Excimer laser–assisted lamellar keratoplasty for the surgical treatment of keratoconus

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PURPOSE: To evaluate the anatomical and functional results of excimer laser–assisted lamellar keratoplasty (ELLK) in keratoconus patients.

SETTING: Eye Clinic, University of L'Aquila, L'Aquila, Italy.

METHODS: This prospective case series comprised patients with keratoconus who had ELLK and were examined preoperatively and 3, 6, 12, and 24 months postoperatively. Outcome measures were uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), refraction, computerized videokeratography, pachymetry, and endothelial specular microscopy.

RESULTS: Forty-one eyes (41 patients) were examined. The UCVA and BSCVA were significantly better at all follow-up examinations than preoperatively. After the 24-month follow-up (33 patients), the UCVA was better than 20/60 in 11 patients (33.3%) and the BSCVA was 20/40 or better in 29 patients (87.9%). The mean refractive astigmatism was 2.20 diopters (D) and the mean manifest refraction spherical equivalent refraction, −1.18 D. Corneal topographic patterns were regularly astigmatic in 28 (84.8%) of 33 eyes, and the mean corneal thickness (440.0 μm) was significantly greater than preoperatively (553.0 μm). No statistically significant changes in mean corneal endothelial cell density were observed postoperatively. Complications included corneal melting treated with penetrating keratoplasty (PKP) (1 case) and postoperative high refractive error requiring topographically guided excimer laser photorefractive keratectomy (7 cases).

CONCLUSIONS: Two-year findings indicate that ELLK is as efficacious as PKP for the surgical treatment of moderate to advanced keratoconus. The procedure is relatively simple. Most steps can be standardized, and there are no time-consuming maneuvers.

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The management of patients with keratoconus varies according to the degree of evolution of the illness.[1] Surgery is considered when patients do not tolerate contact lenses or, when despite their use, do not reach adequate visual acuity. The purposes of surgery are to improve the refractive properties of the cornea by reshaping its curvature, to restore its structural and tectonic characteristics by increasing the corneal thickness, and, when transparency is affected, to reestablish optical properties.

Penetrating keratoplasty (PKP) is the most used and reliable surgical technique to treat keratoconus. However, the procedure also involves the substitution of the corneal endothelium, usually still healthy in eyes with this disease, and puts the patients at risk for immunological rejection for the rest of their lives.[2]

Because of the young age of these patients, it is important to follow a step-by-step therapeutic plan choosing first, when possible, techniques that are less invasive and thus postponing the PKP. Several authors propose different techniques for anterior lamellar keratoplasty. The common principles in all lamellar keratoplasty techniques are to selectively remove only the pathological tissue, saving the deeper corneal layers (Descemet membrane and endothelium), and to restore the

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normal corneal thickness by implanting a lamellar graft. However, hand dissection is a difficult, painstaking procedure that is rarely as precise as required. As a result, microperforation and macroperforation can occur, which may prompt the surgeon to convert to PKP.[3–6] More often, some corneal stroma is left attached to Descemet membrane; the uneven quality of the resulting stromal surface can induce scar formation over time, which in turn can significantly affect visual acuity. In addition, the lack of standardization and reproducibility is a major disadvantage of procedures involving hand dissection.[7] To prevent these problems, some surgeons recently began using an excimer laser to remove the recipient corneal stroma, leaving a good-quality stromal bed surface.[8] Therefore, excimer laser lamellar keratoplasty of augmented thickness was conceived as an alternative to PKP for the treatment of keratoconus.[9]

In this paper, we report the anatomical and functional results obtained by treating keratoconus patients intolerant to spectacles and contact lenses with excimer laser–assisted lamellar keratoplasty (ELLK).

PATIENTS AND METHODS

Eyes with keratoconus were included in this prospective noncomparative case series between June 2002 and January 2005. The study was approved by the ethics committee of the School of Medicine, University of L'Aquila, and all patients provided informed consent.

Selection criteria included poor vision even with spectacle or contact lens correction, poor contact lens tolerance, superficial corneal opacity only, and a pachymetric value greater than 350.0 μm. Patients with diabetes, connective tissue disorders, glaucoma or intraocular hypertension (≥20 mm Hg), dry-eye syndrome, retinal disorders, or amblyopia were excluded from the study. Pregnant women were also excluded.

All patients had a complete eye examination including uncorrected (UCVA) and best spectacle-corrected (BSCVA) visual acuity, refraction, slitlamp biomicroscopy, intraocular pressure measurement, and fundus evaluation. Corneal topography was performed during each examination using computerized videokeratoscopy (CAS videokeratography unit, EyeSys); 4 keratoscopic images were obtained from each eye, and the best one was chosen. The keratometric difference at 3.0 mm was considered to be the keratometric astigmatism. Corneal thickness was evaluated using a 50 MHz ultrasound pachymeter (Corneo Gage Plus, Sonogage). The corneal endothelial pattern was evaluated using noncontact endothelial specular microscopy (SEED SP 500, SEED Co., Ltd.). The endothelium was analyzed using the quantitative parameter of endothelial cell density (ECD) (ie, number of cells/mm^2) and the qualitative parameter of the coefficient of variation (CoV) (ie, standard deviation cell area/mean cell area). The measurements were taken preoperatively and 3, 6, 12, and 24 months after surgery.

Surgical Technique

All procedures were performed by the same surgeon (L.S.) at the same clinic. Local anesthesia was achieved with a peribulbar injection of 10 cm^3 bupivacaine 0.5%–mepivacaine 4.0%. Patients were prepared and draped in the usual fashion.

Several drops of povidone–iodine 5% were instilled in the inferior fornix, and a lid speculum was inserted to keep the eye wide open. After mechanical deepithelialization, a phototherapeutic keratectomy (PTK) ablation was performed in PTK mode using a MEL-70 excimer laser (Carl Zeiss Meditec). The laser setting was wavelength 193 nm, frequency 35 Hz, fluence 180 mJ/cm^2, and ablation rate 0.25 μm. The laser uses a 1.8 mm diameter flying spot with a Gaussian profile. A cone was added to the laser output to control atmosphere; that is, to extract smoke or particles from the air without creating a draft and to remove all obstacles in the path of the laser beam. A 7.0 mm round stainless steel mask was placed on the cornea to create a vertical and regular edge of the ablation. The ablation depth setting ranged from 110.0 to 200.0 μm, always with the goal of a minimum estimated residual corneal bed of 200.0 μm. A 2.5 mm stromal pocket was created around the circumference of the ablation floor with a circular movement using a disk knife (Alcon).

The donor lamellae, procured from the Eye Bank of Veneto, Mestre, Italy, were obtained from a cornea mounted on an artificial anterior chamber, cut with a microkeratome (ALTK system, Moria), and then dehydrated in a silicon gel. After being rehydrated in balanced salt solution (BSS) for 10 minutes before surgery, the donor lamella was secured in the recipient bed with four 10-0 nylon cardinal sutures at the 6, 12, 9, and 3 o'clock positions. After the introduction of the wing of the donor lamella in the stromal pocket, 16 interrupted 10-0 nylon sutures were placed. Finally, the knots were buried and intraoperative suture adjustment was performed. At the end of surgery, the speculum was removed and the eye patched. The patch was removed the day after the surgery.

The postoperative therapy consisted of topical ofloxacin 3% 3 times daily until complete reepithelialization. After the ofloxacin was discontinued, topical dexamethasone 0.1% was administered for at least 1 month and then tapered and titrated. Within 3 months after surgery, all medication was stopped. Preservative-free artificial tears (sodium hyaluronate 0.2%) were used for up to 6 months.

Two months after surgery and based on corneal topography analysis, some sutures that were causing major graft distortion were removed. Over the following 3 months, all remaining sutures were selectively removed to achieve as regular a corneal curvature as possible.

Other Surgical Procedures

To reduce postoperative refractive error in patients not satisfied with their vision, topographically guided excimer laser transepithelial photorefractive keratectomy (PRK) was performed using the same MEL-70 excimer laser linked to a computerized videokeratographer (TMS-3, Tomey) with a topographically supported customized ablation workstation. This technique has been described.[10] The procedure took place at least 12 months after the ELLK and 6 months after complete suture removal.

Penetrating keratoplasty was performed in a patient with poor graft clarity caused by melting of the lamella. The host bed was trephined, leaving the lamellar graft in place. An 8.25 mm donor button was sutured in an 8.00 mm recipient bed with a 12-bite double running 10-0 nylon suture without removal of the small peripheral annulus of donor lamellar

tissue (about 0.5 mm in width) from the previous ELLK surgery.

Statistical Analysis

Data were collected postoperatively and entered into an Excel spreadsheet (Microsoft, Corp.) for subsequent analysis. Data are reported as mean ± SD. Statistical analysis was performed using the Student *t* test. A *P* value less than 0.05 was considered statistically significant.

RESULTS

Forty-one eyes of 41 keratoconus patients (25 men, 16 women) were included in the study. The mean age of the patients was 31.1 ± 9 years (range 22 to 53 years). All 41 patients attended the 3-month and 6-month follow-ups. One-year follow-up results were available for 40 patients and 2-year results, for 33 patients.

There were no intraoperative complications. The mean ablation depth was 185.5 ± 30.7 µm (range 110 to 200 µm). The mean diameter of the donor lamellae was 9.0 ± 0.3 mm (range 8.5 to 9.8 mm) and the mean thickness, 362.7 µm ± 36.3 (range 320 to 420 µm).

All corneas were clear on the first postoperative day, and reepithelialization was complete within 2 weeks from surgery except in 1 patient who developed corneal melting and who had successful PKP 7 months after ELLK. The patient was excluded from the study before the 1-year follow-up examination. In all other patients, the corneal sutures were removed a mean of 3.2 ± 2.3 months postoperatively (range 2 to 5 months). All corneas remained clear throughout the study (Figure 1). No immunologic rejections were observed. There were no cases of corneal vascularization or infection. No compression suture or relaxing incisions were placed.

A mean of 16.6 ± 4.7 months after ELLK, 7 eyes of 7 patients who were not satisfied with their vision had topographically guided excimer laser PRK to correct a postoperative refractive error. These patients were excluded from the study before the 24-month follow-up examination.

Visual Acuity

Table 1 shows the preoperative and postoperative UCVA and BSCVA. Both were statistically significantly better at all postoperative visits than preoperatively.

The preoperative UCVA was 20/60 or worse, ranging from 20/600 to 20/60 (Figure 1). The postoperative was UCVA better than 20/60 in 12 (29.3%) of 41 eyes at 3 months, 18 (43.9%) of 41 eyes at 6 months, 17 (42.5%) of 40 eyes at 1 year, and 11 (33.3%) of 33 eyes at 2 years (Figure 2).

The preoperative BSCVA was or better than 20/40 in 26 patients (63.4%); the preoperative BSCVA ranged from 20/600 to 20/30. After ELLK, the number of patients with a BSCVA better than 20/40 rose to 31 (75.6%) at 3 months, 34 (82.9%) at 6 months, 37 (92.5%) at 1 year, and 29 (87.9%) at 2 years (Figure 3).

At 24 months, the BSCVA had improved by 1 line in 4 (12.1%) of 33 patients and by 2 or more lines in 21 (63.6%). It had decreased by 1 line in 3 patients (90%) and by 2 or more lines in 4 (12.1%).

Refraction

Table 1 shows the mean refractive data over time. The mean decrease in manifest refraction spherical equivalent (MRSE) from preoperatively to 3 months postoperatively was statistically significant ($P = .0004$). The decrease remained statistically significant throughout the follow-up. There were no statistically significant differences in refractive cylinder except at the 2-year examination ($P = .0141$).

In the 7 eyes that had topographically guided excimer laser PRK (Figure 4), the UCVA, BSCVA, and refraction improved after 6 months (Table 2).

Corneal Topography

The mean value of the average keratometric readings obtained from corneal topography decreased statistically significantly from preoperatively to all postoperative visits (all $P < .0001$) (Table 1). At 2 years, corneal topographic patterns were classified as

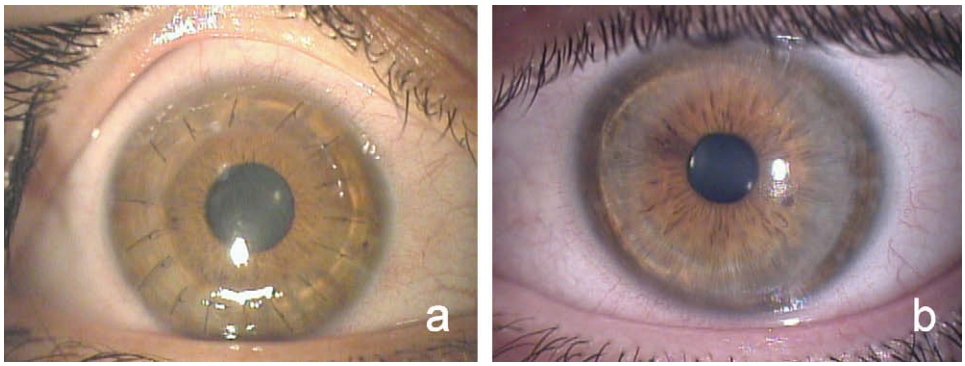

Figure 1. Biomicroscopic examination. *a*: Lamellar graft in a 25-year-old keratoconus patient 1 week after ELLK for keratoconus. Sixteen interrupted 10-0 nylon sutures are visible. *b*: A clear and well-integrated lamellar graft in a 33-year-old keratoconus patient who had ELLK 2 years previously. No suture is present.

Table 1. Preoperative and postoperative mean data of the patients who had ELLK.

Parameter	Preoperative (n = 41)	Postoperative			
		3 Mo (n = 41)	6 Mo (n = 41)	12 Mo (n = 40)	24 Mo (n = 33)
UCVA (logMAR)					
Mean ± SD	1.09 ± 0.41	0.69 ± 0.37	0.55 ± 0.36	0.59 ± 0.37	0.62 ± 0.35
P value	—	.0001*	.0001*	.0001*	.0001*
BSCVA (logMAR)					
Mean ± SD	0.31 ± 0.25	0.20 ± 0.20	0.15 ± 0.20	0.09 ± 0.11	0.11 ± 0.11
P value	—	.0164*	.0023*	.0004*	.0013*
MRSE (D)					
Mean ± SD	−2.68 ± 2.72	−0.36 ± 3.47	−0.32 ± 3.37	−0.94 ± 3.19	−1.18 ± 3.14
P value	—	.0004*	.0001*	.0009*	.0032*
Refractive cylinder (D)					
Mean ± SD	3.37 ± 1.48	3.20 ± 1.51	2.98 ± 1.78	2.66 ± 1.67	2.20 ± 0.95
P value	—	.8266	.1851	.0678	.0141*
Keratometric astigmatism (D)					
Mean ± SD	4.00 ± 1.97	4.33 ± 2.75	3.88 ± 2.69	3.37 ± 2.12	3.13 ± 1.98
P value	—	.8765	.6231	.4468	.2176
Keratometric reading (D)					
Mean ± SD	49.44 ± 3.76	45.84 ± 3.43	47.01 ± 4.85	45.44 ± 3.77	45.29 ± 4.15
P value	—	.0001*	.0001*	.0001*	.0001*
Corneal ECD (cells/mm^2)					
Mean ± SD	2111 ± 157	2072 ± 109	2088 ± 109	2090 ± 111	2094 ±110
P value	—	.1705	.4298	.4871	.5813
Corneal endothelial CoV (SD cell area/mean cell area)					
Mean ± SD	27 ± 6	30 ± 8	28 ± 7	26 ± 5	28 ± 6
P value	—	.2764	.4366	.5294	.4401
Corneal thickness (µm)					
Mean ± SD	440 ± 49	533 ± 82	559 ± 82	564 ± 83	553 ± 83
P value	—	.021*	.0002*	.0001*	.0004*

BSCVA = best spectacle-corrected visual acuity; CoV = coefficient of variation; ECD = endothelial cell density; MRSE = manifest refraction spherical equivalent; UCVA = uncorrected visual acuity
*Statistically significant versus preoperatively ($P < .05$)

regularly astigmatic in 28 (84.8%) of 33 eyes. During the follow-up period, the corneal patterns remained stable in all eyes and no substantial changes were noted (Figure 5).

Corneal Structure

The mean thinnest value of the cornea increased significantly from preoperatively to 3 months after ELLK ($P = .02$). No significant changes in corneal thickness

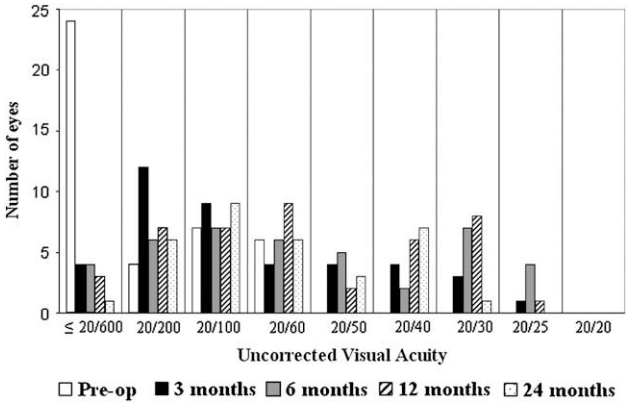

Figure 2. Distribution of UCVA during the follow-up.

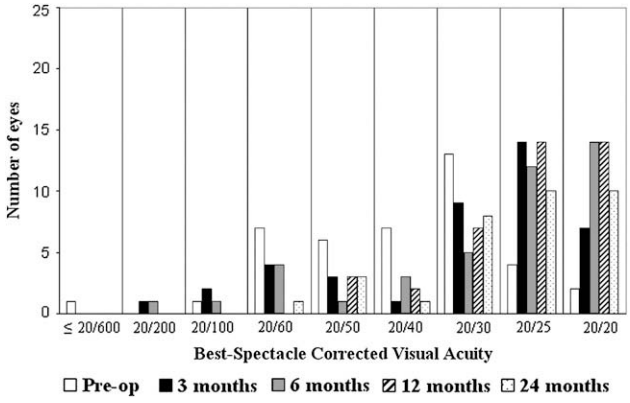

Figure 3. Distribution of BSCVA during the follow-up.

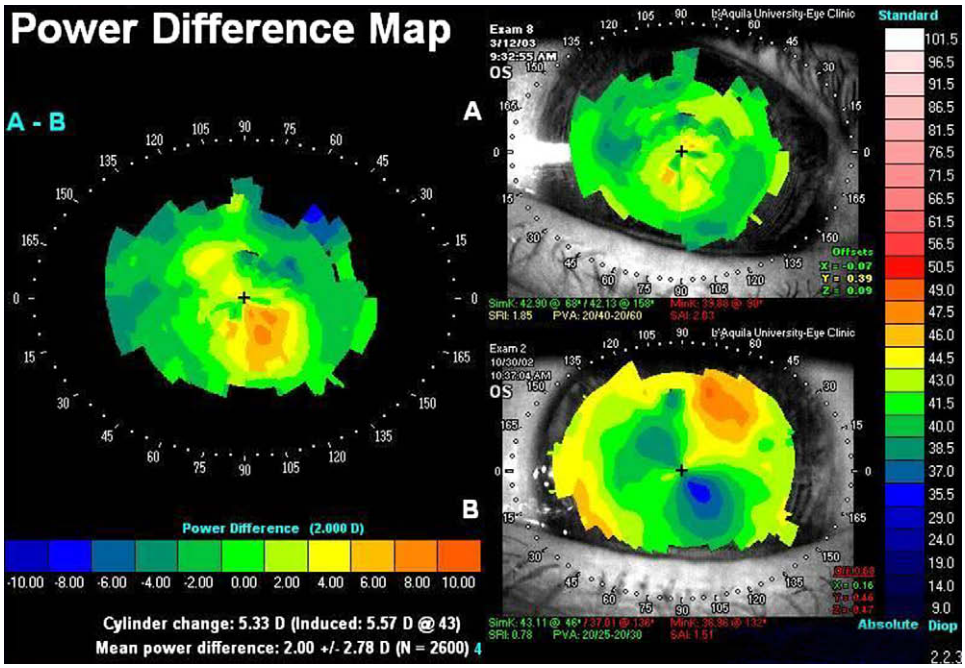

Figure 4. The differential map (*left*) shows the improved corneal profile obtained before (*bottom right*) and after (*top right*) topographically guided transepithelial PRK (TMS-3 absolute scale axial map). The map is of an eye of a 48-year-old woman; 13 months after ELLK, the refractive error was +4.50 D (BSCVA 20/20). The calculated topographically customized ablation in the optical zone was 58.0 µm. The final postoperative MRSE was +0.50 D with a BSCVA of 20/20 (MinK = minimum keratometry value; PVA = potential visual acuity; SAI = surface asymmetry index; SimK = simulated keratometry; SRI = surface regularity index).

occurred from 3 months to the end of the follow-up (Table 1). There was no statistically significant difference in ECD or CoV between preoperatively and postoperatively (Table 1).

DISCUSSION

Penetrating keratoplasty has been the most common, proved, and effective surgical technique in the treatment of keratoconus. Nevertheless, endothelial failure and immunologic graft rejection can affect the long-term outcomes. The annual loss of endothelial cells is 7.8% between the third and the fifth year after PKP.[11]

Table 2. Preoperative and 6-month postoperative data of the patients (n = 7) who had topographically guided transepithelial PRK to correct the refractive error after ELLK.

Parameter	Mean ± SD		*P* Value
	Preoperative	6 Mo Postoperative	
UCVA (logMAR)	0.81 ± 0.34	0.33 ± 0.33	.02
BSCVA (logMAR)	0.11 ± 0.08	0.09 ± 0.08	.64
MRSE (D)	5.33 ± 1	0.75 ± 1.6	<.001
Refractive cylinder (D)	2.78 ± 0.81	1.06 ± 1.21	.009
Keratometric reading (D)	40.08 ± 1.25	42.72 ± 3.14	.06
Corneal thickness (µm)	546.6 ± 17.27	493.3 ± 49.9	.02

BSCVA = best spectacle-corrected visual acuity; MRSE = manifest refraction spherical equivalent; UCVA = uncorrected visual acuity

After 10 years, only 35% of the endothelial cells of the transplanted cornea survive.[12] A variable number of keratoconus patients experience 1 or more endothelial rejection episodes over time; these cause graft decompensation in up to 9% of eyes.[13–16]

In view of this, several authors have used lamellar stromal grafts to treat keratoconus, thus avoiding the unnecessary transplantation of healthy endothelium.[3–6] All types of lamellar keratoplasties have the following additional advantages over PKP surgery: The procedure is extraocular and intraoperative complications are minimized, especially those threatening vision (ie, endophthalmitis and expulsive hemorrhage), and steroidal therapy can be discontinued postoperatively much earlier than it is usually discontinued after PKP, eliminating the risk for posterior capsule opacification and glaucoma.

The poor quality of hand-dissected surfaces in donor corneas and recipient corneas has been reported to be responsible for postoperative scar tissue formation and increased light scattering and, thus, limited vision. More recently, several authors suggest that the visual results of lamellar keratoplasty for keratoconus can be improved if hand dissection is performed very deeply in the recipient cornea.[5] Postoperative stromal scarring caused by healing between the recipient bed and donor full-thickness grafts deprived of their endothelial layer should be less and would not affect vision. According to the studies published to date, similar results can be obtained when Descemet membrane is bared and when a thin layer of deep stroma is left in place.

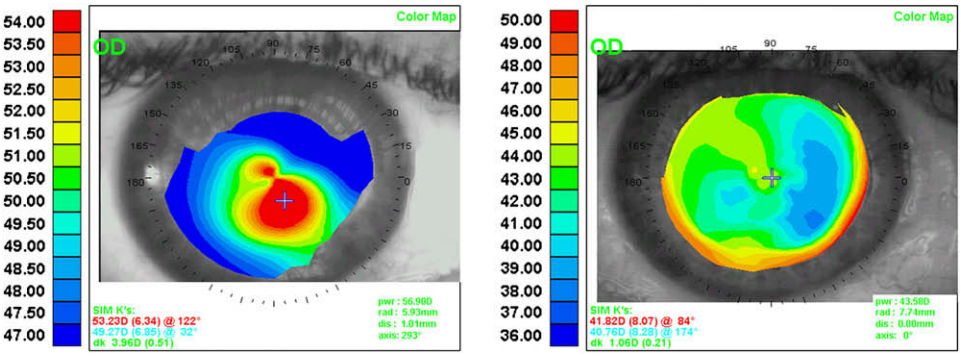

Figure 5. A comparison between the preoperative (*A*) and 2-year postoperative (*B*) topographic corneal map shows flattening of the cone and regularization of the corneal shape obtained after ELLK (EyeSys, normalized scale, axial map) (SIM K's = simulated keratometry value).

However, hand dissection is a painstaking procedure, requiring substantially longer surgical time than standard PKP. The accuracy of stromal removal is strongly dependent on the surgeon's skills; thus, the reproducibility of the procedure is low. Moreover, the learning curve is demanding, and intraoperative complications that often require conversion to PKP are frequent, even in experienced hands.[3] As a result, most keratoplasty surgeons have been unwilling to abandon a well-established technique such as PKP in favor of a time-consuming method with an unknown long-term outcome, such as lamellar keratoplasty. To simplify and standardize lamellar keratoplasty, excimer laser ablation has been used to prepare the recipient bed, with encouraging results in small series.[8,9]

In our experience, excimer laser–assisted dissection is a reproducible technique that requires a short surgical time. The diameter of recipient photoablation in our series was 7.0 mm (the maximum size allowed by the laser we used) and the contour was regular in all cases, despite the wide range of preoperative corneal curvature and degrees of surface irregularity. The overriding advantage of using an excimer laser for lamellar keratectomy is the laser's ability to remove tissue with a microscopic precision that is unattainable with other procedures. The laser does not interfere with wound-healing processes including cell migration and proliferation and production of new tissue.[17] The surgeon sets the depth of laser ablation in relation to the preoperative corneal thickness of the eye, and the laser lamellar keratectomy can be performed with no risk for a wrong cleavage. In our procedures, preoperative planning of the laser ablation with a safety margin of 200.0 µm of residual corneal bed was always the goal. No endothelial damage occurred during the 2 years of follow-up. Normal thickness (>500.0 µm) was restored in all eyes by implanting a donor lamella thicker than the tissue ablated from the recipient cornea. Donor lamellae with a mean diameter of 9.0 mm were used to allow the peripheral portion to be inserted inside the stromal pocket of the recipient cornea. This minimizes the risk for interface epithelialization and encourages peripheral scarring between the tissues.

After the photoablation, the corneal bed keeps an irregular thickness and curvature. However, the use of a 360.0 µm lamella sutured correctly within the peripheral pocket reshapes the anterior surface of the cornea, the most important part from a refractive viewpoint. The improvement in the corneal curvature (<50.0 diopters [D]) was obtained by the flattening effect of the suture placed, as described with other lamellar techniques such as epikeratophakia.[18] During this procedure, a donor lamella is sutured directly on the deepithelialized receiving cornea. Epikeratophakia does not require an incision in the central corneal stroma, is easy to perform, and is potentially reversible. However, some studies[19,20] found poorer visual results with epikeratophakia than with PKP.

In our case series, the patients had slow but steady improvement in visual acuity after surgery. Two years after surgery, the BSCVA was 20/40 or better in 87.9% of patients.

The final visual results were satisfying and similar to those achieved with PKP[21–23] and other lamellar keratoplasty techniques[9,24–30] (Table 3). Studies of deep anterior lamellar keratoplasty (DALK) with ab intrastromal injection of BSS or air to facilitate lamellar dissection found that 1 year after surgery, the BSCVA was 20/40 or better in 80% of patients[24] and 96% of patients.[25] Using the big-bubble technique to perform DALK, Fontana et al.[26] found the same BSCVA in 87% of patients 2 years after surgery. Busin et al.[27] report a BSCVA of 20/40 or better in 93.9% of patients 2 years after microkeratome-assisted lamellar keratoplasty. Buratto et al.[9] report a mean BCVA of 20/30 in 20 keratoconus patients after ELLK. Recently, Bilgihan et al.[28] obtained similar results after treating 5 keratoconus patients with ELLK. The results could have been affected by the use of old-generation lasers and the photoablation of the stromal side of the donor grafts. The slowness of the visual recovery could be due to haze of the graft–bed interface, a lower ability

Table 3. Comparison of visual outcome in studies of various lamellar keratoplasty techniques for treating keratoconus patients.

Study* (Year)	Technique	Eyes	Follow-up (Y)	BSCVA ≥20/40 (%)
Vajpayee[29] (1997)	Epikeratoplasty	10	4	80.0
Amayem[25] (2000)	DALK	24	1	95.8
Coombes[24] (2001)	DALK	25	1	80.0
Fontana[26] (2007)	DALK	30	2	87.0
Bilgihan[30] (2003)	Microkeratome LK	7	1	100.0
Busin[27] (2005)	Microkeratome LK	49	2	93.9
Buratto[9] (1998)	ELLK	20	1.5	80.0
Bilgihan[28] (2006)	ELLK	5	2	80.0
Present	ELLK	33	2	87.9

BSCVA = best spectacle-corrected visual acuity; DALK = deep anterior lamellar keratoplasty; ELLK = excimer laser–assisted lamellar keratoplasty; LK = lamellar keratoplasty
*First author

of the host keratocytes to colonize the rehydrated lamella, or small folds in the recipient bed caused by mechanical tensions of the suture on the lamella. We believe all these factors improved spontaneously and steadily over time in most of our patients. However, a loss of some BSCVA lines occurred in approximately 20% of cases. This could have been the result of individual variability in the processes of integration of the donor lamella. In the future, it would be interesting to evaluate whether the use of fresh instead of dehydrated donor lamellae could further improve the results of ELLK. The early removal of sutures in our study, within 5 months after surgery in all cases, could have affected the patients' refraction because of changes in the spherical equivalent and the refractive cylinder during the postoperative follow-up. We believe that the use of the interrupted sutures instead of a continuous suture allows better control of postoperative astigmatism.

In our series, 7 patients (17.5%) had topographically guided excimer laser PRK to correct a postoperative refractive error that the patients could not tolerate. This percentage is similar to reported results after lamellar keratoplasty[27] and PKP.[22] No case of delayed reepithelialization was noted. Anterior stromal haze was evaluated using Heitzmann criteria (from 0 to 5). After the PRK, no eye in the series of patients had a haze score greater than 1. Corneal haze peaked between 3 months and 6 months after surgery and decreased gradually afterward. No patient had a haze score greater than 1 at the last examination. The refractive results were satisfactory and stable. No vision-threatening complications occurred.

Patients with keratoconus who require surgery are often young, and ELLK does not rule out the need for PKP in the future. In our study, a patient developed corneal melting related to a delay of reepithelialization; this patient had a successful PKP with good visual results. The explanted cornea was sent for histological examination (Figure 6).

Excimer laser–assisted lamellar keratoplasty, as other types of anterior lamellar keratoplasties, has additional advantages over PKP in eye-bank procedures. One is that a quality donor endothelium is not required, which reduces the problem of tissue availability. In addition, donor corneas discarded for endothelium problems and not suitable for PKP can be used for lamellar procedures. Moreover, the corneal lamella can be dehydrated in a silicon gel and stored for a long time.

In conclusion, the results of this 2-year study indicate that ELLK could be considered to treat moderate to advanced keratoconus with in eyes with a minimum corneal thickness of 350.0 µm. In these cases, ELLK could be a valuable alternative to PKP, with similar efficacy but less invasiveness. The preservation of the

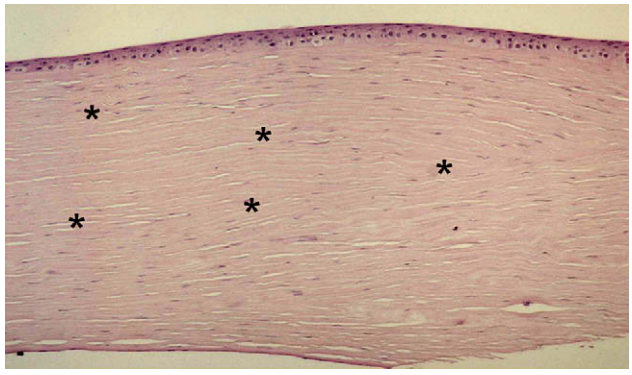

Figure 6. Section of the peripheral cornea removed from the patient who had PKP for melting of the lamella after ELLK. Note the peripheral wing of the lamella inside the corneal recipient pocket (*asterisks*) and the lack of keratocytes in the lamella versus in the recipient cornea (light microscopy; hematoxylin–eosin stain; magnification ×250).

healthy recipient endothelium determines a higher safety profile. The use of the excimer laser allowed us to standardize lamellar keratoplasty by simplifying the surgical maneuvers, to shorten surgical time, and to decrease intraoperative and postoperative complications. In keratoconus patients with specific professional or athletic demands and in those affected by Down syndrome, ELLK could be the treatment of choice. In the near future, the development of new laser devices and customized ablation algorithms could improve the results and expand treatment indications.

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