Corneal ectasia induced by laser in situ keratomileusis

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ABSTRACT

Purpose: To identify factors that can lead to corneal ectasia after laser in situ keratomileusis (LASIK).

Setting: University refractive surgery center.

Methods: In this retrospective study, the charts of all patients (2873 eyes) who had LASIK between May 1995 and November 1999 were reviewed. Fourteen patients (19 eyes, 0.66%) developed post-LASIK ectasia. The mean follow-up was 16.32 months (range 6 to 42 months).

Results: No patient with an attempted correction less than 8.00 diopters or a residual corneal bed thickness greater than 325 μm experienced post-LASIK ectasia. There was a statistically significant positive correlation between corneal residual bed thickness and increasing patient age.

Conclusion: Despite the limitations of the small sample size, the study's results suggest that parameters besides residual corneal bed thickness (eg, age, attempted correction) may have to be considered to avoid post-LASIK ectasia. *J Cataract Refract Surg 2001; 27:1796–1802 © 2001 ASCRS and ESCRS*

The recent widespread growth of refractive surgery, specifically laser in situ keratomileusis (LASIK), has not resulted in notably serious complications.[1,2] However, the few that have occurred are significant considering the elective nature of this procedure and the growing number of alternatives.[3–5]

Laser in situ keratomileusis substantially weakens the mechanical strength and effective thickness of the cornea.[6] There is concern that at some point the tensile strength of the cornea might be reduced to a level that predisposes to postoperative ectasia.

The progressive corneal ectasia that may develop after LASIK probably indicates an altered biomechanical strength in these corneas. The etiology and the biomechanical changes that induce keratectasia after refractive surgery are unknown. We studied a group of patients referred to a university-based refractive surgery center who developed ectasia after LASIK to identify factors that may have contributed to the complication.

Patients and Methods

In this retrospective study, the charts of all patients (2873 eyes) who had LASIK surgery at the Vardinoyannion Eye Institute of Crete between May 1995 and November 1999 were reviewed. Fourteen patients (19 eyes, 0.66%) were found to have developed post-LASIK ec-

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tasia. Ectasia was diagnosed by the slitlamp appearance of corneal thinning in the area of ectasia, unstable topographical steepening (more than 1.0 diopter [D] for each 6-month period of follow-up) (EyeSys Technologies) (Figure 1), thickness (30 μm for each 6-month period of follow-up in the area of the steepening) by ultrasound (DGH 5100 Technology, Inc.) and Orbscan (Orbtek Inc.) pachymetry, decreased visual acuity, unstable refraction, and posterior corneal steepening (Orbscan slit-scanning topography system) (Figure 2).

Patients were excluded if any of the following applied after the preoperative examination: active anterior segment pathology; residual, recurrent, or active ocular disease; intraocular or corneal surgery in the eye having LASIK; history of herpes keratitis; or diagnosed autoimmune disease, systemic connective tissue disease, or atopic syndrome. Six patients with post-LASIK ectasia who had high astigmatism and corneal topographic and pachymetric findings suspicious for keratoconus preoperatively were excluded from the study.[7,8]

All patients received treatment after the creation of a nasally hinged corneal flap 8.5 mm in diameter with an automated microkeratome (Flapmaker disposable microkeratome, Refractive Technologies), while a 5.0 to 6.0 mm diameter ablation was applied to the stromal bed (MEL 60 excimer laser, Aesculap-Meditec). The following information was recorded from review of the patient charts: age, sex, affected eye, and preoperative uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA). Corneal findings, including topography, pachymetry (preoperative and intraoperative after the flap was lifted to determine the flap and residual corneal bed thickness after flap creation), stromal ablation (calculated from the nomograms of the laser according to the attempted correction and optical zone size), and intraocular pressure (IOP) were noted. Operative complications, slitlamp biomicroscopic findings before and after the initial attempt, and surgical parameters (flap thickness, optical zone, attempted correction, residual corneal bed thickness) were recorded. At the last follow-up, UCVA, BSCVA, and slitlamp biomicroscopic findings were charted.

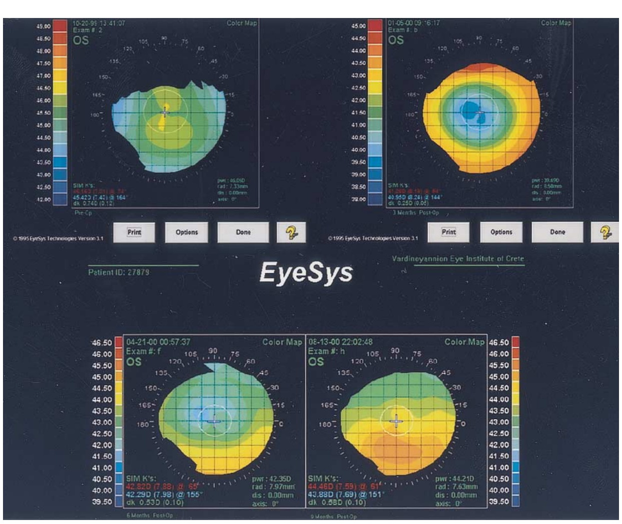

Figure 1. (Pallikaris) Pre-LASIK to post-LASIK (3-, 6-, and 9-month) corneal topographic map of a left eye, demonstrating focal inferior steepening.

Statistical Analysis

Group differences for continuous variables were tested using the unpaired and paired Student t tests and the 1-way analysis of variance for normally distributed data. Differences in categorical variables were tested using the chi-square or Fisher exact test for independence. The dependence of residual corneal bed thickness on age was determined by using least-squares linear regression. Ninety-five percent confidence interval (CI) limits were calculated for differences in mean results. A P value less than 0.05 was considered statistically significant.

Results

The mean age of the 7 men (50%) and 7 women was 37.4 years ± 11.9 (SD) (range 21 to 62 years). Ectasia occurred in 9 right eyes (47%) and 10 left eyes (53%); 5 patients (36%) developed bilateral ectasia.

Preoperatively, the mean spherical equivalent refraction was –15.42 ± 4.41 D (range −8.25 to –24.00 D); the mean keratometry, 42.86 ± 2.05 D (range 39.38 to 46.57 D); and the mean pachymetry, 512.95 ± 18.59 μm (range 495 to 578 μm). Corneal topographic patterns included asymmetric bow tie, 9 (47%); symmetric bow tie, 6 (32%); and round or oval, 4 (21%). The UCVA was uniformly poor at counting fingers; the mean BSCVA was 0.67 (range 0.30 to 1.00). The mean attempted correction was 14.65 ± 4.40 D (range 8.25 to 22.00 D); the mean residual corneal thickness after creation of the flap and stromal ablation, 243.95 ± 46.32 μm (range 175 to 325 μm); and the mean flap thickness, 121.11 ± 16.26 μm (range 90 to 136 μm). The mean IOP was 12.60 ± 2.10 mm Hg

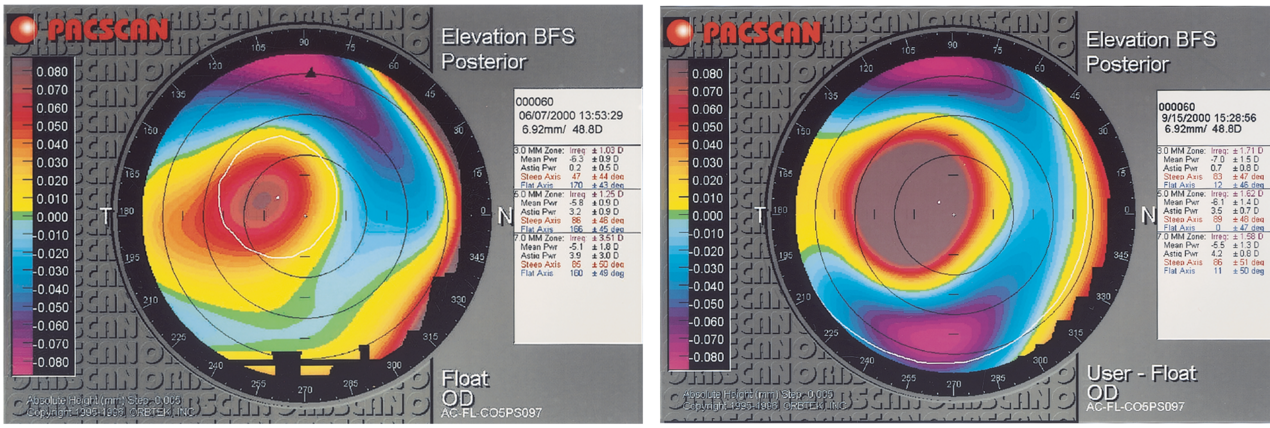

Figure 2. (Pallikaris) The topography of the posterior corneal surface (Orbscan) revealed the progressive ectasia during a 3-month period.

before surgery and 12.20 ± 2.60 mm Hg after surgery (P = .09). Patient data and the operative parameters are summarized in Tables 1 to 3.

The mean follow-up was 16.32 ± 8.26 months (range 6 to 42 months). There was a significant change in refraction between the preoperative examination and post-LASIK follow-up ($P < .01$). In the postoperative evaluation, UCVA was significantly better than preoperatively (P = .01). At the final post-LASIK follow-up, the BSCVA was significantly worse than preoperatively (0.58 ± 0.22 lines [range 0.30 to 1.00] and 0.67 ± 0.21 lines [range 0.30 to 1.00], respectively) (P = .004). Two eyes lost 2 lines and 1 eye, 3 lines. By the last follow-up, 12 eyes (63%) had lost 1 or more lines of BSCVA compared to the preoperative level.

Five patients developed bilateral ectasia and the other 9, unilateral ectasia. There were no statistically significant differences between these groups of patients

Table 1. Patients' preoperative data.

			BSCVA		UCVA		SE (D)			
Patient/Eye	Age (Years)	Sex	Preop	Last Follow-up	Preop	Last Follow-up	Preop	Last Follow-up	Mean Keratometry (D)	Follow-up (Months)
1 OS	25	F	0.60	0.40	CF	CF	18.50	9.25	46.57	42
2 OD/OS	42	F	0.50/0.60	0.50/0.50	CF/CF	CF/CF	24.00/20.00	4.50/3.75	43.10/43.31	23
3 OD/OS	46	F	0.50/0.50	0.30/0.40	CF/CF	CF/CF	13.75/13.00	3.50/4.25	44.67/44.81	15
4 OD	45	F	0.60	0.30	CF	CF	19.00	3.75	40.07	16
5 OD/OS	21	M	0.30/0.30	0.30/0.30	CF/CF	CF/0.10	20.00/18.00	5.50/3.00	42.11/41.89	15
6 OD	27	M	0.50	0.40	CF	CF	20.00	5.50	43.20	19
7 OS	23	F	0.80	0.70	CF	0.10	17.50	2.25	41.48	12
8 OD	42	M	1.00	1.00	CF	0.10	10.50	2.50	43.97	9
9 OD	55	M	0.80	0.70	CF	CF	14.50	6.25	43.60	20
10 OD/OS	45	F	0.70/0.70	0.70/0.60	CF/CF	0.10/0.10	10.00/8.25	2.50/2.00	44.42/43.89	9
11 OD/OS	28	M	0.60/0.90	0.60/0.80	CF/CF	0.10/0.10	18.00/14.50	2.00/2.25	39.38/40.18	6
12 OS	37	F	0.70	0.70	CF	CF	11.00	3.75	46.05	16
13 OS	30	M	0.90	0.80	CF	CF	12.50	5.00	41.57	24
14 OS	62	M	0.90	0.80	CF	CF	10.00	4.00	40.22	16

BSCVA = best spectacle-corrected visual acuity; UCVA = uncorrected visual acuity; SE = spherical equivalent; OS = left eye; OD = right eye; F = female; M = male; CF = counting fingers

Table 2. Patients' surgical data.

Patient	Preop Pachymetry (μm)	Attempted Correction (D)	Flap Thickness (μm)	Optical Zone (mm)	Ablation Depth (μm)	Residual Bed Thickness (μm)
1	08	17.50	123	5.5	160	225
2	517/515	22.00/18.00	103/110	5.0/5.5	170/166	244/239
3	502/506	13.50/12.50	135/132	6.0/6.0	157/144	210/230
4	515	18.00	129	5.5	166	220
5	495/505	20.00/18.00	130/134	5.5/5.5	189/166	176/205
6	530	20.00	96	5.5	189	245
7	502	17.50	134	5.5	160	208
8	500	9.50	136	6.0	105	259
9	578	12.00	136	6.0	137	305
10	514/514	9.00/8.25	90/102	6.0/6.0	99/92	325/320
11	512/508	18.00/14.00	130/135	6.0/6.0	207/163	175/210
12	530	10.50	98	6.0	117	315
13	500	11.00	136	6.0	124	240
14	495	9.00	112	6.0	99	284

in age (P = .72), sex (P = .53), affected eye (P = .82), attempted correction (P = .49), corneal pachymetry (P = .32), flap (P = .79) and residual corneal bed (P = .31) thicknesses, keratometric indications (P = .86), and IOP (P = .72). Reported complications included a free cap (1 eye) and a buttonhole (1 eye). Final UCVA and BSCVA in these patients did not differ significantly from those in patients without complications (P = .2).

The patients were then separated into 2 groups based on the current limit of residual corneal bed thickness (250 μm) (Table 4). In addition to the expected statistically significant differences in refraction (P < .01), attempted correction (P < .01), and optical zone (P = .02), there was a statistically significant increase in the age of patients developing ectasia with residual corneal thicknesses greater than 250 μm (P = .01). In patients with residual thicknesses greater than 250 μm, the mean age was 47.67 ± 9.16 years; in patients with residual thicknesses less than 250 μm, the mean age was 32.62 ± 9.95 years. In all 19 eyes, there was an overall statistically significant positive correlation between residual bed thickness and patient age (r = 0.62, r^2 = 0.39, P = .004) (Figure 3). Similar observations were not found for other parameters such as sex (P = .88), affected eye (P = .88), bilateral ectasia (P = .28), corneal pachymetry (P = .16), flap thickness (P = .11), keratometry (P = .94), topographic pattern (P = .14), and IOP (P = .27).

Discussion

Laser in situ keratomileusis[9] for the surgical correction of myopia is rapidly gaining worldwide acceptance. Quick visual rehabilitation, minimal postoperative discomfort, and the ability to correct high degrees of myopia with little postoperative corneal haze are a few reasons for LASIK's popularity over other surgical vision correction options.

Despite the number of studies that support the efficacy of LASIK,[10,11] concern about the occurrence of postoperative keratectasia is growing. After LASIK, the cornea appears to be mechanically weakened by the tissue ablation and the lamellar cut,[12] but it is not known to what degree this contributes to the cause and mechanism of post-LASIK ectasia.[13]

Several studies report that the amount of residual corneal thickness after ablation is critical to the development of post-LASIK ectasia. In clinical practice, we usually presume that 250 μm is safe. Seiler and coauthors[14] suggest this residual bed thickness to avoid ectasia after LASIK. Holland and coauthors[15] report 5 eyes with

Table 3. Summary of patients' preoperative and surgical procedure data.

	Mean ± SD	Range
Sex (M/F)	7/7	
Eye (R/L)	9/10	
Age (years)	37.4 ± 11.9	21 to 62
Bilateral/unilateral ectasia	5/9	
Refraction (D)	−15.42 ± 4.41	−8.25 to −24.00
Corneal pachymetry (μm)	512.95 ± 18.59	495 to 578
Mean keratometry (D)	42.86 ± 2.05	39.38 to 46.57
UCVA	CF	
BSCVA	0.67 ± 0.21	0.30 to 1.00
Attempted correction (D)	14.65 ± 4.40	8.25 to 22.00
Optical zone (mm)	5.7	5 to 6
Flap thickness (μm)	121.11 ± 16.26	90 to 136
Residual corneal bed thickness (μm)	243.95 ± 46.32	175 to 325
IOP (mmHg)	12.6 ± 2.1	8 to 18

M = male; F = female; R = right eye; L = left eye; UCVA = uncorrected visual acuity; BSCVA = best spectacle-corrected visual acuity

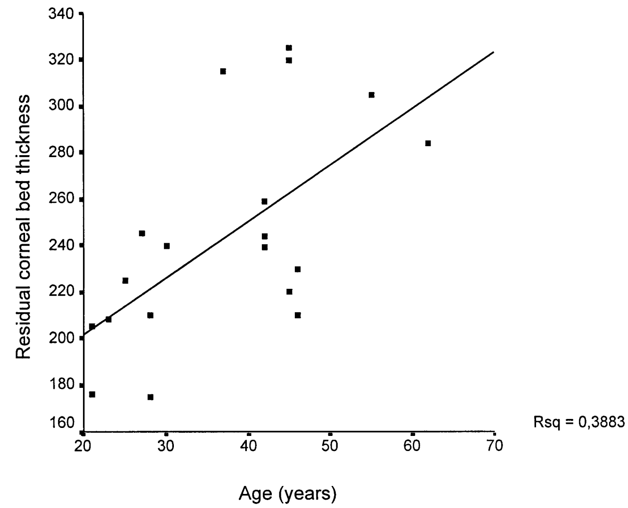

Figure 3. (Pallikaris) The correlation between residual corneal bed thickness (μm) and patient age (r = 0.62, r^2 = 0.39, P = .004).

post-LASIK keratectasia, emphasizing the role of high preoperative refraction and the significant risk of corneal ectasia after hyperopic retreatment of myopic overcorrection. In addition, Schmitt-Bernard and coauthors[16] report an iatrogenic corneal ectasia that developed after LASIK in a case of keratoconus; they suggest, in agree-

Table 4. Distribution of patients by personal, ocular, and LASIK-specific data with respect to a residual corneal bed thickness of 250 μm.

	RCBT<250 μm (13 Eyes/9 Patients)	RCBT>250 μm (6 Eyes/5 Patients)	Significance
Age (Yrs)	32.62 ± 9.95	47.67 ± 9.16	.01*
Sex (M/F)	5/4	2/3	.88†
Eye (R/L)	6/7	2/4	.88†
Bilateral/unilateral ectasia (patients)	4/5	1/4	.28†
UCVA	CF	CF	
BCVA	0.61 ± 0.21	0.80 ± 0.13	.06*
Refraction (D)	17.60 ± 3.33	10.71 ± 2.08	.001*
Corneal pachymetry (μm)	508.85 ± 9.67	521.83 ± 30.14	.16*
RCBT (μm)	217.46 ± 23.33	301.33 ± 25.30	.001*
Mean keratometry (D)	42.83 ± 2.26	42.92 ± 1.70	.94*
IOP (mmHg)	13.00 ± 1.70	11.83 ± 2.7	.27*
Attempted correction (D)	16.92 ± 3.23	9.71 ± 1.35	.001*
Optical zone (mm)	5.65 ± 0.32	6.00	.02*
Flap thickness (μm)	125.15 ± 13.39	112.33 ± 19.65	.11*

RCBT = residual corneal bed thickness; M = male; F = female; R = right; L = left; UCVA = uncorrected visual acuity; BSCVA = best spectacle-corrected visual acuity; IOP = intraocular pressure
*Independent samples t test (Levene's test)
†Fisher exact test

ment with Seiler and Quurke[17] and Buzard and coauthors,[18] that thinning corneal disorders (eg, keratoconus and keratoconus suspects) are contraindications for performing LASIK. Geggel and Talley[19] describe a 44-year-old woman who developed postoperative LASIK ectasia without evidence of preoperative forme fruste keratoconus or an unusually thin residual stromal bed thickness (289 μm), while Joo and Kim[20] suggest that ectasia could develop in patients with myopia less than -12.0 D.

Our results also suggest that the residual corneal bed thickness should be taken into consideration. Most eyes ($n = 13$, 68%) had less than 250 μm of residual stroma after creation of the flap and application of the ablation correction. In addition, 6 eyes (32%) retained a residual stromal bed greater than 250 μm. It seems unlikely that these patients had preexisting keratoconus or forme fruste keratoconus based on normal preoperative topography and corneal pachymetry, normal manifest refraction with minimal astigmatism, and normal keratometry. In these patients, a statistically significant positive correlation with age was observed. It is possible that in these patients, the development of ectasia could be attributed to mechanisms other than corneal weakening by tissue subtraction. These mechanisms could be the result of changes during aging, in endothelial cells, chemical factors (eg, epithelial growth factor, fibronectin), or intracellular links.[21,22]

Another important finding is that no case of post-LASIK ectasia was noted in patients treated with less than -8.00 D of myopia. Some corneas may not adequately tolerate the ablation energy required for corrections above this degree of refractive error. The factors that contribute to this behavior have not been elucidated. They could represent wound-healing "regulators" in the cornea (eg, keratocyte apoptosis[23]) and may play a major role in the corneal remodeling process after laser ablation. The derangement of these systems may be a component in the pathogenesis of ectasia.

In conclusion, until we are better able to identify the patients at risk for ectasia after LASIK and elucidate the variables that define the biomechanical properties of the operated cornea, parameters besides corneal bed thickness (eg, age and attempted correction) may have to be considered to avoid post-LASIK ectasia. Because of the limitations placed by the small sample size of patients referred with ectasia, it is difficult to draw definite conclusions. We propose that a uniform referral system of patients with ectasia be organized to increase the number of study patients and to elucidate the parameters that contribute to the development of this postoperative complication.

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