

LONG-TERM ANALYSIS OF LASIK FOR THE CORRECTION OF REFRACTIVE ERRORS AFTER PENETRATING KERATOPLASTY

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ABSTRACT

Purpose: To determine the long-term safety and effectiveness of laser-assisted in situ keratomileusis (LASIK) in the treatment of refractive errors following penetrating keratoplasty.

Methods: A retrospective review was done of 57 eyes of 48 patients with anisometropia or high astigmatism who were unable to wear glasses or a contact lens after penetrating keratoplasty and who underwent LASIK for visual rehabilitation. Uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BCVA), and corneal transplant integrity were recorded before surgery as well as up to 60 months after LASIK.

Results: The mean follow-up after the LASIK was 21.4 ± 14.2 months (range, 3-60 months). Mean preoperative spherical equivalent (SE) was -4.19 ± 3.38 diopters (D). Mean preoperative astigmatism was 4.67 ± 2.18 D. Preoperative BCVA was 20/40 or better in 42 eyes (74%). At 2 years the mean SE was -0.61 ± 1.81 D and mean astigmatism was 1.94 ± 1.35 D for the 28 eyes with follow-up. UCVA was 20/40 or better in 12 eyes (43%), and BCVA was 20/40 or better in 24 eyes (86%) at 2 years. A gain in BCVA of one line or more was seen in eight eyes (29%). Two eyes (7%) had loss of two or more lines of BCVA at 2 years. Nine eyes (16%) developed epithelial ingrowth. Five eyes (9%) in this series had repeat corneal transplants.

Conclusions: LASIK is effective for reducing ametropia after penetrating keratoplasty. Proper patient counseling is necessary because the results of LASIK after penetrating keratoplasty are not as good as, and complications are more frequent than, in eyes with naturally occurring myopia and astigmatism. Complications are especially common in patients with mismatch of the donor and host cornea and in those with poor endothelial cell function.

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INTRODUCTION

Visual rehabilitation after penetrating keratoplasty remains challenging. The visual success of corneal transplantation is often impaired by high degrees of regular and irregular astigmatism, which, in most cases, is accompanied by large amounts of myopia or hyperopia as well as anisometropia.¹⁻⁶ Usually, this is related to the inherent imprecision of corneal transplantation, with mismatch of donor and host tissue. The keratometry of the postoperative cornea is difficult to predict when performing lens power calculations in the patient undergoing combined penetrating keratoplasty and intraocular lens implantation.^{2,7,8} High degrees of anisometropia may result in a variety of patient complaints, including diplopia and blurred vision. The use of

spectacles for visual rehabilitation is a good option for patients who have small to moderate amounts of ametropia. In more severe cases, contact lenses are often satisfactory.^{9,10} Unfortunately, many patients, especially elderly patients, are unable to tolerate, handle, or maintain contact lenses.

Surgical intervention is considered if optical methods fail to provide adequate visual rehabilitation. Postkeratoplasty astigmatism has been treated with various forms of refractive surgery.^{7,11-41} Unfortunately, predictability after relaxing incisions, astigmatic keratotomy, or wedge resections is not very reliable.^{7,13,28,29,35} Relaxing incisions at the graft host interface are additionally associated with a potential risk of wound dehiscence when there is poor apposition of the posterior edges of the wound. In addition, in some patients, the graft may shift anteriorly during healing, producing irregularities in corneal topography, refraction, and keratometry. Paracentral incisional procedures have also been used in the correction of postkeratoplasty myopia and hyperopia, yet radial keratotomy performed in corneal grafts has high variability and suboptimal predictability.²² Hexagonal keratotomy has been used

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with limited success because of a high incidence of irregular astigmatism.^{42,43} In the last several years, the excimer laser has acquired a significant role in the management of postkeratoplasty refractive errors. The results of photorefractive keratectomy (PRK) performed in this setting have been published in different studies, many of them reporting a significant incidence of stromal haze.^{11,15,21,24,27,31,36,40} The haze appears to be related to the large magnitude of the ablations necessary for these cases, and it is usually coupled with regression of the obtained refractive effect and loss of best spectacle-corrected visual acuity (BCVA). In addition there are some case reports of graft rejection induced by excimer photoablation.^{19,23}

LASIK offers several advantages over PRK in the treatment of myopia and astigmatism.⁴⁴ These include a more rapid visual recovery and less chance of anterior stromal haze. The major disadvantage of LASIK is the risk of complications related to the creation of the lamellar flap. Little long-term information has been reported in eyes with previous penetrating keratoplasty. This study looks at the long-term success of LASIK after penetrating keratoplasty.

SUBJECTS AND METHODS

This study is a retrospective, noncomparative clinical trial of LASIK for visual rehabilitation of significant myopia and astigmatism after penetrating keratoplasty. All patients were intolerant of spectacle correction and contact lenses. A detailed explanation of the proposed surgical treatment was given to all patients. Informed consent was obtained from the patients. The surgery was performed by one of two surgeons in our group (R.L.L. or D.R.H.) between August 1996 and August 2000. All subjects were at least 18 years of age, and contact lens wear was discontinued at least 3 weeks prior to preoperative evaluation. Minimum time from penetrating keratoplasty to LASIK was 13 months (range, 13 months to 20 years), and all eyes had all sutures removed at least 1 month before the LASIK surgery. The study group consisted of 57 eyes of 48 patients.

Preoperative testing included a complete eye examination, consisting of uncorrected visual acuity (UCVA) and BCVA, manifest refraction, tonometry, corneal topography, and ultrasound pachymetry.

SURGICAL PROCEDURE

The surgery was performed in a particle-free environment with patients under topical proparacaine anesthesia. The unoperated eye was taped shut to prevent drying of the cornea, eliminate cross-fixation, and aid the patient in maintaining good fixation. The corneal flap was cut using the Bausch & Lomb automated corneal shaper (ACS) or Hansatome microkeratome (Bausch & Lomb, Miami, Florida). The ACS flaps were hinged nasally (160- μ m flap

thickness, 7.5-mm average diameter), and a superior hinge was made for all eyes with the Hansatome (180- μ m flap thickness, 9.0-mm average diameter). After the flap was lifted, the photoablations were made using the VISX STAR Excimer Laser System (VISX, Inc, Santa Clara, California) with a fluence of 160 mJ/cm² using a maximum optical zone of 6.0 mm. Hydration was monitored visually during the ablation, and the cornea was moistened if it became drier than expected by the surgeon or dried if it became moister than expected.

The desired correction was emmetropia in all eyes. The correction was initially set to 100% of the manifest sphere and cylinder, but early experience showed that this nomogram resulted in residual myopia and astigmatism in many patients. Later a nomogram based on experience in normal eyes was used. Elliptical laser ablations, astigmatic keratotomy, or both, were used to correct astigmatism. For astigmatic treatment, an elliptical ablation was performed with the optical zone along the minor axis of at least 4.5 mm and no greater than 6.0 mm. For astigmatic keratotomy, a square-tipped blade was set to 50 μ m more than the thinnest central corneal depth measured under the flap after myopic ablation. An optical zone of 7 mm was used, and the length was determined by the Chiron Arc-T Lindstrom 9-mm optical zone nomogram. The flap and bed were irrigated with BSS, and the flap was floated back into position and smoothed with a dry Merocel sponge (Medtronic, Jacksonville, Florida). The eye was left open for 5 minutes to allow the endothelial cell pump to remove stromal fluid from underneath the flap and secure the flap in place. At the end of the procedure, antibiotic, steroid, and nonsteroidal anti-inflammatory drops were instilled into the eye. Patients received antibiotic and steroid drops four times daily for the first 2 postoperative weeks and then resumed their maintenance steroid regimen.

Outcome measures included UCVA accuracy and predictability of treatments (percentage within ± 0.5 D and ± 1.0 D of emmetropia), stability of refraction, loss of BCVA, and all complications at 1 day, 1 week, and 1, 3, 6, 12, and 24 months after surgery. Statistical analysis was done with Microsoft Access 97 and Microsoft Excel 97 software (Microsoft, Inc, Redmond, Washington). All means are reported with their standard deviations and ranges.

RESULTS

Fifty-seven eyes with myopia, astigmatism, or both, were treated. Mean patient age was 59.6 ± 17.3 years (range, 24-92 years). Table I shows the demographic characteristics for this population. Spherical corrections ranged from -0.75 D to -15.25 D, and cylindrical corrections ranged from 0.5 D to 10.0 D. Forty-one eyes (72%) had significant

TABLE I: PREOPERATIVE PATIENT CHARACTERISTICS OF STUDY GROUP

CHARACTERISTIC	NO.	%
Total eyes	57	
Right	28	49
Left	29	51
Mean patient age (yr)	59.6 ± 17.3	
Age range (yr)	24-92	
Gender (patients)		
Male	32	67
Female	16	33
Race (patients)		
White	46	96
Asian	1	2
Hispanic	1	2

irregular astigmatism (steep and flat meridians not 90° apart), and 16 eyes (28%) had mostly regular astigmatism. In the eyes with regular astigmatism, 13 had LASIK alone and 3 eyes had very high astigmatism and therefore had LASIK combined with astigmatic keratotomy. Twelve of the eyes with irregular astigmatism received astigmatic keratotomy combined with LASIK. The remaining 29 eyes with irregular astigmatism received LASIK alone.

In this series, many patients were elderly, and 10 eyes (17%) had significant drusen or senile macular degeneration. The most common indication for the penetrating keratoplasty in this series was keratoconus in 27 eyes (47%) and Fuchs' endothelial dystrophy in 16 eyes (28%) (Table II). Previous corneal surgeries were relaxing incisions after penetrating keratoplasty in one eye and glaucoma surgery in one eye. Two eyes had had one transplant before the transplant that received LASIK. Five eyes had glaucoma in the study group. The other anterior segment problems included 12 eyes with significant dry eye, 5 eyes with chronic significant blepharitis, 17 eyes with override of the corneal graft wound with localized ectasia, and 3 eyes with multiple corneal graft rejection episodes. Nine eyes (16%) had borderline endothelial cell count below 1,000 cells/mm² by specular microscopy. Endothelial cell counts were not performed routinely early in the study, yet

TABLE II: INDICATIONS FOR ORIGINAL PENETRATING KERATOPLASTY

DIAGNOSIS	NO. OF EYES	% OF EYES
Keratoconus	27	47
Fuchs' dystrophy	16	28
Pseudophakic corneal edema	6	11
Traumatic corneal scar	5	9
Herpes simplex keratitis	1	2
Acanthamoeba keratitis	1	2
Iridocorneal endothelial syndrome	1	2

preoperative pachymetry was over 600 µm thick in 8 of the eyes in which specular microscopy was not performed.

Six-month follow-up data are available for 53 eyes (93%), 1-year follow-up data for 52 eyes (91%), and 2-year follow-up data for 28 eyes (49%). Follow-up of 3 years or more is available for 12 eyes (21%).

UNCORRECTED VISUAL ACUITY

Before surgery, all eyes had UCVA worse than 20/40 (range, 20/80 to count fingers). At 1 year, follow-up is available for 52 eyes, and UCVA is 20/40 or better in 20 eyes (38%) (Figure 1). UCVA stays stable in most eyes over time (Figure 2).

BEST SPECTACLE-CORRECTED VISUAL ACUITY

Before surgery, 42 eyes (74%) had BCVA of 20/40 or better. At 1 year, 39 eyes (75%) had BCVA of 20/40 or better. Seven eyes (13%) had a loss of more than two lines of BCVA (Figure 3).

REFRACTIVE ERROR

Figure 4 shows the mean spherical equivalent manifest refractive error (SE) over time through 3 years. The SE was relatively stable by 6 months, yet 12 eyes (23%) still had more than 1 D of change in manifest refraction SE from 3 to 6 months. The mean difference in SE between 3 and 6 months was 0.4 toward the myopic direction. Figure 5 represents the accuracy of the attempted versus achieved SE correction at 1 year. Most patients had correction between -2 and +2 D (Figure 6).

ASTIGMATIC CORRECTION

Figure 7 shows the mean refractive cylinder over time. Most eyes were relatively stable by 3 months, yet 8% of eyes had more than 1 D of increase in astigmatism between 3 and 6 months, and 6% of eyes had more than 1 D of improvement in astigmatism between 3 and 6 months. The mean change in astigmatism between 3 and 6 months was 0.01 D.

INTRAOCULAR PRESSURE

None of the eyes in this study had intraocular pressure greater than 25 mm Hg or an increase in intraocular pressure of more than 10 mm Hg above preoperative baseline. Five eyes had glaucoma in this study, and pressure control was maintained with glaucoma medications.

PACHYMETRY

Mean central corneal thickness before LASIK was 572 ± 45 µm (range, 487-709 µm). Mean laser corneal ablation depth was 55 ± 27 µm and varied from 15 to 134 µm. Mean calculated residual stromal bed thickness was 346 ± 59 µm (range, 209-498 µm). Twelve eyes (21%) had a stromal bed

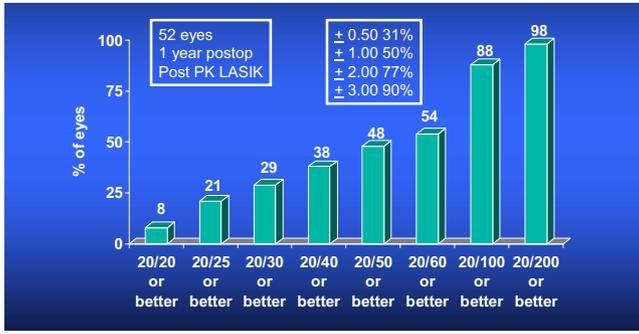


FIGURE 1

Uncorrected visual acuity of 52 eyes at 1 year.

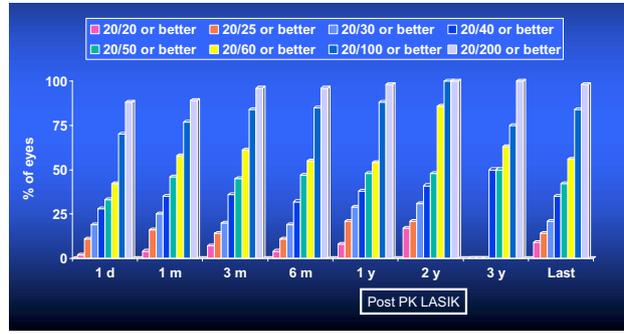


FIGURE 2

Uncorrected visual acuity of eyes at all time points.

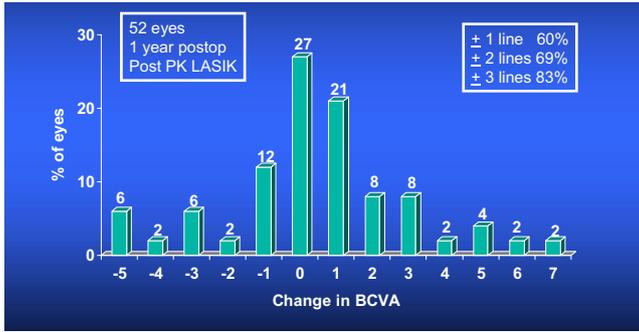


FIGURE 3

Change in best corrected visual acuity at one year. Numbers to left of zero represent patients with loss of best corrected visual acuity (BCVA). Numbers to right of zero represent patients with gains of BCVA.

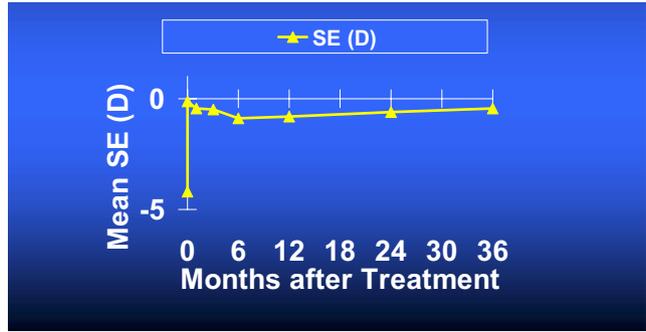


FIGURE 4

Mean spherical equivalent over time.

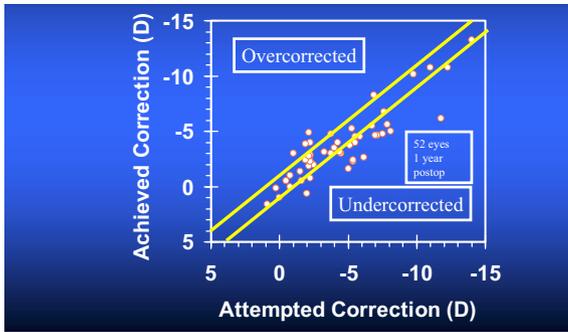


FIGURE 5

Attempted versus achieved spherical equivalent at 1 year. Points above the line represent eyes that have an overcorrection of more than 1 diopter (D). Points below the line represent eyes that have an undercorrection of more than 1 D.

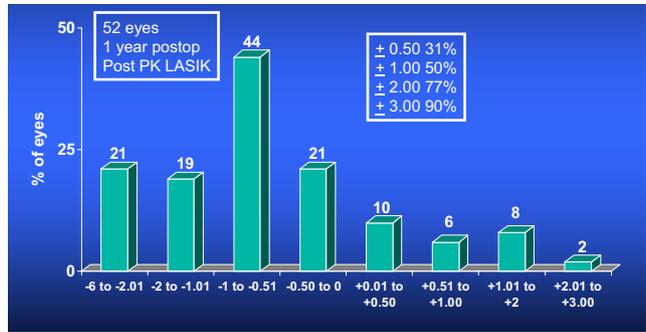


FIGURE 6

Postoperative defocus at 1 year.

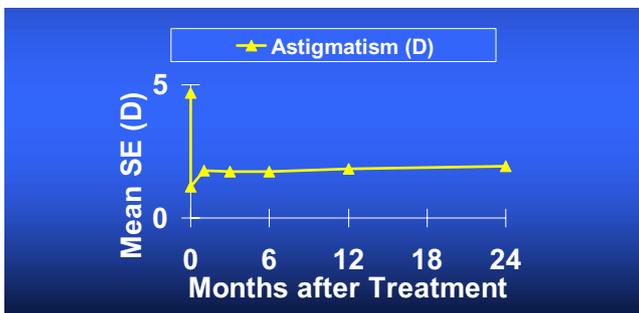


FIGURE 7

Mean residual astigmatism over time.

thickness below 300 μm . Two eyes (4%) had a residual stromal bed thickness below 250 μm (209 and 249 μm).

CORNEAL ENDOTHELIAL CELL COUNT

Specular microscopy was available preoperatively for 23 eyes. Mean endothelial cell count before LASIK was $1,250 \pm 729$ cells/ mm^2 (range, 0-2,697 cells/ mm^2). Nine eyes had an endothelial cell count less than 1,000 cells/ mm^2 . Endothelial cell counts were measured postoperatively in only 10 eyes. One patient with a significant rejection episode at 2 years had a loss of over 1,000 cells/ mm^2 . The

other nine eyes that were measured showed no significant change in endothelial cell density.

COMPLICATIONS AND ADVERSE REACTIONS

A summary of complications and adverse reactions is detailed in Table III. Epithelial ingrowth occurred in nine eyes (16%), all of which had override of the donor wound over the host before the LASIK. One eye had recurrent herpes simplex keratitis at 6 months, which resolved after treatment with no loss of BCVA. Two eyes developed interface fluid pockets between 1 month and 3 months. Four other eyes had flap dislocation between 1 day and 1 week: two required sutures to stabilize the flap, one flap was removed, and one flap was repositioned successfully without sutures. Other complications occurred, including sterile interface inflammation, corneal striae, and corneal edema. In one eye a microperforation occurred during arcuate keratotomy under the flap, which required a suture of the microperforation. This suture was later lysed with the argon laser without complication. Five eyes (9%)

eventually had another penetrating keratoplasty. Two of these were for early loss of graft clarity due to low cell counts, one was due to edema from a rejection episode 2 years after the LASIK, and two were for persistent irregular astigmatism from ectasia at the interface between the graft and the host that existed prior to LASIK.

ENHANCEMENTS

Five eyes (9%) underwent an enhancement procedure for residual correction. Further LASIK was performed in these eyes using a lift flap technique. One of these eyes developed epithelial ingrowth, which did not require removal after the enhancement.

DISCUSSION

High anisometropia following penetrating keratoplasty is not uncommon and can lead to significant patient dissatisfaction. The resolution of anisometropia was the goal of LASIK in most patients in this study. Because of the differences in indication for the procedure, as well as the difference in results, we prefer to use the term *therapeutic lamellar keratectomy* (TLK) to describe the procedure in these eyes. In most of the patients, the goal of TLK was met, with improvement in the anisometropia. Many patients were older and had other associated eye problems, such as age-related macular degeneration or other anterior segment problems. Three patients had a history of multiple episodes of graft rejection prior to the TLK procedure. These associated problems limited visual acuity preoperatively in many eyes. Rehabilitation with spectacle correction or rigid gas-permeable contact lens is typically preferred over TLK; however, in elderly patients poor manual dexterity, tremor, arthritis, or decreased visual acuity in the other eye may limit the tolerance of contact lenses. Contact lenses can also be problematic in patients with chronic blepharitis and severe dry eye and may induce chronic irritation and peripheral neovascularization, also increasing the risk of corneal graft rejection.¹¹

LASIK after penetrating keratoplasty has a higher complication rate than in patients with normal corneas, but typically management of those complications is the same.^{45,46} In a series of LASIK in normal eyes from the same time frame from our own group, we found flap displacement on day 1 of 0.7% and epithelial ingrowth in 0.2% of eyes.⁴⁶ This same study showed that 97% of eyes with low myopia and 56% of eyes with high myopia have 20/40 or better visual acuity by 1 month.

In the current series, the mean preoperative astigmatism was very high at 4.7 D. Many of the eyes had significant levels of irregular astigmatism, which is not uncommon after penetrating keratoplasty.^{6,7,10} Currently, excimer laser systems are approved in the United States to treat irregular astigmatism through a phototherapeutic

TABLE III: SUMMARY OF COMPLICATIONS AND ADVERSE REACTIONS RELATED TO SURGICAL PROCEDURE AT ANY TIME IN THE POSTOPERATIVE COURSE

COMPLICATIONS*	NO. OF EYES†	%	INTERVAL COMPLICATION NOTED
Sterile interface inflammation	3	5	1 wk to 1 mo
Epithelial ingrowth requiring removal	4	7	1 wk to 12 mo
Ingrowth not requiring removal	5	9	1 mo to 3 mo
Mild flap striae	4	7	1 day to 1 wk
Interface fluid pocket	2	4	1 mo, 3 mo
Herpes simplex keratitis recurrence	1	2	6 mo
Repeated graft for persistent irregular astigmatism	2	4	1 yr to 3 yr
Repeated graft for edema	3	5	8 mo to 3 yr
Flap dislocation	4	7	1 day, 1 wk
Microperforation	1	2	Intraoperative

*Other complications that occurred transiently include corneal edema and punctate epitheliopathy.

†Same subject may be included in more than one complication.

approach. All eyes in our study received spherocylindrical treatments, only without any wavefront or topographic adjustments. Future modalities, such as wavefront or topographically directed treatments, may improve results in these patients, though early studies still are less satisfactory for the treatment of irregular astigmatism than regular astigmatism.⁴⁷⁻⁴⁹ Proper axis alignment and centration of the laser ablation are critical in high astigmatism and difficult or impossible with standard treatments in eyes with irregular astigmatism. The success of treatment in eyes with irregular astigmatism is also difficult to measure, because the astigmatism itself is difficult to measure. We chose to use refractive astigmatism for the analysis, since wavefront testing was not available at the time the study was performed. Newer wavefront techniques may prove to be more useful in defining, measuring, or treating irregular astigmatism.^{50,51}

There is the potential risk of damage to the corneal transplant after TLK, such as wound dehiscence, corneal graft rejection, and flap complications. The minimum time for TLK after all sutures had been removed in this study was 1 month, and the minimum time for TLK after the penetrating keratoplasty was 13 months. Mean time of TLK after penetrating keratoplasty was 70 months. This report confirms that adequate wound integrity is present to prevent disruption of the corneal wound in the treated eyes. We did perform LASIK on 17 eyes with moderate wound override due to poor healing of the corneal wound where the transplant was displaced anteriorly. These eyes were at increased risk for epithelial ingrowth. The clinical pattern in these eyes was poor early adherence of the flap in the area of the wound override, with epithelial ingrowth beginning in the area of the override. We had nine eyes (16%) overall that developed epithelial ingrowth and four eyes (7%) that required removal of the epithelial ingrowth. Eyes with wound override also have more irregular astigmatism and are less likely to achieve desired results with the TLK procedure, as evidenced by the fact that two of these patients desired another keratoplasty.

Postoperative flap dislocation or poor adherence is more likely to occur in eyes with low endothelial cell counts preoperatively. In two of our patients, fluid-filled cysts developed in the interface, both of which had very low endothelial cell function. Two cases of interface fluid have previously been reported, yet these were associated with steroid-induced ocular hypertension, not related to endothelial cell pump function from low numbers of cells.⁵² Eyes with corneal transplants probably lose endothelial cells at a more rapid rate than normal eyes and do not always display typical guttata, so specular microscopy is helpful in identifying those eyes at risk of poor adherence.⁵³⁻⁵⁵ LASIK probably has little detrimental effect on the endothelium.⁵⁶ Still, patients with low cell counts may not tolerate LASIK and may require other surgical intervention,

including repeated penetrating keratoplasty.

Preoperative topical steroid had been suggested to reduce the incidence of graft rejection, yet this was not a large problem in this series. These eyes did well with continuation of their baseline steroid dosage with a strong steroid four times daily for the first month after the TLK procedure.

Some investigators have suggested a two-step procedure, first creating the flap, then at a later time repeating refraction and the laser treatment to increase the accuracy of the procedure.¹⁷ In our series, we performed the procedure in one step to allow quicker visual rehabilitation and limit the potential for complications to one surgery if possible. This is important, because the rate of epithelial ingrowth as a complication is higher in enhancement procedures (Davis, EA, Lindstrom M, Hardten DR, Lindstrom RL; Lifting versus Recutting for LASIK Enhancements, in press, *Ophthalmology*, 2002). The expectations of these patients are typically less than of patients with naturally occurring myopia or astigmatism, and despite the fact that the results were less optimal than in naturally occurring myopia, our enhancement rate was quite low (8.8%), even with an average follow-up of almost 2 years, showing the practicality of our approach.

The one arcuate keratotomy complication in our study was a microperforation, which occurred because of uneven thickness of the stromal bed in a patient with herpes simplex keratitis. Caution should be taken to avoid arcuate keratotomy incisions in areas of uneven thickness, because ultrasonic pachymetry or even scanning slit optical measurements may not adequately describe the thickness in these regions. Sutures prevented fluid leakage underneath the LASIK flap, and this eye healed uneventfully, with a good refractive result after argon laser lysis of the suture. The availability of a more diverse pattern of astigmatic treatments, such as mixed astigmatism or irregular astigmatism, should reduce the need for concomitant astigmatic keratotomy.

PRK has also been used to treat residual refractive errors after penetrating keratoplasty, yet has been associated with haze in several other studies.^{15,27,57} Haze in eyes that have PRK after radial keratotomy has also been reported.⁵⁸ It may be that patients who have had ocular surgery have a higher incidence of haze. These reports are of cases that occurred before mitomycin-C was used to reduce haze after PRK or phototherapeutic keratectomy.^{59,60} So far, use of mitomycin-C with PRK has not been reported after penetrating keratoplasty; this may be useful for cases with some override or low endothelial cell count where the risk of epithelial ingrowth or poor flap adherence is high, but further study is required.

The results of therapeutic lamellar keratectomy were not as predictable in eyes with irregular astigmatism when compared with regular astigmatism. Newer ablation profile software and newer diagnostic techniques such as topography or wavefront guidance to refine the pattern of

ablation will need to be investigated in order to improve the quality of vision in eyes with irregular astigmatism after penetrating keratoplasty. Still, therapeutic lamellar keratectomy is useful for many patients with postkeratoplasty anisometropia or astigmatism where contact lenses or glasses correction is not tolerated. Careful patient selection, especially with attention to transplant alignment and endothelial cell density, can improve results.

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DISCUSSION

DR WALTER J. STARK. It is my pleasure to discuss the presentation by Drs Richard Lindstrom and David Hardten on the analysis of LASIK for the correction of refractive errors after penetrating keratoplasty. The authors have presented results on 57 eyes of 48 patients who underwent LASIK for a wide range of refractive errors after penetrating keratoplasty. Fifteen of the cases also had astigmatic keratotomy. The spherical errors of the eyes ranged from -0.75 diopters to -16.25 diopters and a cylindrical error ranged from 0.5 diopters to 10 diopters. Seventy-two percent of the eyes had significant irregular astigmatism, which could not be fully treated with the lasers used in the study. Forty-seven percent of patients had keratoconus, as one would expect for patients having high astigmatic and refractive errors after penetrating keratoplasty. Follow-up was 91% at a year, 41% at two years, and 21% at 3 years. Best spectacles corrected vision improved or remained the same in 74% of eyes and decreased in 28% of eyes.

The authors' results parallel the short-term results of others that have been referenced in their articles, including a paper in the journal *Ophthalmology* by Dr Eric Donnenfeld in 1999, where 59% of his 21 patients had keratoconus. After publication of Donnenfeld's article and review of Hardten's paper, I have had concern about LASIK in patients who have had keratoplasty for keratoconus. These patients have keratoconus in the recipient bed and will have instability of the recipient cornea over time. I have seen numerous keratoconus patients 20 years after keratoplasty where there is progressive thinning of the cornea at the inferior graft-host junction, with progression of the keratoconus in the inferior recipient bed. My concern is that a LASIK procedure, where the microkeratome cuts through this recipient cornea, will lead to progressive ectasia of the recipient bed and instability of the postoperative refraction. I contacted Dr Eric Donnenfeld last week to get information on long-term

follow-up on his keratoconus patients who have had LASIK after keratoplasty. He has noted some progression of ectasia in the recipient cornea, and therefore he has switched to performing PRK rather than LASIK in these keratoconus eyes. Haze has been a reported problem after PRK in corneal graft, and we have seen this in our cases. To reduce the chances of haze, he is using mitomycin-C 0.02% for 20 to 30 seconds. Also, newer lasers that give a smoother corneal bed may lead to less haze and regression in these cases.

For nonkeratoconus eyes after keratoplasty where there is good donor-recipient healing and regular astigmatism, LASIK may be the preferred option to PRK to reduce ametropia, but there are still some concerns about LASIK in eyes after keratoplasty. The keratome cut alone has been shown to cause major changes in the astigmatism. Therefore, some advocates of this procedure recommend a keratome cut of the cornea with no laser treatment, followed by refraction 1 month later, and then lifting the flap for laser treatment of the residual refractive error. In my opinion, this would increase the rate of complications, especially epithelial ingrowth under the flap, which occurred at a rate 16% in Lindstrom's series and was serious enough to require removal in 7% of eyes.

Cutting the corneal flap does put some stress on the graft-host junction. We have seen patients who have had disruption of their graft-host junction 20 years after keratoplasty from seemingly minor trauma. Therefore, disruption of the graft-host junction must be considered as a potential complication with this procedure.

Finally, a good contact lens service makes a corneal transplant service successful. Over 50% of cornea transplant recipients will have 4 diopters or more of astigmatism, and in many cases this will be irregular astigmatism. These patients will achieve their best-corrected visual acuity only with a contact lens. At this time, irregular astigmatism is difficult to treat with a laser. Therefore, we recommend repeated attempts at contact lens correction before considering LASIK or PRK in eyes after keratoplasty.

In the discussion, I would like Dr Lindstrom to comment on the percent of eyes still requiring a contact lens after LASIK for functional vision and provide some information on patient satisfaction. For contact lens-intolerant eyes we are hopeful that in the future, topographically controlled lasers and custom corneal ablations that can correct irregular astigmatism will lead to better results in complicated cases, such as those presented by Dr Lindstrom and his associates. The authors are to be commended for their work on the complicated eyes after keratoplasty.

DR VERINDER S. NIRANKARI. We presented a similar paper at the Academy two years ago looking at high

astigmatism and anisometropia in patients following PK. Our results were very similar. It would be very helpful to know which patients should not have LASIK after PK. We had three patients that developed flap adherence problems after LASIK, and all three required another PK. At what level of endothelial cell counts or pachymetry readings is the LASIK contraindicated?

DR JAMES C. BOBROW. How long after graft surgery were the LASIK procedures performed? How did you handle the problem of peripheral vascularization? Were there any special techniques for using the microkeratome? Are there any control groups or prior studies to compare these results against?

DR RICHARD C. TROUTMAN. I have no experience with LASIK. The most difficult cases of astigmatism to treat, either by relaxing incision or wedge resection, have been patients that had keratoconus for a long time. These patients had temporized with contact lenses. When you trephine the cornea in these patients, the peripheral cornea drops back on the iris. In these situations, you are going to have high astigmatism postoperatively.

DR RICHARD L. LINDSTROM. The patients were 1 year to 20 years postkeratoplasty; all were at least 1 month after all suture removal. The surgical technique with the microkeratome was routine; there were no intraoperative complications with the keratome. We are believers in a one-stage procedure, because, as we have looked at our data in routine LASIK eyes, the complication rate of an enhancement is about three times the complication rate of a primary procedure. So, in our experience, flap-lift enhancements have a higher complication rate than a primary LASIK procedure. Thus, subjecting the patient to two operations with an increased risk of complications does not make sense to us.

The cases not to do, or at least the ones that we are not going to do, Dr Nirankari, are the ones that have significant graft override, or very low cell counts. We are concerned about our keratoconus patients, Dr Stark, and we are watching those. Some of them do show inferior ectasia on their topography, and it may be progressive and that certainly would be a concern. We do have a good contact lens service, and we do fit a lot of patients with contact lenses that are referred for keratoplasty or LASIK after keratoplasty.

As an aside, I rarely disagree with my senior colleague, Dr Troutman, but there are two schools of thought on treating keratoconus. One of them is early surgery, if you will, a prophylactic keratoplasty, for keratoconus. We don't believe in that. We basically wait until patients become contact lens-intolerant before recommending

keratoplasty. We do not think that a keratoplasty stops the process of keratoconus. The same issue that was mentioned by Dr Stark, that the ectasia can continue after keratoplasty, leads us to wait until patients are contact lens-intolerant before we operate. We find one way to

make a patient contact lens-tolerant is to operate on the first eye. Bilateral contact lens-intolerant patients often become contact lens-tolerant in their second eye after they have had keratoplasty surgery in the first eye.