Excimer Laser Photorefractive Keratectomy and Laser *in situ* Keratomileusis for Myopia and Astigmatism†

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Abstract

The efficacy, predictability, safety, and short-term stability of excimer laser photorefractive keratectomy (PRK) and laser *in situ* keratomileusis (LASIK) for treatment of myopia and astigmatism were determined. The preoperative myopia ranged from −1.50 to −15.75 D and the astigmatism was less than 4.0 D. Of the 147 eyes, 73 and 74 underwent PRK and LASIK, respectively. Mean preoperative spherical equivalent refraction (SE) was -3.72±1.69 D in the PRK group and −7.66±2.30 D in the LASIK group. Mean postoperative SE at the last examination (3 to 6 months) was -0.13±0.82 D and −0.38±1.19 D in the PRK and LASIK groups, respectively. Eighty six percent in the PRK group and 77 per cent in the LASIK group achieved a SE within ± 1.0 D and the refractions were stable between 1 month and 3-6 months. Uncorrected visual acuity of 20/40 or better was noted in 91 per cent in the PRK group and 97 per cent in the LASIK group. No eyes lost one or more lines of best spectacle-corrected visual acuity in both groups. PRK and LASIK appear to be effective, safe, predictable, and short-term stable in treating myopia and astigmatism. Longer follow-up studies will help evaluate the long-term stability of the procedure and possibility of later complications.

Key word : Excimer Laser, Photorefractive Keratectomy (PRK), Laser *in situ* Keratomileusis (LASIK)

KASETSUWAN N, et al
J Med Assoc Thai 2000; 83: 182-192

There are two ways to treat myopia (nearsightness) by excimer laser corneal surgery(1). The first is photorefractive keratectomy (PRK) which was introduced in the late 1980's. The procedure includes removal of the corneal epithelium followed by shooting the laser. The amount of laser used is dependent on the degree of attempted correction. The second method, laser *in situ* keratomileusis (LASIK) is the combination of keratomileusis, which use microkeratome to ablate the cornea

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† This study was presented at the Royal Thai College of Ophthalmology Annual Meeting, Bangkok, July 1998.

partially first, followed by lasering. This method has also demonstrated encouraging results for the treatment of myopia and astigmatism. The aim of this study was to evaluate the efficacy, safety, predictability and short-term stability of the visual and refractive outcome by excimer laser PRK and LASIK procedures.

PATIENTS AND METHOD

We retrospectively analyzed the results of excimer PRK in 73 eyes of 51 patients, and 74 eyes of 46 patients treated with LASIK. We divided the LASIK group further into three subgroups: (a) low myopia range from −1.0 to -6.0 D, 23 eyes; (b) moderate myopia range > -6.0 to −10.0 D, 36 eyes; and (c) high myopia > -10.0 D, 15 eyes. Astigmatism in both PRK and LASIK groups was less than 4.0 D. In the PRK group, 43 per cent were male and 57 per cent were female, whereas, in the LASIK group, 26 per cent were male and 74 per cent were female. The mean age was 29±6 and 32±7 in PRK and LASIK group respectively. Preoperative examinations included uncorrected visual acuity, spectacle-corrected visual acuity, keratometry, videokeratography, pachymetry, slit-lamp biomicroscopy, tonometry, and dilated fundus examination. Exclusion criteria included age less than 18 years, changing refraction of more than one diopter over the past year, keratoconus, central pachymetry less than 450 μm, prior refractive or cataract surgery, and collagen vascular diseases. All treatments were performed using the Nidek EC-5000 excimer laser. Fifteen minutes before treatment, proparacaine HCl 1 per cent drops were instilled into the treated eyes, one drop each three times, 5 minutes apart. The fellow eyelid was taped closed, preventing cross fixation. The patient was treated in the supine position and was asked to fixate on the green fixation target in the laser tube. A rigid eyelid speculum was used. In PRK procedures, corneal epithelium approximately 0.5 mm larger than the treatment zone was removed either by mechanical or laser ablation. Debris on the surface of the cornea was removed with a moistened microsurgical sponge and the treatment was then performed using the single zone technique with patient fixation. In the LASIK procedure, three circular marks at the 6, 6.30 and 9 o'clock positions for the right eye; 3, 6 and 6.30 o'clock positions for the left eye were made. The Chiron automated corneal shaper (Chiron Vision, Irvine, CA) suction ring was placed on the eye concentric to the pupil. The suction pump was activated to a pressure of approximately 25 mmHg and the applanation lens was used to determine the adequacy of intraocular pressure to be 60-65 mmHg as recommended by the manufacturer. The microkeratome head was then placed into the groove of the suction ring and a 160-μm flap was dissected by activating the forward motion on the foot pedal. Reverse actions on the foot pedal permitted retraction of the microkeratome head. The microkeratome head and suction ring were removed together, and the corneal flap was elevated using a spatula to expose the underlying corneal stroma. The laser ablation was then performed in the stromal bed. The microsurgical sponge was used to protect the flap during treatment. After the ablation was completed, the stroma was wiped clear and the flap was repositioned.

The Nidek EC-5000 excimer laser is an argon-fluoride excimer laser with an output wavelength of 193 nm. The laser utilizes a scanning slit delivery system with a variable fluence (100 to 140 mJ/cm^2), and a repetition rate of 10 to 50 Hz. In this study, we used a repetition rate of 40 Hz. Treatment zone was 5.5 to 6.5 mm with a transition zone from 6.5 to 7.5 mm depending on attempted correction and pupil diameter. At the conclusion of the treatment, topical diclofenac 1 per cent, fluorometholone 0.1 per cent, and tobramycin were instilled into the treated eyes and a soft contact lens was applied only in the PRK eye.

In the PRK group, topical tobramycin together with fluorometholone 0.1 per cent were started four times a day immediately after the surgery. Topical tobramycin was then stopped if complete reepithelialization occurred. Topical diclofenac was used only if the patients felt pain or discomfort, usually for the first 24 hours and no longer than 3 days. Fluorometholone 0.1 per cent was instilled four times a day for one month and then tapered in two to three months. In the LASIK group, topical tobramycin and fluorometholone 0.1 per cent were started four times a day on the first postoperative day, topical tobramycin was stopped after one week if there was no sign of infection, whereas, fluorometholone was continued for one month. Follow-up visits were scheduled at 1 day, 4 days, 1 week, 1, 3, 6 and 12 months after treatment. During the postoperative visits, uncorrected visual acuity, spectacle-corrected visual acuity, slit-lamp biomicrosopy and tonometry were performed.

Table 1. Number of patients and eyes, mean age and gender in the PRK and LASIK group.

	PRK	LASIK		
Eyes (patients)	73 (51)		74 (46)	
		Low myopia	-1.0 to -6.0 D	23 eyes
		Moderate myopia	> -6.0 D to -10.0 D	36 eyes
		High myopia	> -10.0 D	15 eyes
Mean age (year)	29±6		32±7	
F/M	22 (43%) / 29 (57%)		34 (74%) / 12 (26%)	

F: female M: male

Table 2. Results of postoperative refraction in the PRK group.

Baseline Refraction* (mean SE)	-3.72±1.69
Range of SE	-1.50 to -10.50
P/O Refraction	
Mean SE at 1 week	0.61±1.09
Mean SE at 1 month	0.18±1.01
Mean SE at 3 to 6 months	-0.13±0.82
P/O SE within ± 1.0 D	85.92
P/O SE within ± 0.5 D	70.91

* Refraction express in diopter
SE: Spherical Equivalent Refraction
P/O: Postoperative
D: Diopter

Table 3. Results of postoperative refraction in the LASIK group.

Baseline Refraction* (mean SE)		-7.66±2.30
Range of SE		-3.12 to -15.75
P/O Refraction		
Mean SE at 1 week		0.65±1.52
Mean SE at 1 month		0.43±0.94
Mean SE at 3 to 6 months		-0.38±1.19
P/O SE within ± 1.0 D		77.14
	Low myopia	82.61
	Moderate myopia	70.59
	High myopia	84.62
P/O SE within ±0.5 D		60
	Low myopia	78.26
	Moderate myopia	52.94
	High myopia	46.15

* Refraction express in diopter
SE: Spherical Equivalent Refraction
P/O: Postoperative
D: Diopter

Pachymetry was assessed at the 1, 3, and 6 months examinations. Additional measurements and examination were performed as needed.

RESULTS

Demographic data of the patients treated with PRK and LASIK is shown in Table 1.

Refractive results:

Baseline Refraction:

Mean preoperative spherical equivalent refraction in the PRK group was -3.72±1.69 D (range -1.50 to -10.50 D); in LASIK group, -7.66± 2.30 D (range -3.12 to -15.75 D)

In the PRK group

The mean postoperative spherical equivalent refraction was +0.61±1.09 D at 1 week, +0.18±1.01D at 1 month and -0.13±0.82 D at 3 to 6 months. Table 2 and Fig. 1 detail baseline refraction compared to postoperative refraction after 1 week, 1 month and the last examination (3 to 6 months). Eighty six per cent of eyes were within ±1.0 D and 70.91 per cent within ±0.5 D of the desired postoperative refractive error as shown in Table 2 and Fig. 2.

In the LASIK group

The mean postoperative spherical equivalent refraction was +0.65±1.52 D after 1 week, +0.43±0.94 D at 1 month and -0.38±1.19 at 3 to 6 months (Table 3 and Fig. 3). Seventy seven per cent of eyes were within ±1.0 D (82.61% in low myopia, 70.59% in moderate myopia and 84.62% in high myopia); 60 per cent of eyes were within ±0.5 D (78.26% in low myopia, 52.94% in

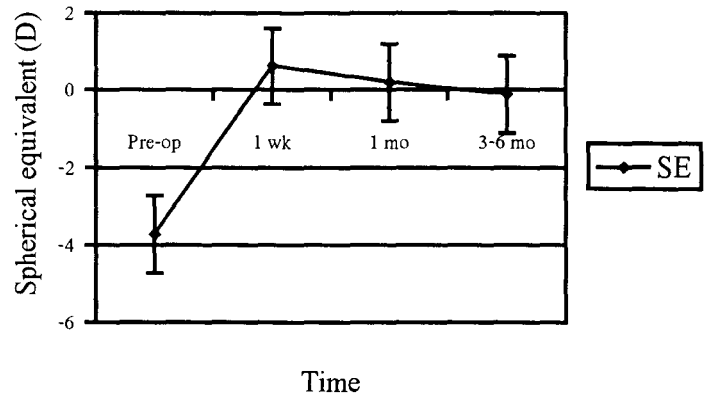

Fig. 1. Mean spherical equivalent refraction in the PRK group.

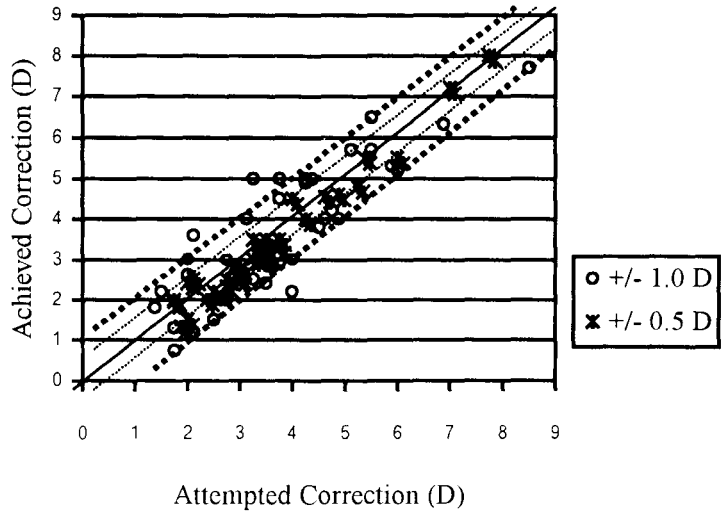

Fig. 2. Attempted *vs* achieved correction (D) at 3 to 6 months after PRK.

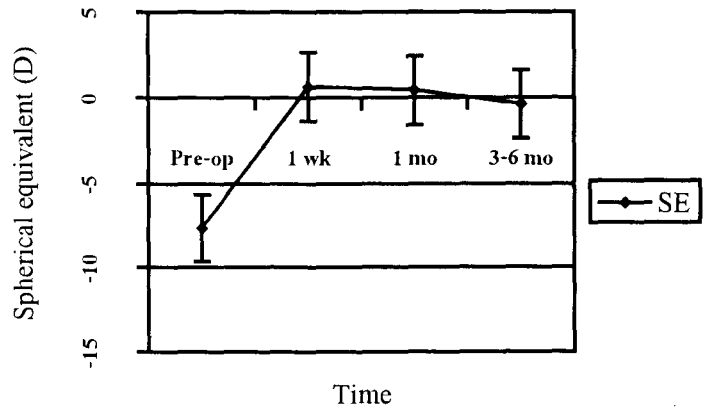

Fig. 3. Mean spherical equivalent refraction in the LASIK group.

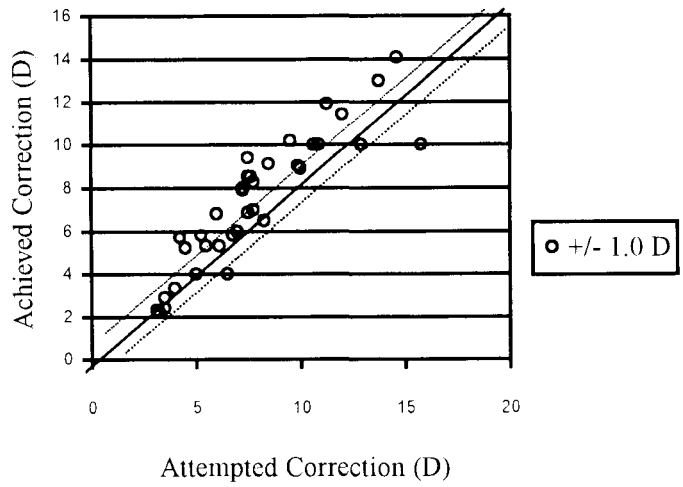

Fig. 4. Attempted *vs* achieved correction (D) at 3 to 6 months after LASIK (average of 3 subgroups).

moderate myopia and 46.15% in high myopia) as shown in Table 3 and Fig. 4.

Visual results:

In the PRK group

Preoperative best spectacle-corrected visual acuity was 20/40 or better in 91.78 per cent, 20/25 or better in 82.19 per cent and 20/20 or better in 69.86 per cent. After surgery, these same levels of visual acuity without correction have been achieved at the last examination (3 to 6 months) in 91.18 per cent, 88.89 per cent and 81.54 per cent respectively as shown in Table 4 and Fig. 5. A gain of more than 2 Snellen lines was 4.11 per cent, two lines in 6.85 per cent and one line in 31.51 per cent. A loss of one, two or more than two Snellen lines of best spectacle-corrected visual acuity was 0 per cent at the last examination as shown in Fig. 6. The efficacy index, which is the ratio of the mean postoperative uncorrected visual acuity to the mean preoperative best spectacle-corrected visual acuity, multiplied by 100, was 113.08. The safety index which is the ratio of mean postoperative best spectacle-corrected visual acuity over mean preoperative best spectacle-corrected visual acuity, multiplied by 100, was 120.28.

Table 4. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity, in the PRK group.

Snellen visual acuity	Pre-op BCVA	P/O UCVA
≥ 20/40	91.78	91.18
≥ 20/25	82.19	88.89
≥ 20/20	69.86	81.54
≤ 20/200	0	0

Pre-op BCVA: Preoperative best spectacle-corrected visual acuity
P/O UCVA: Postoperative uncorrected visual acuity

In the LASIK group

Before surgery, best spectacle-corrected visual acuity was 20/40 or better in 64.86 per cent, 20/25 or better in 43.24 per cent and 20/20 or better in 36.49 per cent. After surgery at the last examination, the overall uncorrected visual acuity was 97.30 per cent, 81.08 per cent and 44.10 per cent respectively (Table 5 and Fig. 7). When we considered the subgroups as previously described in low, moderate and high myopia, the visual results are shown in Table 5 and also correspond to Fig. 8, 9 and 10. Per cent gain or loss of Snellen lines are shown in Fig. 11. The efficacy index in the LASIK group was 148.58 and the safety index was 152.76.

Complications:

Table 6, 7 identify the observed intraoperative and postoperative complications in PRK and LASIK procedures respectively.

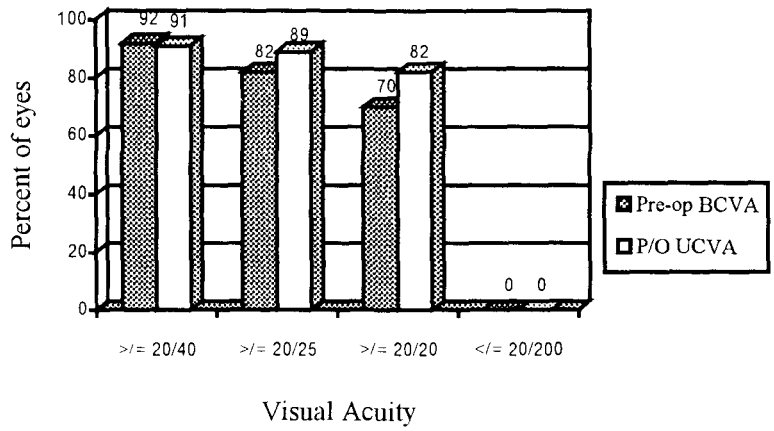

Fig. 5. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity at different levels of visual acuity at 3 to 6 months after PRK.

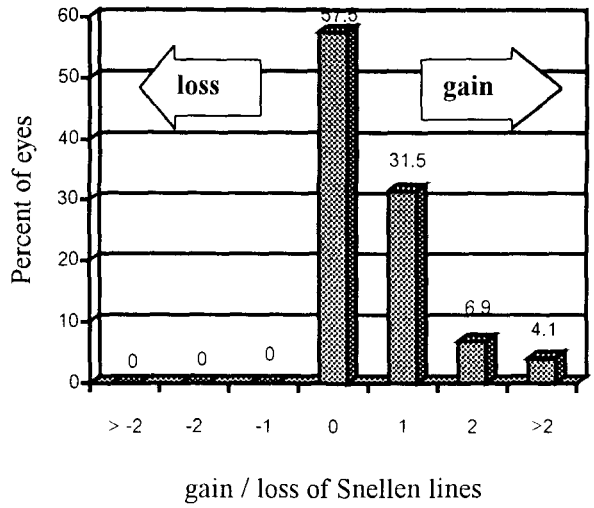

Fig. 6. Percentage of eyes with gain or loss in spectacle-corrected visual acuity at 3 to 6 months after PRK.

DISCUSSION

Excimer laser PRK and LASIK are the latest in a long line of treatments devised to correct refractive errors[1]. Better preservation of corneal structural integrity and absence of a late hyperopic shift are perceived as advantages of these procedures over the previous radial keratotomy[2]. Previous authors have indicated that PRK appears to be successful in the correction of low to moderate degree of myopia, whereas, LASIK appears to be effective and safe in moderate and high myopia[3-14].

In looking at pre-operative BCVA in PRK and LASIK in the low myopic subgroup (Table 4, 5), in general, we expected that there would be no difference between these 2 groups. Our study does not show this expectation since it is a retrospective nonrandomized study, the distribution of the popu-

Table 5. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity, in the LASIK group.

	Low myopia	Moderate myopia	High myopia	Average of 3 subgroups
Pre-op BCVA ≥ 20/40	82.60	75.0	33.33	64.86
Pre-op BCVA ≥ 20/25	69.54	47.22	6.67	43.24
Pre-op BCVA ≥ 20/20	60.87	36.11	0	36.49
Pre-op BCVA ≤ 20/200	0	25	20	9.46
P/O UCVA ≥ 20/40	100	100	93.33	97.3
P/O UCVA ≥ 20/25	78.26	77.78	60	81.08
P/O UCVA ≥ 20/20	52.17	47.22	20	44.10

Pre-op BCVA: Preoperative best spectacle-corrected visual acuity
P/O UCVA: Postoperative uncorrected visual acuity

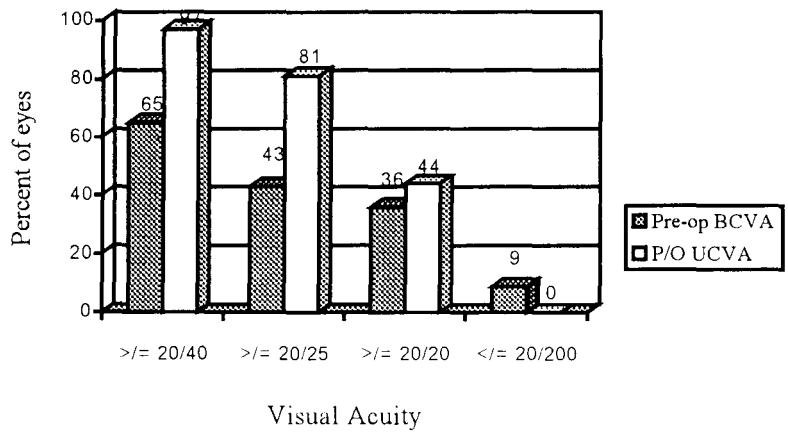

Fig. 7. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity at different levels of visual acuity at 3 to 6 months after LASIK (average of 3 subgroups).

lation is different. In the PRK group, even though the mean SE is −3.72+1.69 D, range −1.50 to −10.50 D, sixty seven per cent of the population had pre-operative SE < -4.0 D (49/73) compared to the LASIK low myopic subgroup, all had pre-operative SE > -3.0 D, and > -4.0 D was found 69.56 per cent (16/23).

The use of any refractive procedure should be evaluated on the efficacy of reducing the refractive error, predictability, stability of the refractive outcome and safety of the procedure. Our study supports that both excimer PRK and LASIK effectively reduce refractive errors. The efficacy to achieve postoperative uncorrected visual acuity of 20/40 or better at 3 to 6 months follow-up after surgery was 91 per cent in the PRK group and 97 per cent in the LASIK group. The predictability of the results in the PRK group, which is the post-operative spherical equivalent within ±1.0 D is 86 per cent and 71 per cent are within ±0.5 D of the desired postoperative refractive error. In the LASIK group, the average predictability of the 3 sub-groups is 77.14 per cent within ±1.0 D and is nearly the same in the three subgroups but the predictability within ±0.5 D is apparently more in the low myopic subgroup than in the moderate and high myopic subgroups (78% *versus* 53 and 46%).

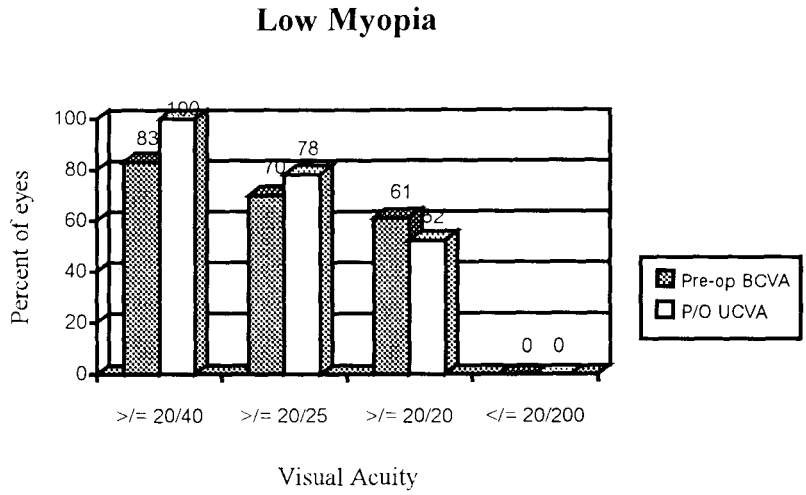

Fig. 8. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity at different levels of visual acuity at 3 to 6 months after LASIK in the low myopic subgroup.

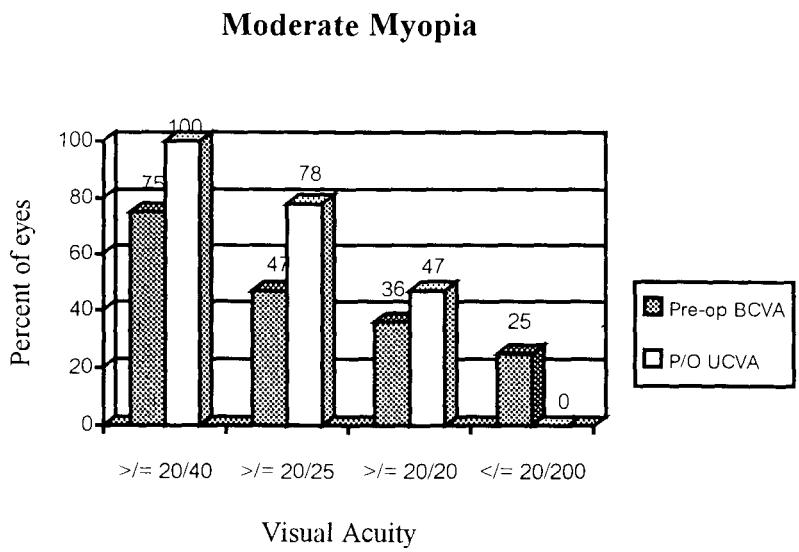

Fig. 9. Comparison of preoperative best-spectacle corrected visual acuity to postoperative uncorrected visual acuity at different levels of visual acuity at 3 to 6 months after LASIK in the moderate myopic subgroup.

Besides, the refraction was grossly stable both in the PRK and LASIK group. As we know from previous studies[3-6,10-13]; after PRK and LASIK procedures, the refraction usually overshoots to hyperopia. The amount of the overshoot refraction is according to the attempted correction; the more preoperative attempted correction, the higher the overshot refraction found postoperatively. However, this event will decrease to the desired refraction at around 1 to 3 months. Our results also con-

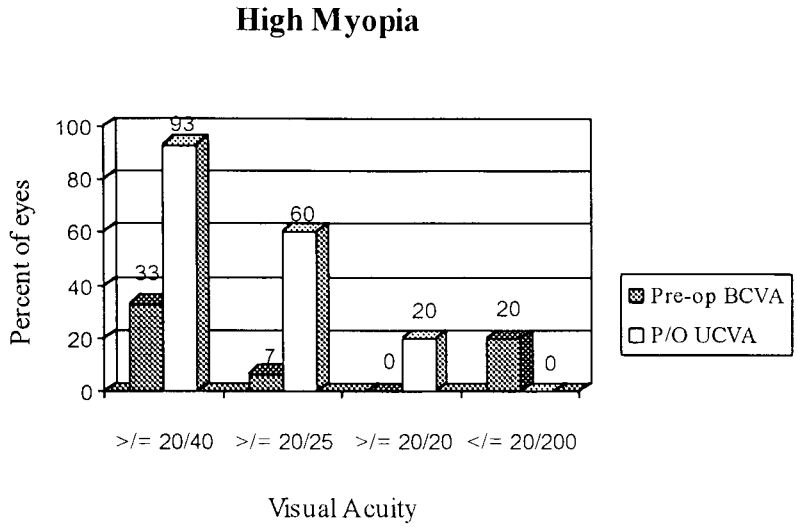

Fig. 10. Comparison of preoperative best spectacle-corrected visual acuity to postoperative uncorrected visual acuity at different levels of visual acuity at 3 to 6 months after LASIK in the high myopic subgroup.

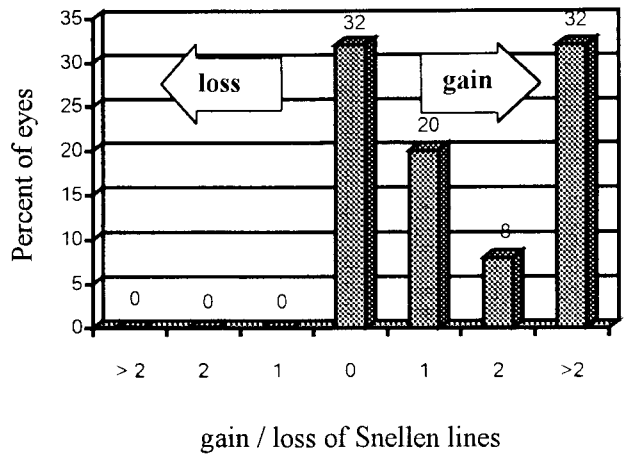

Fig. 11. Percentage of eyes with gain or loss in spectacle-corrected visual acuity at 3 to 6 months after LASIK.

firm these findings as shown in Fig. 1 and 3 but this stability is only short-term (≤ 6 months). This may need a longer follow-up to make a good conclusion for the stability of the procedures.

Both PRK and LASIK are very safe since there was no eye loss in one or more Snellen line of best spectacle-corrected visual acuity. Additionally, complications that occurred were low except for subconjunctival hemorrhage and nonspecific interface inclusion or debris. Subconjunctival hemorrhage usually disappears within two weeks, whereas, nonspecific interface inclusion will last forever but this event appears to have no visual or refractive effect.

We used efficacy and safety indices as recommended by Koch D[15] in order to analyze the result easier and more reasonably since the indices we calculated are the ratio between pre-

Table 6. Intraoperative and postoperative complications in the PRK group.

Complications	% of incidence (eyes)	% losing ≥ 1 Snellen lines of spectacle-corrected visual acuity
	Intraoperative	
Decentration of abrasion	2.74 (2)	0
	Postoperative	
Delayed epithelial healing (> 7 days)	1.37 (1)	0
Subepithelial haze (grade 0.5)	5.48 (4)	0
Corneal ulcer	1.37 (1)	0
Descemet fold	1.37 (1)	0

Table 7. Intraoperative and postoperative complications in the LASIK group.

Complications	% of incidence (eyes)	% losing ≥ 1 Snellen lines of spectacle-corrected visual acuity
	Intraoperative	
Corneal bleed from limbal vessels or corneal pannus	4.05 (3)	0
Thin flap determined by surgeon judgement	5.41 (4)	0
Button-hole flap	2.70 (2)	0
Incomplete flap	1.39 (1)	0
Free cap	2 (2.70)	0
	Postoperative	
Subconjunctival hemorrhage	81.08 (60)	0
Punctate epithelial keratopathy	2.70 (2)	0
Nonspecific interface inclusion/debris	40.54 (30)	0

operative and postoperative visual acuity. The indices are also very helpful in order to compare with other series. The efficacy index that is more than 100 means that the efficacy is good; the higher the number is, the more the efficacy of the procedure appears. The efficacy index in both groups is high (113 in the PRK group and 149 in the LASIK group) showing high effectiveness. Besides, the safety idices are also high both in the PRK and LASIK group (120 and 153). This means that both procedures are apparently safe.

In conclusion, this series confirms the findings of previous investigators that excimer laser PRK and LASIK are safe, predictable and effective methods for the treatment of any degree of myopia. Further follow-up is needed to assess the long-term stability of these procedures.

(Received for publication on April 11, 1999)

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การแก้ไขสายตาสั้นและเอียงด้วยเอ็กไซม์เมอร์เลเซอร์

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การศึกษาผลการรักษาสายตาสั้นและเอียงโดยเอ็กไซม์เมอร์เลเซอร์สองวิธี คือ Photorefractive keratectomy (PRK) และ Laser *in situ* keratomileusis (LASIK) ในแง่ของประสิทธิภาพ การคาดคะเนและความคงที่ของผลที่ได้รับตลอดจนความปลอดภัยของการรักษา ในจำนวน 147 ตา 73 ตาได้รับการรักษาโดยวิธี PRK และ 74 ตาได้รับการรักษาโดยวิธี LASIK โดยมีระยะเวลาของการติดตามผลอย่างน้อย 3-6 เดือน ระดับสายตาสั้นก่อนการรักษาตั้งแต่ -1.50 ถึง -15.75 ไดออปเตอร์ ระดับสายตาเอียงก่อนการรักษาน้อยกว่าหรือเท่ากับ 4.0 ไดออปเตอร์ ระดับสายตาสั้นเฉลี่ยก่อนการรักษาโดยวิธี PRK และ LASIK คือ -3.72 ± 1.69 ไดออปเตอร์ และ -7.66 ± 2.30 ไดออปเตอร์ตามลำดับ ระดับสายตาหลังการรักษาโดยวิธี PRK คือ -0.13 ± 0.82 ไดออปเตอร์ โดยวิธี LASIK คือ -0.38 ± 1.19 ไดออปเตอร์ ระดับสายตาที่อยู่ภายในความคาดคะเน ±1.0 ไดออปเตอร์พบ 86% โดยวิธี PRK และ 77% โดยวิธี LASIK นอกจากนี้ยังพบว่าระดับสายตานี้อยู่ในระดับคงที่ในช่วงระหว่าง 1 เดือน และ 3 ถึง 6 เดือน ประสิทธิภาพของการอ่านโดยตาเปล่าในระดับเท่ากับหรือดีกว่า 20/40 พบ 91% โดยวิธี PRK และ 97% โดยวิธี LASIK ในแง่ความปลอดภัยไม่พบการสูญเสียของระดับการอ่านเท่ากับหรือมากกว่า 1 บรรทัด สรุปได้ว่าการผ่าตัดแก้ไขสายตาสั้นโดยใช้เอ็กไซม์เมอร์เลเซอร์ทั้ง 2 วิธีให้ผลการรักษาที่สูงและปลอดภัย แต่การศึกษาครั้งนี้เป็นการศึกษาระยะสั้น ดังนั้นจึงจำเป็นที่จะต้องติดตามผลการรักษาในระยะยาวเพื่อติดตามความคงที่ของระดับสายตารวมทั้งอาการแทรกซ้อนที่อาจเกิดขึ้นได้

คำสำคัญ : เอ็กไซม์เมอร์เลเซอร์, สายตาสั้น, สายตาเอียง, Photorefractive Keratectomy (PRK), Laser *in situ* Keratomileusis (LASIK)

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จดหมายเหตุทางแพทย์ ฯ 2000; 83: 182-192

* ภาควิชาจักษุวิทยา, คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย, กรุงเทพ ฯ 10330