK

Accommodation disturbances such as insufficiency of accommodation attributable to prepresbyopic state, uncorrected anisometropia, inadequate refractive correction, and asymmetrical nuclear sclerosis have been reported in myopic patients without any history of refractive surgery.[1] It has been proposed that corrected myopes have a higher effective accommodation compared with emmetropes and hypermetropes.[2] They need near addition at an older age, which might be due to higher effectiveness of concave vs. convex lenses and prismatic effect of minus lenses for near vision.[2]

Delayed far and near visual recovery are of the most frequent shortcomings of photorefractive keratectomy (PRK) in myopic patients.[3,4] This might be due to the process of epithelial healing and remodeling, defective precorneal tear film, and accommodative disturbances. Most often, near-vision complaints continue despite full distant visual recovery in the early weeks after surgery. These near-vision complaints might be not only due to disturbances in amplitude of accommodation (AA) but also due to other factors such as infacility (inertia) of accommodation, sudden increase in the amount of accommodation required for near vision, and disproportionate accommodation such as accommodation spasm and ill-sustained accommodation (poor stamina).[5]

To the best of our knowledge, there is no published article in the literature evaluating accommodative disturbances, including AA and facility of accommodation (FA) in these patients. The purpose of this study is to evaluate AA and FA changes after PRK in myopic patients.

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METHODS

This study was performed on myopic patients who underwent PRK at Labbafinejad Medical Center, Shahid Beheshti University of Medical Sciences, from March to August 2008. The study protocol was based on the Tenets of Declaration of Helsinki and was approved by the medical ethics committee of Ophthalmic Research Center. All possible risks were explained, and informed consent was obtained from all patients.

All patients underwent a thorough ophthalmologic examination before surgery including measurement of uncorrected visual acuity and best spectacle-corrected visual acuity (BSCVA), manifest and cycloplegic refraction, slit lamp examination, Goldmann applanation tonometry, and fundus examination. In addition, corneal elevation topography by Orbscan II (Bausch and Lomb, Rochester, NY) and Ultrasonic pachymetry (Nidek UP-1000; Nidek Company, Gamagori, Japan) were performed. Inclusion criteria for surgery were age ≥20 years, spherical equivalent (SE) between −1.00 and −8.00 D, cylinder ≤−1.00 D, BSCVA of at least 20/40, and a stable refraction for at least 1 year before surgery. Patients with a history of previous ocular surgery, mesopic pupil size ≥6 mm, keratoconus or any ectatic corneal disorder, keratoconus suspect by topography, preoperative corneal opacity, any corneal dystrophies, presence of pterygium, retinal disorders, collagen vascular disorders, diabetes mellitus, glaucoma, cataract, pregnancy, breastfeeding, and systemic corticosteroid therapy were excluded.

One of the authors (H.B.) scheduled and referred the patients for refractive and accommodative measurements. All pre- and postoperative refractive and accommodative measurements were performed by one skilled optometrist (A.A.S.), who was masked to preoperative refraction, age, surgery date, and later duration after PRK. AA and FA were measured before and at 2 weeks, 1 month, and 3 months after surgery. To minimize the effect of fatigue and cycloplegic refraction, accommodative tests were performed the day before usual follow-up visits. All patients were requested to discontinue contact lenses 3 months before surgery because of its probable effects on the AA and FA.

To evaluate the effect of age on changes in accommodation, the patients were arbitrary divided into two groups: <30 and ≥30 years. Data were analyzed using SPSS statistical software (version 15; SPSS, Chicago, IL). To compare the values within groups in different times, we used repeated measure analysis of variance test. Multiple comparison correction was performed by Sidak method. Analysis of covariance was performed to evaluate the relative role of different factors on AA and FA.

Surgical Procedure

All patients underwent PRK using Technolas 217Z (Bausch and Lomb, Rochester, NY) in a standard method. One surgeon (FK) performed all procedures. Corneal epithelium was removed by using ethanol (15%) for 20 s. Optical zone was 6 mm. At least 400 μm of residual corneal stromal bed was kept after ablation as a safe margin in all cases. Mitomycin-C (0.02%) was applied for 10 s if ablation depth was >70 μm. Then, the stromal bed was copiously irrigated with balanced saline solution. A bandage contact lens was placed over the cornea for 2 to 3 days until epithelialization was complete. All patients received chloramphenicol (0.5%) for 1 week and betamethasone (0.1%) four times per day for 2 weeks. Steroid drop was changed to fluorometholone (0.1%) in the third week, which tapered off between second and third months.

Measurement of AA

Refractive errors were corrected using trial frame during the accommodative tests. AA in diopters was measured using "minus lens method" in a constant illumination with a target at 40-cm distance. Minus half diopter (D) was added to the measured amount of AA to compensate for minification resulting from minus lenses. The visual near target was standard two parallel lines on the near chart. Increasing minus and plus lenses with 0.25 D steps were subsequently placed in front of the patients' eyes until first sustained blur. The concept of "blur" was explained to the patient by inserting a +0.25 D lens in front of his or her eyeglasses while looking with BSCVA.

Subjective Accommodative Facility Measurements

Monocular accommodative facility for the test eye was evaluated at 40 cm. Accommodative facility in the near was measured with a ±2.00 D lens combination mounted in a semiautomated flippers (Vision Co-operative Research Center, Sydney, Australia) with the subject viewing reduced 20/30 letters. The fellow eye was occluded with a filter (87C Wratten filter; Eastman-Kodak, Rochester, NY), which transmits infrared light by allowing the photorefractor (PowerRefractor; Multichannel Systems, Rutlingen, Germany) to obtain an objective dynamic reading of accommodation, while occluding the visual input to that eye. For patients older than 30 years, target distance was 40 cm, and ±1.5 D lenses were used.

The flipper, which was interfaced with a computer, was mounted on a handle that contained a mercury tilt switch for cycle detection and a start button for the operator. A commercial program (LabWindows/CVI, version 6.0; National Instruments, Austin, TX) was used to run the flippers. The time between the flips was recorded using an incorporated 60-s timer. Each time when the lens was flipped by the examiner (i.e., when the subject tapped the table to indicate clarity), the mercury switch triggered the circuit. The duration and frequency of each accommodative phase was recorded.

As the first lens was introduced, the timer was activated by pressing the "start" button on the flipper. Each test was performed for 60 s. The plus side of the flipper was always presented first. The subjects were instructed as follows: "You should look at the letters and try to keep them clear. The machine will put a lens in front of your eye and the letters will blur for a short time and then become clear again. As soon as they are clear again, please tap the table. The machine will then change the lens, and the letters might be blurred again. Tap the table as soon as you can see the letters clearly again. The machine will go on repeating this procedure to see how often you can clear the lenses in a 1-min period."

A dummy run, in which the flipper was flipped at the maximum possible speed for a period of 30 s, was conducted to test the reaction time of the operator and the mechanics of the flipper. The results showed that the time taken to flip the lenses on average was 0.30 s, so that operator and lens-change delays accounted for roughly 0.6 s of each cycle period.

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RESULTS

One hundred sixty eyes of 80 patients (26 men and 54 women) with a mean age of 26.1 ± 5.4 years (20 to 42 years) were included. Mean preoperative SE was −3.75 ± 1.62 D (−0.75 to −8.5 D), which improved to −0.18 ± 0.44 D (−1.25 to + 1.50 D) at 1 month and −0.08 ± 0.35 D (−1.50 to + 1.00 D) at 3 months after surgery ($p < 0.001$). BSCVA was 0.016 ± 0.063 logMar (0.4 to 0.0), 0.014 ± 0.059 logMar (0.4 to 0.0), and 0.009 ± 0.067 logMar (0.7 to 0.0) before, 1 month, and 3 months after surgery ($p < 0.001$). Three months after surgery, 98.1% and 90.6% of eyes were within ±1D and ±0.5 D, respectively.

In younger age group, AA and FA were more than older group before surgery ($p < 0.001$; Tables 1 and 2). After PRK, AA increased significantly in younger group at 3 months after surgery. However, in the older group, AA did not change significantly after PRK (Fig. 1). In both the groups, the FA increased significantly at 1 and 3 months after surgery (Fig. 2). Two weeks after surgery, while evaluating simultaneous effect of different factors (preoperative AA, preoperative FA, preoperative SE, age, and sex; adjusted $R^2 = 0.234$), preoperative AA ($p < 0.001$) and SE ($p = 0.04$) had a significant effect on the postoperative AA (Table 3). Preoperative FA ($p < 0.001$) and age ($p = 0.02$) had a significant effect on the postoperative FA (Table 4). Preoperative AA and age were found to have a significant effect on postoperative AA 3 months after surgery ($p < 0.001$; Table 5). There was no relation between preoperative FA, preoperative SE, and sex with postoperative AA. Considering the same factors, postoperative FA was positively related to preoperative FA and female sex ($p < 0.05$). There was no relation between preoperative AA, preoperative SE, and age with postoperative FA (Table 6).

DISCUSSION

This study showed that AA and FA increased 3 months after PRK in young myopic patients wearing spectacles. In older myopes, FA increased significantly, whereas AA did not increase. In early days after surgery, AA was dependent on preoperative AA and SE, whereas 3 months later, it was dependent on preoperative AA and age. Preoperative FA and age were effective on postoperative FA in early days after PRK, whereas 3 months later, the role of preoperative FA and sex was significant.

The amount of accommodation for each near target by a myopic patient with or without corrective eyeglasses is less than an emmetrope.[6] This means that the attempted effort of the ciliary body in a myopic patient is less than a normal individual, which could lead to lower activity of ciliary muscles and longer preservation of accommodation. This study showed that AA will increase after PRK in younger group. This increase was not observed in patients older than 30 years, which might be due to ciliary body and zonular fibers dysfunction and lens stiffness in prepresbyopic population. It seems that the younger the patient is, the more the potential for ciliary body and lens microstructure to improve. In the other words, in younger patients, presbyopia might be delayed after refractive surgery. Whether this increase is more than age-matched normal population needs to be determined. This increase in younger group might be related to postoperative pseudoaccommodation resulting from multifocality, asphericity, higher order ocular aberrations, and resultant better-than-expected uncorrected near visual acuity.[7–9] These factors might influence the eye's depth of field, which in turn controls the pseudoaccommodative effect in association with the remaining optics of the eye.[10] Artola et al.[7] predicted that the depth of field after PRK can be 0.2 to 1.0 D higher than expected in normals. They suggested underlying intracorneal optical interactions, coupled with the changes in corneal front surface multifocality, are the most likely factors responsible for higher than normal AA in the patient who underwent PRK.[7] They also proposed both the corneal front surface topography and the increase in total ocular aberrations with specific reference to spherical aberration as responsible factors for the pseudoaccommodation and better uncorrected near visual acuity in patients who underwent PRK.[7]

It is known that accommodative facility rate is dependent on several factors, including ocular depth-of-focus; subject's criteria for clear vision; velocity and AA; reaction time; and the time taken to change the lenses, together with the operator's reaction and motor times.[11–14] It seems that FA is lower in myopes than emmetropes.[13] In this study, FA increased after surgery. This might be due to the effect of clearer vision and more obligatory usage of accommodation on FA. Although it was not statistically significant, the role of clear vision is also suggested by the decrease in FA in younger group in the early days after PRK.

Both AA and FA decreased early days after PRK in younger myopes. This might partly explain near-vision complaints of myopes in early days after PRK. Although we did not have any subjective questionnaire to evaluate patients' symptoms, this finding suggests that accommodative problems might be more frequently expected in younger patients, especially with higher refractive errors. Decrease in AA and FA could be attributed to decreased visual acuity, blurred vision, pain, tearing, lower or higher order aberrations, and sudden increase in demand of accommodation required for near vision in a patient with previous myopia. Long-term usage of eyeglasses might induce sort of ac-

TABLE 1.
Amplitude of accommodation in two age groups

Age group (yr)	Before surgery (D)	After surgery (D)			P1	P2	P3	P4	P5	P6
		2 weeks	1 month	3 months						
<30	7.77 ± 1.75	7.54 ± 1.76	7.11 ± 1.32	8.36 ± 1.26	0.673	0.170	0.001	<0.001	<0.001	0.102
≥30	6.66 ± 1.41	6.74 ± 1.51	6.86 ± 1.41	6.72 ± 1.26	1.000	0.920	1.000	0.969	1.000	0.924

Paired t-test: P1, P2, and P3 comparing before with 2 weeks, 1 month, and 3 months after surgery; P4 and P5 comparing between 2 weeks and 1 and 3 months after surgery; and P6 comparing between 1 and 3 months after surgery.

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TABLE 2.
Facility of accommodation (cpm) in two age groups

Age group	Before surgery (cpm)	After surgery (cpm) 2 weeks	1 month	3 months	P1	P2	P3	P4	P5	P6
<30	7.75 ± 3.97	7.15 ± 4.31	10.00 ± 4.75	11.57 ± 4.20	0.612	<0.001	<0.001	<0.001	<0.001	<0.001
≥30	5.05 ± 3.26	7.55 ± 4.56	8.64 ± 4.24	9.58 ± 4.29	0.022	<0.001	<0.001	0.027	0.008	0.330

Paired t-test: P1, P2, and P3 comparing before with 2 weeks, 1 month, and 3 months after surgery; P4 and P5 comparing between 2 weeks and 1 and 3 months after surgery; and P6 comparing between 1 and 3 months after surgery.

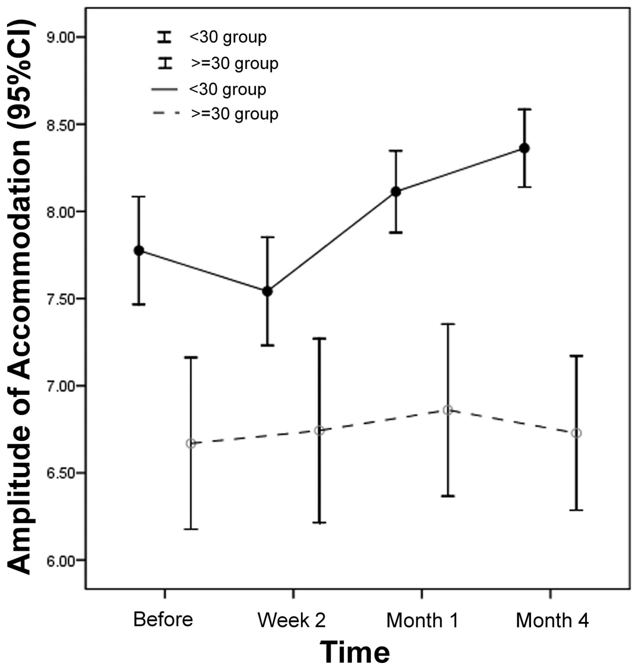

FIGURE 1.
Mean changes of AA (OD or OS) in different age groups before and after surgery.

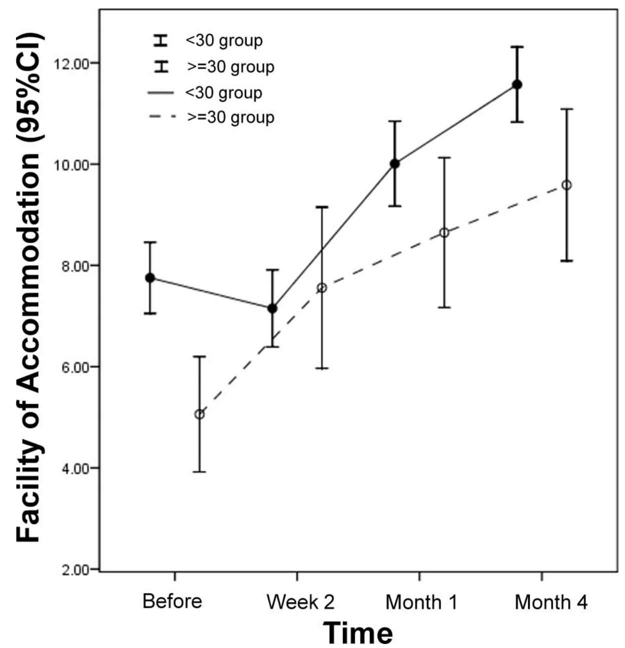

FIGURE 2.
Mean changes of FA (OD or OS) in different age groups before and after surgery.

commodative disturbance, which may interfere with clear vision in early days after surgery. This accommodative disturbance is also frequently seen after switching of eyeglasses to contact lenses in myopic patients.[6,15] It is also known that AA and FA may be different between myopic patients wearing spectacles vs. contact lenses.[6,15] For minus power lens correction, the amount of required accommodation is greater for contact lens correction than spectacle lens correction of equal power.[1,6]

Refractive error has been shown to have an effect on different accommodative measurements[16] such as accommodative convergence or accommodation ratio,[17–19] accuracy of the accommodative response,[20–22] tonic accommodation,[18,23,24] near work-induced transient myopia,[25–28] and lower accommodative facility.[16,22,29] The proportional effect of these factors on the AA and FA may be different. We found the preoperative AA and SE as significant determinants of postoperative AA in early days after surgery. This emphasizes on the possible role of the amount of refractive error on AA disturbance. Three months after surgery, preoperative AA and age were found to have a significant effect on postoperative AA. These findings suggest that accommodative disturbances related to the amount of refractive error will improve a few months after surgery and finally the age, and rehabilitative potential of ciliary body and zonular fibers, is the most important determinant of AA.

TABLE 3.
Effects of different factors on amplitude of accommodation using multiple linear regression analysis 2 weeks after surgery

Factors	Regression coefficient	95% Confidence interval	p
Preoperative amplitude of accommodation	0.399	0.243–0.555	<0.001
Preoperative facility of accommodation	0.060	−0.009–0.129	0.106
Preoperative spherical equivalent	−0.151	−0.304–0.002	0.044
Age[a]	0.360	0.266–0.986	0.254
Sex (male)[a]	0.381	−0.136–0.898	0.148

$R^2 = 0.258$ (adjusted $R^2 = 0.234$).
[a]Female and older group were considered as baseline.

Preoperative FA and age had a significant effect on postoperative FA 2 weeks after surgery, whereas preoperative FA and sex were

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TABLE 4.
Effects of different factors on facility of accommodation using multiple linear regression analysis 2 weeks after surgery

Factors	Regression coefficient	95% Confidence interval	p
Preoperative amplitude of accommodation	0.398	−0.018–0.814	0.091
Preoperative facility of accommodation	0.348	0.165–0.532	<0.001
Preoperative spherical equivalent	−0.137	−0.545–0.272	0.510
Age[a]	−1.918	−3.588–−0.248	0.025
Sex (male)[a]	−0.179	−1.556–1.199	0.798

$R^2 = 0.160$ (adjusted $R^2 = 0.133$).
[a]Female and older group were considered as baseline.

TABLE 5.
Effects of different factors on amplitude of accommodation using multiple linear regression analysis 3 months after surgery

Factors	Regression coefficient	95% Confidence interval	P
Preoperative amplitude of accommodation	0.341	0.225–0.458	<0.001
Preoperative facility of accommodation	−0.006	−0.058–0.045	0.807
Preoperative spherical equivalent	0.033	−0.082–0.147	0.575
Age[a]	−1.340	−1.808–0.872	<0.001
Sex (male)[a]	0.355	−0.031–0.741	0.071

$R^2 = 0.387$ (adjusted $R^2 = 0.367$).
[a]Female and older group were considered as baseline.

found to be effective on postoperative FA 3 months later. Interestingly, female sex was found to have a positive effect on postoperative FA. We cannot definitely justify this finding, but it could be due to higher cooperation and enthusiasm of women and needs to be evaluated in future studies.

There are some limitations in our study. The follow-up period of the study is not long enough to judge about the stabilization course of AA and FA after surgery. We did not evaluate other aspects of accommodation dynamics, which might be affected after PRK. We did not have a control group to compare with normal population. Although, our data are suggestive of higher frequency of near-vision problems in younger myopes, we did not subjectively evaluate their frequency and severity using a questionnaire in these patients.

In conclusion, this study suggests that some of the near-vision problems in younger myopic patients after PRK might be due to decreased AA and FA in early postoperative days. However, AA and FA will eventually increase compared with preoperative values. In early days after surgery, the amount of preoperative SE has a negative relation to postoperative AA; however, after a few weeks, its role will be replaced by age. Three months after surgery, preoperative AA and age and preoperative FA and sex are effective factors on postoperative AA and FA, respectively. In older patients, compared with preoperative values, despite the increase in FA, AA does not change.

TABLE 6.
Effects of different factors on facility of accommodation using multiple linear regression analysis 3 months after surgery

Factors	Regression coefficient	95% Confidence interval	p
Preoperative amplitude of accommodation	0.183	−0.206–0.573	0.354
Preoperative facility of accommodation	0.403	0.231–0.575	<0.001
Preoperative spherical equivalent	0.063	−0.320–0.446	0.745
Age[a]	0.573	−0.991–2.137	0.470
Sex (male)[a]	−1.569	−2.860 to −0.279	0.017

$R^2 = 0.240$ (adjusted $R^2 = 0.215$).
[a]Female and older group were considered as baseline.

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