Elliptical Nonmechanical Corneal Trephination

Intraoperative Complications and Long-Term Outcome of 42 Consecutive Excimer Laser Penetrating Keratoplasties

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Purpose: To assess intraoperative complications and long-term outcome of elliptical excimer laser trephination for penetrating keratoplasties (EELPKs) performed at the Friedrich–Alexander University of Erlangen, between 1989 and 2002.

Methods: This was a retrospective, longitudinal, single-center, clinical, interventional case series. Forty-two eyes (14 Fuchs dystrophy, 11 corneal ulcer, 7 aphakic/pseudophakic bullous keratopathy, 9 corneal scars, 1 keratotorus) after EELPK were observed. Trephination was performed with a 193-nm Meditec excimer laser along metal masks with 0-8 orientation teeth/notches. Horizontal/vertical graft diameters ranged from 7.0/6.0 to 8.0/7.0 mm, and 12 to 24 interrupted sutures were used. Simultaneously, 11 eyes (26.2%) underwent cataract surgery, 3 (7.1%) underwent intraocular lens (IOL) exchange, and 1 (2.4%) underwent secondary IOL implantation. The main outcome measures included intraoperative complications, immune reactions, and final astigmatism/visual acuity at the end of follow-up.

Results: During surgery, 4 (9.5%) recipients had iris bleedings, and 10 (23.8%) ring-shaped superficial corneal thermal donor damages were detected. One (2.4%) immunologic graft rejection was seen in Fuchs dystrophy, and 3 (7.1%) in corneal ulcers occurred during follow-up (4.7 ± 3.2 years). At the end of follow-up, corrected visual acuity (0.1/0.4; $P < 0.001$) and keratometric astigmatism (2.3 D/4.7 D, $P = 0.001$) increased significantly.

Conclusions: In EELPK, intraoperative disadvantages, such as the need for interrupted sutures and a tendency toward higher and more irregular astigmatism, may be expected. This study does not have the power to statistically confirm the tendency of EELPK toward a lower rate of immunologic graft rejections after normal-risk keratoplasty. However, EELPK may have advantages in deep or perforated elliptically shaped corneal ulcers (such as in acanthamoeba keratitis).

Key Words: elliptical shape, penetrating keratoplasty (PKP), nonmechanical trephination, excimer laser penetrating keratoplasty

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During the past decades, the microsurgeon's main attention in corneal transplantation started to shift from preserving a clear graft to achieving a good refractive outcome in normal-risk keratoplasties. With improved trephination techniques (from handheld, motor trephines to guided trephine systems and nonmechanical excimer laser trephination), postkeratoplasty astigmatism could be reduced but not avoided.

However, in "high-risk" eyes, the prevention of immunologic graft rejection is still a concern. The shape of the human cornea is typically not round, but horizontally elliptical.[1] Thus, 1 way to reduce the rate of immunologic graft rejection could be an elliptical-shaped corneal graft, by which a similar distance of the graft to conjunctival limbal vessels in the whole circumference—especially in the 12 o'clock area—could be achieved.

Castroviejo and Hollwich[2] were the first in the 1930s to perform noncircular corneal trephinations by using knives with parallel blades to obtain square grafts. In an experimental study, Lang et al[3] found that, by using excimer laser trephination, an elliptical button placed in an elliptical recipient bed is more stable than a round button in a circular opening. However, they recommended that interrupted sutures be reconsidered to avoid torquation of the button–bed complex. The first 2 patients who underwent elliptical excimer laser keratoplasty in 1989 have shown favorable short-term outcome.[4] However, the long-term impact of elliptical-shaped grafting on the incidence of immune reactions and corneal astigmatism is not known.

The purpose of this study was to assess the intraoperative complications and long-term outcome of elliptical excimer laser trephination for penetrating keratoplasty (EELPK).

MATERIALS AND METHODS

Setting

This was a retrospective, longitudinal, single-center, clinical, interventional case series.

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Patient and Donor Details

The study population consisted of 42 consecutive eyes of 42 patients (21 men; 50%) that underwent elliptical excimer laser trephination at the Friedrich–Alexander University of Erlangen–Nürnberg between 1989 and 2002. Patient age was 64.3 ± 17.0 years (range, 15.5–88.4 years). The diagnoses were Fuchs dystrophy (14 eyes; 33.3%), acute corneal ulcer (11 eyes; 26.1%), aphakic/pseudophakic bullous keratopathy (7 eyes; 16.7%), corneal scars (9 eyes; 21.4%), and keratotorus (1 eye; 2.4%). Twenty-two of the operated eyes (52.4%) were left eyes. Twelve of the donor corneas (28.5%) had been preserved in organ culture. Sixteen (38.0%) corneoscleral buttons and 26 (62%) whole globes were used. Other donor parameters were as follows: donor age, 54.7 ± 20.4 years; postmortem time, 10.8 ± 13.2 hours; preservation time, 139.1 ± 250.5 hours; donor cell density, 2664 ± 330/mm^2.

The study was carried out in conformance with the tenets of the Helsinki Declaration. Institutional review board/ethics committee approval was not required for this retrospective study.

Trephination and Suturing Techniques

Nonmechanical trephination was performed by 6 experienced surgeons using the 193-nm MEL 50 (22 eyes, 52.3%) and MEL 60 (20 eyes, 47.6%) excimer lasers (Carl Zeiss-Meditec, Jena, Germany), using elliptical metal masks. All donor masks had a round central opening of 3.0-mm diameter. All recipient masks had a round outer shape of 12.9 mm (Fig. 1). The shape of the metal masks, number, direction (inward, outward), and size of orientation notches/teeth are presented in Table 1. With a repetition rate of 25/s to 30/s, at the donor site, 9885 ± 3099 pulses (range, 5296–17,300 pulses) were used (pulse energy, 18.5 ± 1.9 mJ; range, 13–22 mJ); with recipient trephination, the respective parameters were 6001 ± 2371 pulses (range, 1704–12,000 pulses) and 21.7 ± 3.8 mJ (range, 18–35 mJ). Donor trephination was performed from the epithelial side by using corneoscleral buttons fixed in an artificial anterior chamber (Polytech, Rossdorf, Germany) or using the whole globe. Graft horizontal/vertical diameters were 7.1/6.1 (3 eyes; 7.1%) 7.6/6.6 (4 eyes; 9.6%), and 8.1/7.1 mm (35 eyes; 83.3%). Graft oversize was routinely 0.1 mm. After fixation of the donor button in the recipient bed by using 4 interrupted sutures, permanent wound closure was achieved using 12 (1 eye; 2.4%), 16 (26 eyes; 61.9%), 17 (2 eyes; 4.7%), 18 (1 eye; 2.4%), 20 (2 eyes; 4.7%), 21 (1 eye; 2.4%), or 24 (8 eyes; 19.0%) interrupted sutures. The details of this trephination and suturing technique have been described in previous reports.[5–8]

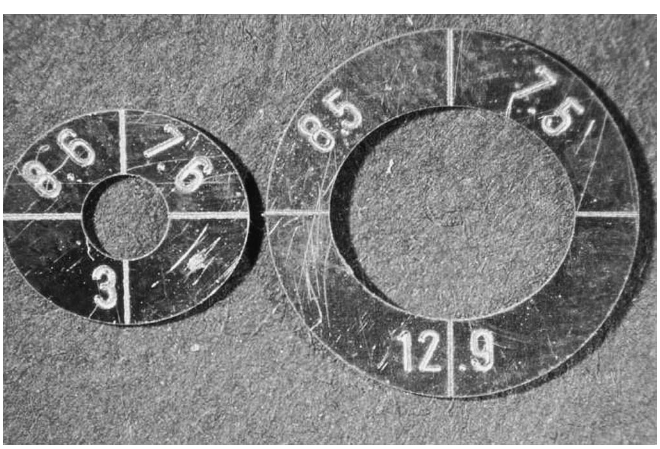

FIGURE 1. In elliptical nonmechanical excimer laser trephination, all donor masks had a round central opening of 3.0-mm diameter. The laser beam is guided along the outer elliptical edge of the mask. All recipient masks had a round outer shape of 12.9 mm. The laser beam is guided along the inner edge of the mask.

Eleven eyes (26.2%) underwent simultaneous cataract surgery, 3 (7.1%) had anterior chamber lens removal and sclera-fixated posterior chamber lens implantation, and 1 (2.4%) had secondary sclera-fixated posterior chamber lens implantation.

Main Outcome Measures

Main outcome measures included intraoperative complications, immune reactions, final astigmatism/visual acuity at the end of follow-up, and additional surgeries required.

Subjective refractometry (trial glasses in a trial frame), standard keratometry (Ophthalmometer type H 190071; Zeiss, Jena, Germany), and computer-assisted corneal topographic analysis (TMS-1 topographer; Tomey, Erlangen, Germany) were performed before surgery and at the end of follow-up (4.7 ± 3.2 years; maximum, 13.4 years) to determine net astigmatism (refractive cylinder; keratometric and topographic astigmatism), central corneal power (CCP; keratometric and topographic), spherical equivalent (SEQ); and topographic parameters provided by the TMS-1 system, such as potential visual acuity (PVA), surface regularity index (SRI), and surface asymmetry index (SAI).

Data for analysis were extracted from patients' records.

Statistical Analysis

For statistical analysis, the software package SPSS/PC version 12.0 (Windows XP) was used. Comparisons between variables were performed using nonparametric tests (Mann–Whitney *U* test for unpaired samples, Wilcoxon test for paired samples). $P < 0.05$ was considered statistically significant.

RESULTS

At the last available follow-up, results refer to the following stages of suture removal: 10 (23.8%) with all sutures in, 1 (2.4%) after partial suture removal, and 31 (73.8%) with all sutures out.

Pre- and postoperative data of patients are shown in Tables 2 and 3.

Intraoperative Complications

During surgery, 4 (9.5%) minor iris bleedings (in patients B.H. 82.2; K.E. 74.8; W.J. 53.7; W.J. 62.7 years) occurred at the time of corneal perforation. In the first 10 (23.8%) donors, ring-shaped superficial corneal thermal

TABLE 1. Diagnosis and Intraoperative Data of Patients With Elliptical Nonmechanical Penetrating Keratoplasty

Name/age (y)	Diagnosis	Date of Surgery	Simultaneous Lens surgery	Donor Mask Size; Teeth No.	Teeth Size (Base/Height in; Base/Height out) (mm)	Sutures/Mask Shape
S.K./75.6	ABK	08.06.1989	—	8.1/7.1; no	-	16/Flat
S.E/68.2	Trauma	08.06.1989	—	8.1/7.1; no	-	16/Flat
G.F./70.9	Herpetic scar	02.07.1990	—	8.1/7.1; no	-	16/Flat
B.H./82.2	ABK	02.07.1990	Sec. PCL	7.1/6.1; no	-	16/Flat
M.E./77.4	ABK	09.07.1990	—	8.1/7.1; no	-	16/Flat
S.R./49.7	Fuchs dystrophy	09.07.1990	—	8.1/7.1; no	-	17/Flat
P.H./77.0	Fuchs dystrophy	16.07.1990	Triple	8.1/7.1; no	-	16/Flat
M.G./65.0	Fuchs dystrophy	18.07.1990	Triple	8.1/7.1; no	-	17/Flat
J.A./82.6	PBK	01.08.1990	IOL exchange	7.6/6.6; no	-	16/Flat
S.M./88.4	PBK	03.08.1990	IOL exchange	7.6/6.6; no	-	16/Flat
K.M./67.3	Ulcer	03.08.1990	—	8.1/7.1; no	-	16/Flat
E.O./80.5	Nonherpetic scar	10.08.1990	—	7.6/6.6; no	-	16/Flat
N.M./62.8	Fuchs dystrophy	16.08.1990	—	8.1/7.1; no	-	16/Flat
K.A./73.2	Fuchs dystrophy	06.10.1990	Triple	8.1/7.1; no	-	16/Flat
H.X./80.4	PBK	11.10.1990	IOL exchange	8.1/7.1; no	-	18/Flat
H.A./70.4	Fuchs dystrophy	12.10.1990	Triple	8.1/7.1; no	-	21/Flat
P.I./59.2	Fuchs dystrophy	08.11.1990	—	8.1/7.1; no	-	16/Flat
V.H./72.2	Fuchs dystrophy	14.11.1990	Triple	8.1/7.1; no	-	16/Flat
K.B./69.8	Fuchs dystrophy	14.11.1990	—	8.1/7.1; no	-	16/Flat
W.M./74.1	Fuchs dystrophy	16.11.1990	—	8.1/7.1; no	-	16/Flat
D.H./69.0	Fuchs dystrophy	12.12.1990	Triple	8.1/7.1; no	-	12/Flat
B.T./61.8	PBK	12.12.1990	IOL exchange	8.1/7.1; no	-	16/Flat
K.M./69.5	Fuchs dystrophy	08.11.1991	—	8.1/7.1; 4 in	0.4/0.2; -	16/Flat
S.R./51.1	Fuchs dystrophy	26.11.1991	—	8.1/7.1; 4 in	0.4/0.2; -	16/Flat
T.S./63.4	Herpetic scar	27.11.1991	Triple	8.1/7.1; 4 in	0.4/0.2; -	24/Flat
K.E./74.8	Fuchs dystrophy	18.12.1991	Triple	8.1/7.1; 4 in	0.4/0.2; -	16/Flat
W.J./53.7	Ulcer	10.06.1994	—	8.1/7.1; 4 in	0.4/0.2; -	20/Flat
S.R./27.3	Ulcer	26.10.1994	—	8.1/7.1; 4 in	0.4/0.2; -	24/Flat
W.J./62.7	Ulcer	10.11.1994	—	8.1/7.1; 4 in	0.4/0.2; -	16/Flat
R.O./82.3	Ulcer	07.03.1995	Triple	8.1/7.1; 4 in	0.4/0.2; -	24/Flat
W.K./77.5	Ulcer	14.06.1996	—	8.1/7.1; 2 in 2 out	0.3/0.15 both	24/Curved
L.I./59.3	Ulcer	24.10.1996	—	8.1/7.1; 4 in	0.4/0.2; -	24/Flat
H.W./82.7	Ulcer	13.12.1996	Triple	8.1/7.1; 2 in 2 out	0.3/0.15 both	16/Curved
S.T./45.1	Ulcer	10.09.1997	—	8.1/7.1; 2 in 2 out	0.3/0.15 both	20/Curved
K.R./15.5	Nonherpetic scar	10.12.1997	—	8.1/7.1; 2 in 2 out	0.3/0.15 both	24/Curved
K.D./29.6	Herpetic scar	15.01.1998	—	7.1/6.1; 2 in 2 out	0.3/0.15 both	16/Curved
K.E./62.5	Herpetic scar	26.11.1998	—	8.1/7.1; 2 in 2 out	0.3/0.15;0.4/0.2	24/Curved
H.P./57.7	Keratotorus	30.03.1999	—	8.1/7.1; 2 in 2 out	0.3/0.15;0.4/0.2	16/Curved
L.B./77.7	Ulcer	22.12.1999	Triple	7.1/6.1; 2 in 2 out	0.3/0.15;0.4/0.2	16/Curved
S.R./69.6	Ulcer	14.01.2000	—	8.1/7.1; 1 in 7 out	0.3/0.15;0.4/0.2	16/Curved
S.A./28.6	Herpetic scar	21.07.2000	—	7.6/6.6; 1 in 7 out	0.3/0.15;0.4/0.2	24/Curved
M.M./32.9	Herpetic scar	11.07.2002	—	8.1/7.1; 1 in 7 out	0.3/0.15;0.4/0.2	No data/Curved

ABK, phakic bullous keratopathy; PBK, pseudophakic bullous keratopathy; Keratotorus, pellucid marginal degeneration; Sec. PCL, secondary sclera-fixated posterior chamber lens implantation; Triple, triple procedure; IOL exchange, anterior chamber lens removal and sclera-fixated posterior chamber lens implantation; Teeth no., teeth number; Teeth in/out, orientation teeth inward/outward.

damage along the inner edge of the flat metal masks was detected.

Immune Reactions

During follow-up, 2 acute diffuse (in patients with corneal ulcer 0.1 and 3.7 years after penetrating keratoplasty [PKP]) and 2 chronic focal (one 0.8 and 2.6 years after PKP of corneal ulcer, 1 in a patient with Fuchs dystrophy 8.4 years after PKP) immunologic graft reactions (9.5%) occurred. Thus, the rate of immune reactions was only 2.4% in cases of elective PKP in noninflamed eyes. Only 1 was irreversible and needed repeat keratoplasty (1/42; 2.3%) in an eye with partly

TABLE 2. Pre- and Postoperative Data of Patients With Elliptical Nonmechanical Penetrating Keratoplasty

Name/Age (y)	Type/Time of Additional Surgery After PKP (y)	BCVA Before PKP	Final Refractive Astigmatism	Final BCVA	Immune Reaction Time (y)	Follow-up (y)	Comments
S.K./75.6	—	0.1	1.5	0.5	—	7.6	
S.E/68.2	ECCE+PCL/3.3	0.2	2.5	0.9	—	7.6	
G.F./70.9	ECCE+PCL/1.5	0.25	2.0	0.6	—	6.7	
B.H./82.2	—	0.25	0.0	0.05	—	6.3	15.1.1997*
M.E./77.4	—	0.2	1.0	0.6	—	5.1	15.1.1996*
S.R./49.7	—	0.3	No data	1.0	Chronic focal 8.4	13.4	
P.H./77.0	Nd:YAG capsulotomy/1.1	0.4	3.5	0.6	—	6.7	
M.G./65.0	Nd:YAG capsulotomy/1.8	0.04	2.0	0.8	—	7.8	
J.A./82.6	—	FC	0.0	0.3	—	2.3	
S.M./88.4	—	FC	3.5	0.1	—	6.5	
K.M./67.3	—	0.02	5.5	0.3	—	2.8	
E.O./80.5	Transverse keratotomies/2.8 ECCE/3.9	0.1	3.5	0.6	—	5.1	
N.M./62.8	ECCE/1.0 Transverse keratotomies/2.5 Nd:YAG capsulotomy/6.4	0.3	5.5	0.6	—	9.9	
K.A./73.2	Transverse keratotomies/2.2	0.02	1.5	0.4	—	3.1	
H.X./80.4	—	0.05	5.5	0.6	—	3.7	30.7.1994*
H.A./70.4	Nd:YAG capsulotomy/1.3	0.3	2.0	0.9	—	6.2	
P.I./59.2	Repeat keratoplasty/1.3	0.3	6.0	0.6	—	3.4	
V.H./72.2	—	0.1	2.2	1.0	—	6.0	
K.B./69.8	—	0.4	2.0	1.0	—	5.7	
W.M./74.1	—	0.3	2.0	0.7	—	2.1	
D.H./69.0	—	0.04	3.75	1.0	—	6.1	
B.T./61.8	—	0.1	2.25	0.6	—	1.8	
K.M./69.5	ECCE/1.0 Nd:YAG capsulotomy/5.8 Cyclocryocoagulation./10.5 Cyclophotocoagulation./10.6	0.1	0.0	0.02	—	11.0	
S.R./51.1	—	0.5	No data	0.9	—	12.0	
T.S./63.4	Nd:YAG capsulotomy/2.3	0.1	9.5	0.1	—	9.9	
K.E./74.8	Nd:YAG capsulotomy/2.1	0.2	2.5	0.5	—	5.8	
W.J./53.7	ECCE/2.0	0.07	3.0	1.0	—	3.7	
S.R./27.3	—	0.1	5.5	1.0	Acute diffuse 3.7	4.6	
W.J./62.7	ECCE+PCL/1.2	LP	4.0	0.5	—	2.9	
R.O./82.3	—	LP	0.0	0.02	Acute diffuse 0.1	2.0	
W.K./77.5	—	LP	0.75	0.05	—	2.5	
L.I./59.3	ALT/0.75 Repeat keratoplasty/2.3	0.1	0.0	0.005	Chronic focal 0.8 and 2.6	2.6	
H.W./82.7	—	LP	0.0	0.02	—	0.6	15.10.1998*
S.T./45.1	Sec. PCL impl./1.8	LP	5.5	0.1	—	2.5	
K.R./15.5	—	0.1	4.5	0.3	—	1.4	
K.D./29.6	—	0.02	0.0	0.1	—	0.2	
K.E./62.5	—	LP	5.5	0.5	—	3.6	
H.P./57.7	—	No data	3.5	0.3	—	1.4	
L.B./77.7	—	0.2	No data	No data	—	0.05	
S.R./69.6	Conjunctival flap/0.2	HM	No data	No data	—	0.08	
S.A./28.6	Transverse keratotomies/3.3	0.2	No data	0.7	—	4.3	
M.M./32.9	—	No data	No data	0.6	—	1.9	

*Died during follow-up.

PKP, penetrating keratoplasty; ECCE+PCL, extracapsular cataract extraction and posterior chamber lens implantation; Nd:YAG capsulotomy, neodymium: yttrium–argon–garnet laser capsulotomy; ECCE, extracapsular cataract extraction; ALT, argon laser trabeculoplasty; Sec. PCL, secondary sclera-fixated posterior chamber lens implantation; FC, finger counting; LP, light perception; HM, hand motion; BCVA, best-corrected visual acuity.

TABLE 3. Measurements (Mean ± SD; Range, Min.-Max.) Before Keratoplasty and At the End of Follow-up (n = 42): Visual Acuity, Astigmatism (3 Measurement Methods), Spherical Equivalent, Central Corneal Power (2 Measurement Methods), and Computerized Topography Parameters (TMS-1, Tomey)

Time point	BCVA	A (r)	A (k)	A (t)	SEQ	CCP (k)	CCP (t)	SAI	SRI	PVA
Before keratoplasty	0.1 ± 0.1 (0.0001–0.5)	0.6 ± 1.3 (0.0–6.0)	2.3 ± 3.3 (0.0–12.0)	7.2 ± 4.0 (1.7–12.3)	0.4 ± 3.9 (–13.0 to 12.0)	44.3 ± 3.0 (38.2–53.3)	46.0 ± 3.8 (42.6–52.9)	2.8 ± 1.8 (0.3–5.6)	2.2 ± 1.5 (0.3–5.0)	0.4 ± 0.2 (0.2–1.0)
At the end of follow-up	0.4 ± 0.3 (0.005–1.0) **P < 0.001**	2.7 ± 2.1 (0.0–9.5) **P < 0.001**	4.7 ± 2.5 (1.0–11.5) **P = 0.001**	5.3 ± 2.3 (1.6–9.5) P = 0.2	–0.3 ± 4.0 (–10.0 to 15.0) P = 0.1	43.2 ± 2.5 (37.0–47.2) P = 0.2	45.5 ± 1.5 (42.5–48.7) P = 0.9	0.9 ± 1.1 (0.2–5.6) **P = 0.02**	1.0 ± 0.5 (0.5–3.2) **P = 0.03**	0.7 ± 0.1 (0.3–1.0) **P = 0.03**

P values refer to a comparison with the status before keratoplasty (statistically significant values shown in bold).

SEQ, spherical equivalent of the spectacle correction (diopters); BCVA, best-corrected visual acuity (Snellen lines); A(r), astigmatism as measured by subjective refraction; A(k), by keratometry; A(t), by computerized topography; CCP(k), central corneal power as measured by keratometry; CCP(t), by computerized topography; SAI, surface asymmetry index; SRI, surface regularity index.

vascularized corneal scars (caused by recurrent zoster keratitis) 1.2 years after elliptical transplantation.

Final Outcome

Outcome measures such as best-corrected visual acuity (BCVA), refractive/keratometric/topographic astigmatism, SEQ, keratometric/topographic CCP, SAI, SRI, and PVA of patients before keratoplasty and at the end of follow-up are shown in Table 3. At the end of follow-up, BCVA was significantly higher ($P < 0.001$) and refractive and keratometric astigmatism increased ($P < 0.001$ and $P = 0.001$, respectively) compared with preoperative values. SEQ and keratometric and topographic CCP did not change significantly compared with preoperative values ($P = 0.2$, 0.1, and 0.2, respectively). However, SAI and SRI significantly decreased ($P = 0.02$ and 0.03, respectively) and PVA increased ($P = 0.03$). Nevertheless, at the end of follow-up, 7 (16.6%) eyes still had irregular astigmatism that could not be measured with keratometry. Six of these 7 patients had all sutures in, and only 1 had all sutures removed.

Sequential Surgeries

Eight eyes (19.0%) needed subsequent cataract surgery after 2.2 ± 1.2 years, 7 (16.6%) needed neodymium:yttrium–argon–garnet laser capsulotomy after 3.0 ± 2.2 years, 4 (9.5%) needed transverse keratotomies after 2.7 ± 0.4 years, 2 (4.7%) needed repeat keratoplasties after 1.3 and 2.3 years, 1 (2.4%) needed cyclophotocoagulation and cyclocryocoagulation after 1.5 years each, 1 (2.4%) needed laser trabeculoplasty after 0.75 years, and 1 (2.4%) needed a conjunctival flap 0.2 years after PKP.

The 4 eyes that underwent transverse keratotomies had a diagnosis of Fuchs dystrophy (2 eyes) and herpetic and nonherpetic scars. Mean refractive astigmatism decreased from 6.0 ± 3.5 (range, 2.5–9.5 D) to 3.5 ± 2.0 D (range, 1.5–5.5 D) after limbus-parallel keratotomies and compression sutures in 4 eyes (data not shown).

DISCUSSION

Lieberman[9] performed an elliptical recipient opening in 1 human patient in 1974, and a round donor button was obtained from punching from the endothelial side. This planned procedure induced ~24.0 D of corneal astigmatism. Pallikaris[10] described oval grafts in 1980. In an animal study, Villariz et al[11] found that, with increasing ovality of the recipient bed, a corresponding increase in the postoperative astigmatism at 3 months after suture removal can be detected. The theory of "other than round" corneal transplantation has been previously discussed in several reports[9–12]; however, we did not find any case series studying the outcome of elliptical grafts in elliptical beds.

The first 22 elliptical grafts were the first nonmechanical excimer laser keratoplasties ever performed. Therefore, since the first excimer laser trephination, many details of the technique had to be improved. In excimer laser trephination, an increase in the repetition rate and a decrease in the rotation speed was shown to result in greater temperature rise of the exposed cornea.[13] Also, in our first 10 patients with higher (30 Hz) repetition rate and pulse energy, thermal damage of the superficial donor cornea (so-called thermal ring) could be detected. In addition, in a few cases (3) with lower repetition rate (25 Hz), minimal iris bleeding was detected during corneal penetration. This finding might be attributed to the shock waves induced by the laser pulses.

Although the elliptical window wherein the long axis of the ellipse is horizontal may afford dimensional stability superior to that of round trephination, "horizontal torsion" of the graft could be reduced even more by introduction of "orientation teeth" at the donor trephination margin and corresponding notches in the recipient bed.[8,14] Therefore, the shape of the metal masks was also varied over the years.

Besides well-established optical advantages, round nonmechanical trephination using the excimer laser seems to have neither immunologic drawbacks nor advantages in contrast to conventional mechanical trephination.[15] In patients with Fuchs dystrophy and keratoconus, the incidence of immunologic endothelial graft reaction was 6.8% after excimer laser trephination, in contrast to 7.7% after motor trephination during follow-up of 3.3 ± 1.2 years.[15] For immunologic purposes, the size of the graft should be "as small as necessary," but because smaller grafts are supposed to deteriorate optical performance, they should also be "as large as possible."[1,16–20] Elliptical transplantation may follow these rules by reducing the amount of transplanted tissue, because the human cornea has a horizontally elliptical shape with a decreased vertical width of the clear area by typically wider superior limbus vascularization. By having similar distance of the graft to conjunctival limbal vessels in the whole circumference, an elliptical graft may also reduce the immunologic reaction rate. If the incidence of immunologic graft reaction in elliptical and round nonmechanical trephination was the same, 3 immune reactions (6.8%) were to be expected in this study.[15] With elliptical-shaped trephination in patients with Fuchs dystrophy and keratotorus, only 1 immunologic reaction (2.4%) occurred during a mean follow-up of 6.7 ± 3.7 years (eye with Fuchs dystrophy after 8.4 years). In contrast, 3 patients with corneal ulcers (7.1%) developed acute diffuse or chronic focal immunologic graft reaction. There was only 1 patient with corneal ulcer caused by zoster keratitis who developed irreversible immunologic graft rejection 10 months after transplantation, needing subsequent repeat keratoplasty. Such irreversible reactions caused by recurrent neurotrophic varicella-zoster virus keratopathy have been reported previously in the literature.[21] It was our clinical impression that the incidence of immunologic graft reaction was reduced in elliptical transplantation taking into account the patients' corneal size for choosing the actual mask size. In ~17% of cases, smaller than the "standard" size of 7.0 × 8.0 mm was chosen because of a smaller host cornea.[1] Nevertheless, this study does not have the power to statistically confirm the tendency of EELPK toward a lower rate of immunologic graft rejections after normal-risk keratoplasty.

With round nonmechanical excimer laser keratoplasty mean, "all sutures out" BCVA increased from 0.2 to 0.7 in patients with Fuchs dystrophy and keratoconus.[6] In this study, BCVA increased from 0.1 to 0.4. However, this patient group was much older (64.3 vs. 50.6 years), and besides patients with the diagnosis of Fuchs dystrophy and keratoconus, patients with scars, ulcers, keratitis, and bullous keratopathy were included. These conditions are generally accepted to have a worse prognosis concerning visual outcome. Nevertheless, the high degree of irregular astigmatism may also add to the poorer visual acuity at the end of follow-up after EELPK.

Concerning astigmatism, nonmechanical corneal trephination with the excimer laser has been found to yield superior results (reduced postoperative astigmatism) compared with mechanical trephination.[6] The main advantage of the excimer laser trephination technique performed from the epithelial side in donor and recipient is the avoidance of mechanical distortion induced by radial and tangential forces during trephination, resulting in smooth, almost perpendicular cut edges that are congruent in donor and patient, thus avoiding "vertical tilt" and horizontal torsion.[8] However, in EELPK, the results concerning astigmatism were less favorable. The mean values of the final refractive/keratometric/topographic astigmatism were 2.7 D/4.7 D/5.3 D in elliptical trephination, in contrast to 2.8 D/3.0 D/3.8 D in round nonmechanical trephination of patients with Fuchs dystrophy and keratoconus.[6] Such interstudy comparisons are notoriously inaccurate, especially in cases of small numbers of eyes and high numbers of surgeons involved. Nevertheless, our prospective randomized study[6] may serve as a solid baseline for the quality of outcome that can be achieved with excimer laser trephination.

The above results could be reached only after refractive keratotomies and compression sutures in 4 (9.5%) patients. The proportion of refractive keratotomies was by far higher than that reported after the first 1000 round nonmechanical trephinations (2.2%).[7] In this study, limbus-parallel keratotomies and compression sutures, as described in a previous report,[22] could significantly reduce the disturbing postkeratoplasty astigmatism from 6.0 ± 3.5 to 3.5 ± 2.0 D.

With all sutures in 38.0% of eyes, whereas with all sutures out only 2.4% of eyes had highly irregular astigmatism that could not be measured by keratometry. The interrupted sutures are well known to result in higher "suture in" irregular astigmatism than the double-running suturing technique.[23] Our study was in accordance with the results of Lin et al,[24] who reported that surface asymmetries may decrease even after removal of one running 10/0 nylon suture.[25]

We conclude that EELPK intraoperative disadvantages, such as the need for interrupted sutures and a tendency toward higher and more irregular astigmatism, may be expected. This study does not have the power to statistically confirm the tendency of EELPK toward a lower rate of immunologic graft rejections after normal-risk keratoplasty. However, EELPK may have advantages in deep or perforated elliptically shaped corneal ulcers (such as in acanthamoeba keratitis).[25]

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