ARTICLES

Two-year follow-up of conductive keratoplasty for the treatment of hyperopic astigmatism

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PURPOSE: To evaluate the safety, efficacy, predictability, and stability of conductive keratoplasty (CK) for the treatment of hyperopic astigmatism.

SETTING: University of Crete Medical School, Vardinoyannion Eye Institute of Crete, Heraklion, Greece.

METHODS: In this prospective nonrandomized noncontrolled single-center study, 47 eyes of 34 patients (15 women and 19 men) were treated for hyperopic astigmatism (up to + 3.50 diopters [D]) with a Refractec ViewPoint CK system and followed for 24 months ± 0.6 (SD). The treatment consisted of 4 to 36 spots applied to the periphery of the cornea. Mean age was 48.5 years ± 9.7 years, range 25 to 68 years. All the treated eyes were analyzed for safety, efficacy, predictability, and stability.

RESULTS: The mean patient age was 48.5 ± 9.7 years (range 25 to 68 years). Preoperatively, the mean manifest refraction spherical equivalent (MRSE) was +2.11 ± 0.88 D (range −0.50 to + 4.13 D); at 12 months, it was −0.52 ± 0.73 D and at 24 months, −0.50 ± 0.77 D. At 24 months, the mean MRSE was within ±0.50 D in 61% of eyes, within ±1.00 D in 83%, and within ±2.00 D in all eyes. At 24 months, the uncorrected visual acuity was 20/20 or better in 37% of eyes and 20/40 or better in 97%. By the end of the follow-up period, no eye had lost ≥2 Snellen lines or had an induced cylinder ≥1.50 D.

CONCLUSIONS: Conductive keratoplasty for low hyperopic astigmatism was a safe, effective, and stable procedure. Nomogram adjustments and careful patient selection should contribute to higher levels of predictability when treating hyperopic astigmatism.

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Excimer laser correction is the procedure of choice for the surgical treatment of hyperopia and hyperopic astigmatism.[1–15] Laser in situ keratomileusis (LASIK) procedures are effective, relatively painless, and provide fast visual recovery.[1–11] However, many patients are not good candidates for a hyperopic laser procedure and might opt for a thermokeratoplasty treatment.[16–28] The considerations are either anatomical, such as small corneal diameter, excessively steep or flat cornea,[8] deep eye orbit, dry-eye syndrome, or epithelial basement membrane dystrophy, or psychological, such as fear of a corneal cut or the idea of corneal tissue removal.

Conductive keratoplasty (CK), a less-invasive procedure for the treatment of hyperopia and astigmatism,[19–26] does not involve flap creation and therefore flap-related complications, is nonlaser, produces a larger functional optical zone than LASIK,[24] significantly improves near vision,[25] and operates outside the central clear zone of the cornea.

With CK, high-frequency (radio frequency 350 kHz), low-energy current is delivered within the stroma of the peripheral cornea with a keratoplasty tip inserted in the cornea.[26] The technique uses electrical properties of the

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corneal tissue. The tissue temperature increase is induced by electric impedance in the flow of energy through collagen fibrils, causing collagen shrinkage when the temperature reaches 65°C.[26]

The treatment probe is inserted in the cornea in a spot-by-spot manner, each time completing circles of 8 spots beginning at 6 mm optical zone and expanding, if demanded by the nomogram, to the 7 mm and 8 mm zones for the treatment of a spherical component and is followed by 4 to 6 additional spots on the flat meridian of astigmatism for astigmatic corrections.

The ability to add asymmetrical single spots based on topography or the wavefront map of the cornea enables a surgeon to perform a series of customized treatments in cases of previously decentrated ablation, corneal trauma, or even keratoconus.[21] This report presents 2-year results of CK for the correction of hyperopic astigmatism.

PATIENTS AND METHODS

In this prospective nonrandomized noncontrolled single-center clinical study, 47 eyes of 34 patients (15 women and 19 men) were treated for hyperopic astigmatism with CK. The treatment was performed with a ViewPoint CK system (Refractec Inc.). The intended refraction was plano in all cases. A detailed informed consent was obtained from the entire patient group before surgery. The Institutional Review Board (IRB) approval was assessed for the study.

Protocol

No patient enrolled in the study had an existing or chronic ocular or systemic disease; a history of ocular surgery or trauma; steroid-responsive increase in intraocular pressure; or unstable, progressive hyperopia. Soft contact lens users (there were no hard contact lens wearers in this study) were advised to discontinue lens use 21 to 30 days before the preoperative evaluation and the procedure. The patients had to have a clear cornea image in slitlamp microscope examination as well as undistorted mires in the central keratometry examination. Patients with ultrasound (US) pachymetry readings of <550 μm at the 6 mm zone and eyes with distance uncorrected visual acuity of 20/32 or better were excluded from the study.

The examination protocol for all patients at each examination included manifest refraction (fogging technique), cycloplegic refraction, uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA), computerized corneal topography, slitlamp microscopy, dilated fundus examination, central and peripheral (6 mm optical zone) US pachymetry, and measurement of intraocular pressure (Goldman applanation tonometry). Follow-up examinations were scheduled at 1 and 24 hours and 1, 3, 6, 9, 12, and 24 months.

Measurements of manifest and cycloplegic refraction at a distance were performed using a Snellen chart. Cycloplegic refraction was measured after at least 2 applications of cyclopentolate 1% drops 10 minutes apart, 30 minutes after the first application. Computerized corneal topography was performed with a C-Scan corneal topography unit with ray tracing (Technomed GmbH). Corneal thickness (central and peripheral) was measured with US pachymetry (DGH 5100 Technology Inc).

Attempted correction was based on cycloplegic refraction. In all eyes, the number of spots for the spherical hyperopic component was selected in accordance with a standard Refractec nomogram for spherical hyperopia treatment. The standard normal-pressure CK technique was used in all the treated eyes. The correction of the spherical component was followed by the application of additional 4 to 6 spots at 7 mm to 9 mm optical zones on the flat meridian of astigmatism (the minus cylinder axis). The astigmatic spots were applied in groups of 2 or 3, "straddling" the flat meridian of the astigmatism (Figure 1). The patients received 4 to 36 spots of treatment at the circles of 6 mm to 9 mm zones. Thirty-six–spot treatments were applied in 2 cases only to treat high refractive errors. The suggested nomogram (Figure 1) offers treatment with the maximum of 30 spots to treat hyperopia up to $+2.25$ D with astigmatism up to $+1.75$ D.

Surgical Procedure

Both unilateral and bilateral treatments were performed. All procedures were carried out in the same center by the same surgeon (I.G.P.) with a ViewPoint CK System. All procedures were performed under topical anesthesia. A drop of propocaine 0.5% was administered in the operative eye 15 minutes prior to the procedure followed by the second application immediately before the surgery. Eyes were prepared with povidone–iodine, and lids were retracted with a ViewPoint CK speculum.

Careful attention was paid to marking with a CK ViewPoint marker the 6 mm, 7 mm, and 8 mm optical zones centered on the cornea. The surface was irrigated with balanced salt solution and then dried with a fiber-free sponge. According to the marking, the spots were applied to the cornea starting with a circle at the 6 mm optical zone and followed, when necessary, by circles of spots at the 7 mm, 8 mm, and 9 mm zones as advised by the nomogram. The treatment spots were applied to the cornea with the Keratoplast tip (Refractec, Inc) placed perpendicular to the corneal surface. All eyes were treated with the standardized setting of 350 kHz, 60% power for 0.6 seconds per spot. As soon as the procedure was completed, drops of tobramycin 0.3% as well as a drop of flubiprofen sodium 0.03% were administered.

All patients were examined with a slitlamp microscope 1 hour after surgery.

Postoperative Treatment

After surgery, the patients received treatment consisting of tobramycin 4 times a day for 2 weeks combined with flubiprofen sodium 0.03% 4 times a day for the first 2 days. Patients were encouraged to use a drop of artificial tears 5 to 6 times a day for the first 2 weeks.

Statistical Analysis

All refractive data were analyzed by the method of dioptric power matrix suggested by Kaye and Harris[29] to perform quantitative analysis of refractive data. Preoperative and postoperative data as S/CxA for 1, 3, 6, 12, and 24 months were first converted into Long's dioptric power matrix as follows:

$$\mathbf{F} = \begin{pmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{pmatrix}$$

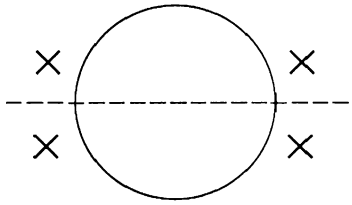
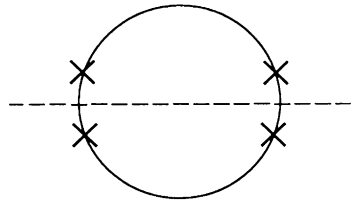
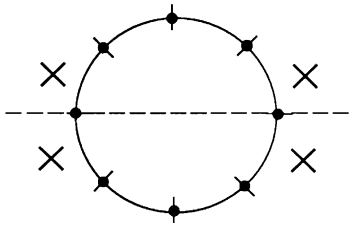
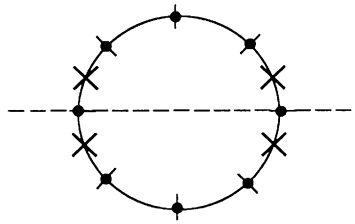
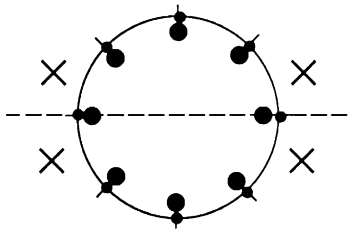
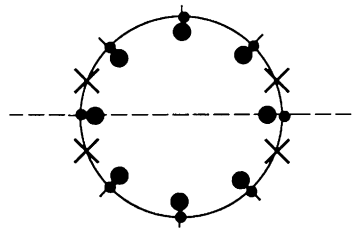
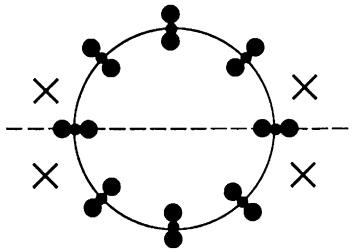
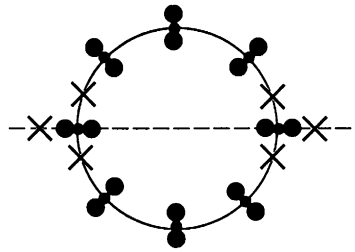
Sphere (Plus Cylinder Manifest Refraction)	+0.50 to +1.00 Cyl	+1.12 to +1.75 Cyl
Plano to +0.63 DS	4 spots @ 8mm straddling the flat meridian 	4 spots @ 7mm straddling the flat meridian 
0.75 to +0.87 DS (8 spots)	8 spot spherical tx 4 spots @ 8mm straddling the flat meridian 	8 spot spherical tx 4 spots @ 7mm straddling the flat meridian 
+1.00 to +1.63 DS (16 spots)	16 spot spherical tx 4 spots @ 8mm straddling the flat meridian 	16 spot spherical tx 4 spots @ 7mm straddling the flat meridian 
+1.75 to +2.25 DS (24 spots)	24 spot spherical tx 4 spots @ 8mm straddling the flat meridian 	24 spot spherical tx 4 spots @ 7mm straddling the flat meridian 2 spots @ 9mm on the flat meridian 

Figure 1. Nomogram for the treatment of hyperopic astigmatism with CK.

The 4 numbers (entries or components) in the matrix were calculated using Long's equations:

$$f_{11} = S + C \sin^2 A$$

$$f_{12} = f_{21} = -C \sin A \cos A$$

$$f_{22} = S + C \cos^2 A$$

Matrixes were added, and a mean value was calculated for each of the 4 parameters. From the deconvolution of the data, mean values for sphere, cylinder, and axis were extracted. Predictability results were extracted the same way by subtracting the preoperative and postoperative matrixes and establishing values of refractive surgical effect at each postoperative period (Table 1).

Based on the same study[29] and using MATLAB for determining matrix analysis results, multivariate analysis was performed to evaluate the differences between preoperative and postoperative data. The difference was significant at a level of $\alpha = 5\%$ if $W > F_{0.05,3,N-3}$ where $F_{0.05,3,N-3}$ represents the familiar F distribution with 3 and N−3 degrees of freedom. The astigmatic error was analyzed as proposed by Holladay et al.[30] as well as mean cylinder refraction and double-angle plot diagram.

RESULTS

Mean age of the patients was 48.5 years ± 9.7 (SD) (range 25 to 68 years). Treated eyes had +1.00 to +4.50 diopters (D) of hyperopia and −0.50 to −3.50 D of cylinder (cycloplegic refraction), an off-label use of ViewPoint CK system. No sight-threatening complications were observed during the course of the surgeries. The mean follow-up was 24 ± 0.6 months.

Slitlamp Microscopy

Stromal edema surrounding each spot of treatment was evident with slitlamp microscopy 24 hours after surgery. Corneal opacities at each treatment spot were observable in slitlamp microscopy during the entire follow-up period. Folds in Descemet's membrane were detectable with a slitlamp microscopy in all eyes. Fluorescein staining found a small epithelial defect corresponding to the treatment spot. The epithelial defect was healed during the first 48 to 72 hours in all treated eyes.

Table 1. Achieved refractive surgical effect at different postoperative intervals.

	RSE		
Postop Interval (mo)	Sph	Cyl	Axis
3	−2.21	0.42	159
6	−1.97	0.43	166
12	−1.78	0.37	171
24	−1.83	0.39	165

RSE = refractive surgical effect; Sph = sphere; Cyl = cylinder

Uncorrected Visual Acuity

Values of UCVA before and after surgery are shown in Figure 2. Preoperatively, mean UCVA was 0.59 (20/32) ± 0.66 (range 0.008 to 0.9) (20/2500 to 20/25). At 12 months, mean UCVA was 20/20 or better in 11 of 42 eyes (29%) and 20/40 or better in 39 of 42 eyes (93%). At 24 months, 16 of 41 eyes (37%) had a UCVA of 20/20 or better; 26 eyes of 41 (63%) had a UCVA of 20/25 or better. Uncorrected visual acuity was 20/40 or better in 40 of 41 eyes (97%). Mean UCVA at this period was 0.9 (20/25) ± 0.86 (range 0.2 to 1.2) (20/100 to 20/16).

There was a statistically significant difference in UCVA measurements before and 24 months after surgery (t stat = 6.8, df = 40 $P < .001$). After surgery, the differences between the postoperative 3-, 6-, 9-, 12- and 24-month groups were not significant.

Best Spectacle-Corrected Visual Acuity

Before surgery, mean BSCVA was 0.98 (20/20) ± 0.93 (range 0.6 to 1.2) (20/32 to 20/16). There was no significant difference in the BSCVA values between the preoperative and postoperative measurements (t stat = 2.1, F = 0.096, df = 40 166, $P < .041$). By the end of the follow-up period, no eye had lost ≥2 Snellen lines or had surgically induced cylinder ≥1.50 D; BSCVA was better than 20/40 in all the treated eyes.

The distribution of BSCVA line change is shown in Figure 3. A total of 7.1% of the eyes gained 1 Snellen line; loss of 1 line was observed in 16.7% of eyes at 12 months. At 24 months, 7.3% of the eyes gained 1 Snellen line; loss of 1 line was observed in 24%. Sixty-eight percent of the treated eyes had no change in BSCVA at 24 months.

Predictability

Before surgery, mean manifest refraction spherical equivalent (MRSE) was +2.11 ± 0.88 D (range −0.50 to +4.13 D). At 12 months, mean MRSE was −0.52 ± 0.73 D; at 24 months, it was −0.50 ± 0.77 D. At the latest follow-up examination (24 months after surgery), it was within ±0.50 of plano in 25 of 41 eyes (61%), within ±1.00 D in 34 of 41 eyes (83%), and within ±2.00 D in 100% of the eyes (Figure 4). Figure 5 features a predictability scattergram comparing attempted refraction with achieved refraction 24 months after the CK treatment.

There was a significant difference in MRSE between the preoperative and postoperative groups (t stat = 16.1, df = 40, $P < .001$). At 24 months, 7 of 41 eyes (17%) were undercorrected ≥1.00 D of hyperopia and 1 of 41 eyes (2.0%) was overcorrected ≥1.00 D in terms of MRSE. During this period, 18 of 41 eyes (44%) were within ±0.50 D of astigmatism, 31 of 41 eyes (76%) were within ±1.00 D,

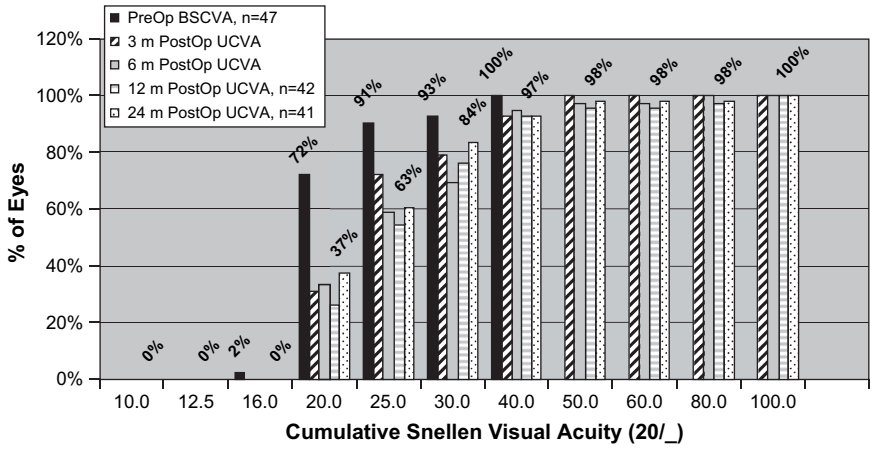


Figure 2. Cumulative UCVA (n = number of eyes).

and 40 of 41 eyes (97.5%) were within ±2.00 D of refractive astigmatism with regard to their preoperative and residual refractive astigmatism. Achieved refractive surgical effect at different postoperative intervals is shown in Table 1. Double-angle plot diagram featuring preoperative versus postoperative astigmatism at 24 months is shown in Figure 6. Postoperative defocus equivalent refraction is shown in Figure 7.

Stability

All eyes were evaluated for stability (mean diopter change in MRSE over time). The stability results for MRSE are shown in Figure 8. The stability results for cylinder are shown in Figure 9. Mean MRSE changed −0.05 D between 3 and 6 months, −0.16 D between 6 and 12 months, and 0.02 D between 12 and 24 months postoperatively. Changes in MRSE between the follow-up examinations are shown in Figure 8. There was a significant difference between the spherical equivalent at all postoperative intervals compared with those preoperatively, whereas there were no significant differences in the spherical values for spherical equivalent between 12 and 24 months. Stability was achieved 6 months after surgery.

Complications and Adverse Events

No sight-threatening complications were observed intraoperatively or postoperatively. In the course of the first 48 hours, moderate discomfort and foreign-body sensation was reported in 11 of 41 eyes (26.8%). These symptoms resolved in all eyes in the course of the first 72 hours. Light sensitivity in the first 48 hours was reported in 15 of 41 eyes (39%). In 2 of 41 eyes (4.9%), the patients complained of starbursts up to 3 and 6 months postoperatively, respectively. The described symptoms resolved without additional treatment in both cases. No retreatments were performed.

DISCUSSION

Efficacy

Significant increase in UCVA was achieved early in the follow-up period. By the end of the follow-up period, mean

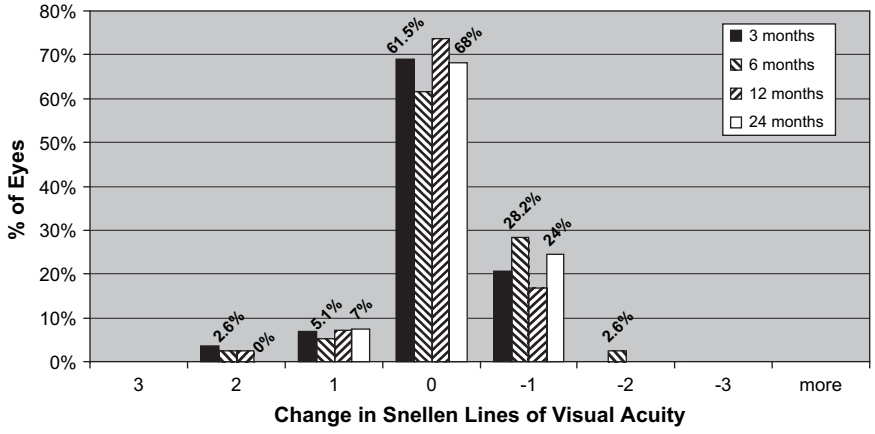


Figure 3. Change in BSCVA compared with the preoperative values. VA = visual acuity.

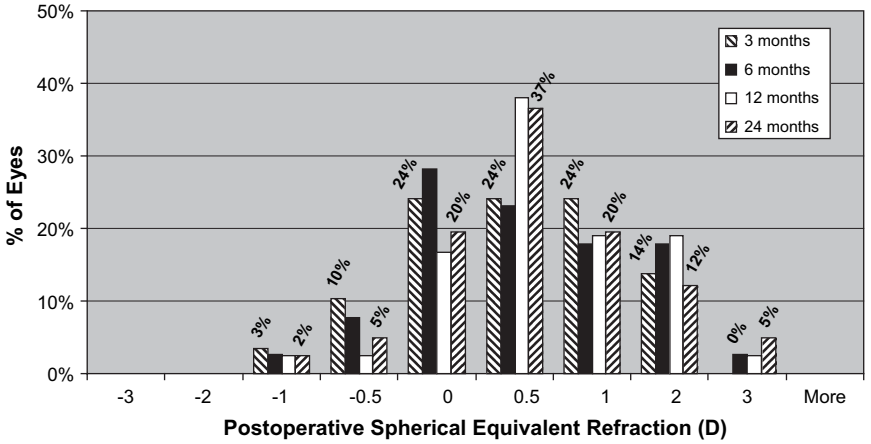


Figure 4. Refractive error after CK procedure.

UCVA of the group was 0.9 (20/25) ± 0.86. At 12 months, the UCVA was 20/20 or better in 29% and 20/40 or better in 93%. At 24 months, it was 20/20 or better in 16 of 41 eyes (37%) and 20/40 or better in 40 of 41 eyes (97%).

Compared with photorefractive keratectomy (PRK) astigmatic corrections, the observed results are similar or better than in reviewed studies[8,12–15]: El-Agha et al.[8] report an efficacy of 20/20 or better in 57.9% of the cases at 9 months in a PRK-treated group with a preoperative mean cylinder of +1.31 D; Vinciguerra et al.[12] mention a mean UCVA of 0.37 (20/50 to 20/63) at 12 months; in 2 consecutive PRK studies, Nagy et al.[13,14] report a UCVA of 20/20 or better in 46% and 77.2% of the eyes in matching to our toric groups.

The efficacy described in this study of 20/20 or better (37%) is better than that reported in several LASIK studies: Arbelaez and Knorz[1] report a mean UCVA of 20/20 or better in 13% in the low toric group and 7% in the moderate toric group; Pineda-Fernandez et al.[4] report a mean UCVA of 20/20 in 0% in both low and moderate toric groups, 20/40 or better in 66.6%, and 44.4% in the low and moderate toric groups, respectively. Other LASIK studies comment on higher levels of achieved UCVA: Lian et al.[5] report a UCVA of 20/20 or better in 63.6% and 20/40 or better in 92.6% of the cases at 12 months; Salz and Stevens[7] report 20/20 or better in 53% and 20/40 or better in 93.8%; Barraquer and Guitierrez[2] and Lindstrom et al.[3] report a UCVA 20/40 or better in 71% and 79% of the treated eyes, respectively, at 6 months.

The comparison with laser thermal keratoplasty (LTK) corrections of hyperopic astigmatism is difficult because of the lack of data on LTK astigmatic corrections. When compared with the study by Eggink et al.,[16] CK showed higher efficacy. Eggink et al. report low effectiveness and broad spectrum of efficacy in a small study of 9 eyes with a mean follow-up of 11 months.

The reported efficacy levels of astigmatic CK in this study are much lower than the efficacy levels of spherical hyperopic CK treatments: Lin and Manche[23] report a UCVA of 20/20 or better in 64% and UCVA of 20/40 or better in 95%.

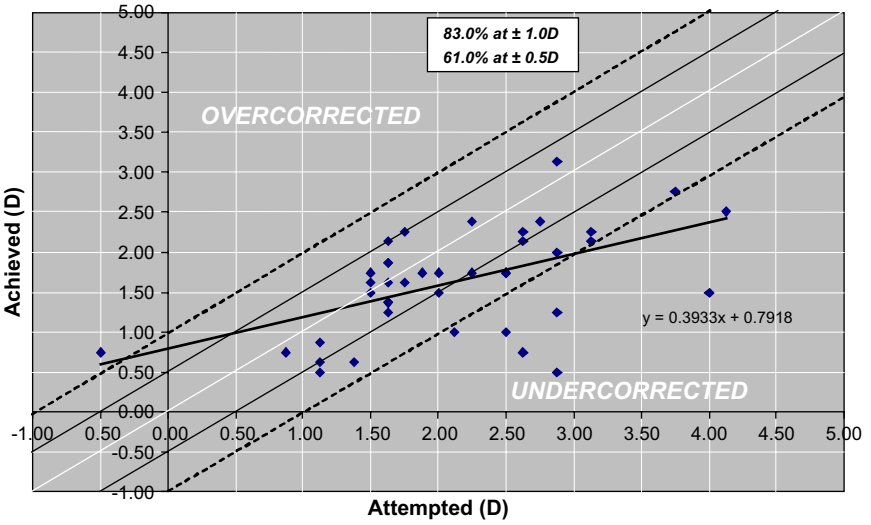


Figure 5. Predictability scattergram: Attempted versus achieved correction 24 months postoperatively (n = number of eyes).

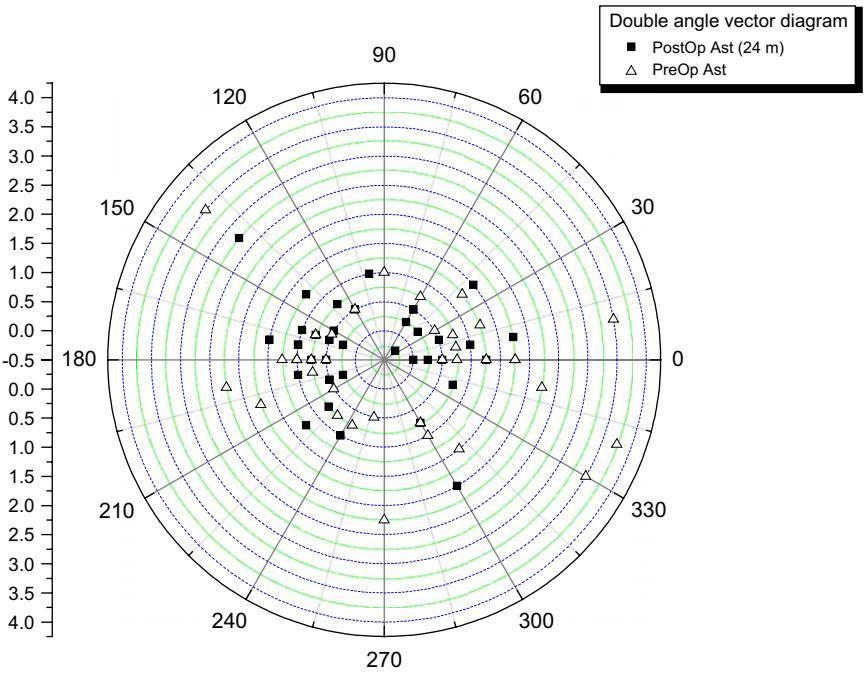


Figure 6. Double-angle plot diagram. (m = months, postop ast = postoperative astigmatism, preop ast = preoperative astigmatism).

A CK study by McDonald et al.[20] report higher efficacy levels of 20/20 or better in 57% at 1 year. In our previous reports[22,31] on 1-year and 2.5-year results of the procedure, a UCVA of 20/20 or better was reported in 50% and 52.5%, respectively.

Predictability

Twelve months after the treatment, MRSE was −0.52 ± 0.73 D. At 24 months, the mean MRSE was −0.50 ± 0.77 D and was within ±0.50 D of plano in 25 of 41 eyes (61%), within ±1.00 D in 34 of 41 eyes (83%), and within ±2.00 D in 100% of the eyes. Overcorrection occurred in only 2% of eyes, whereas undercorrection occurred in 17%.

Predictability of CK in this study exceeds the results achieved with most PRK corrections[12–14]: Vinciguerra et al.[12] report 31% of the eyes within ±1.00 D of intended refraction with the mean sphere decreased by 2.08 D and mean cylinder by 1.40 D at 12 months; Nagy et al.[13] report the mean preoperative spherical equivalent of +4.57 D with a mean cylinder of +1.57 D decreased to +1.13 D with +0.38 D of cylinder; 52% were within ±0.50 D of the intended refraction, and 82% were within ±1.00 D. A later toric PRK study by Nagy et al.[14] report 68.1% within ±1.00 D of plano.

Concerning predictability of the refractive outcome, results were similar overall to those obtained with LASIK for hyperopic astigmatism.[1–11] In this comparison group, Arbelaez and Knorz[1] report predictable results

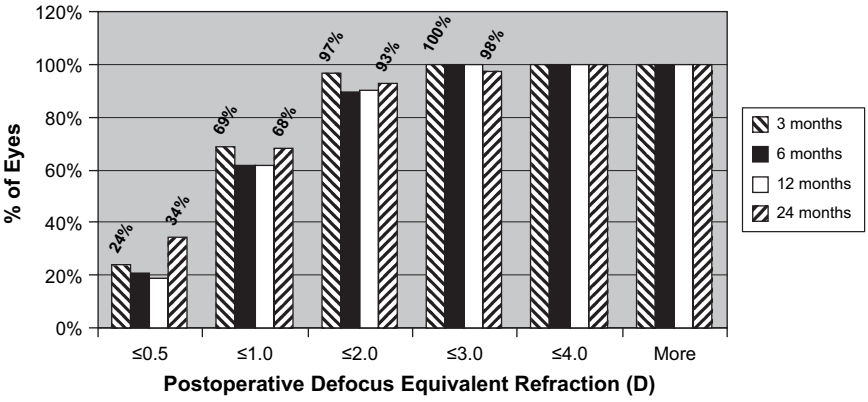


Figure 7. Postoperative defocus equivalent refraction.

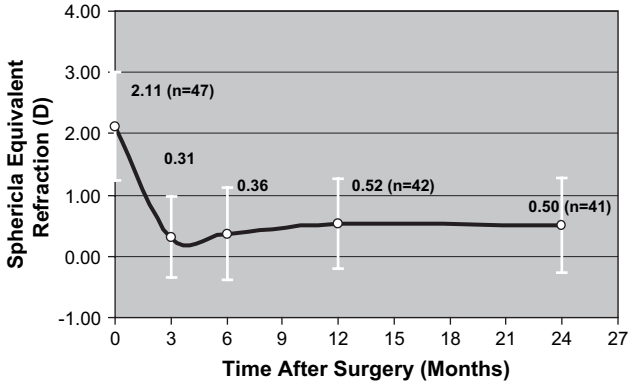


Figure 8. Mean MRSE during the follow-up period (n = number of eyes).

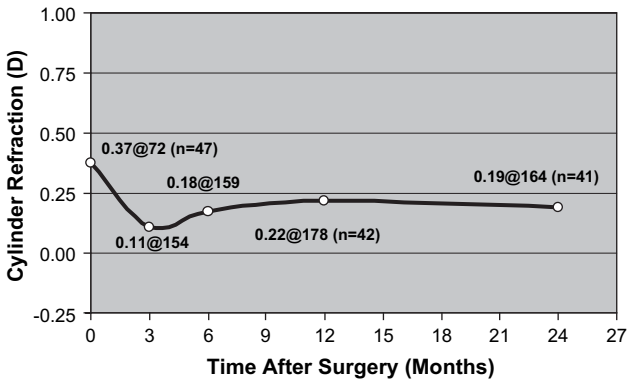


Figure 9. Mean cylinder refraction during the follow-up period (n = number of eyes).

in low and moderate toric groups: 61% in the low toric within ±0.50 D of intended refraction and 36% in the moderate toric group. In the low toric group, no eye had overcorrection by more than 1.00 D; in the moderate toric group, 7% were overcorrected by more than 1.00 D and 36% were undercorrected by more than 1.00 D.[1] Reviglio et al.,[10] Pineda-Fernandez et al.,[4] and Barraquer and Guitierrez[2] comment on similar results of spherical equivalent refraction within ±0.50 D (62%, 53%, and 60%, respectively).

In the astigmatic LTK study by Eggink et al.,[16] 3 of the 9 treated eyes achieved a change in cylindrical component or spherical equivalent refraction of 1.00 D or more at 11 months.

Studies of CK treatments of spherical hyperopia show higher predictability in the MRSE when compared with the authors' data on astigmatic CK corrections: Lin and Manche[23] report 64% of eyes within ±0.50 D of plano and 91% within ±.00 D at 24 months. Mendez and Mendez Noble[19] report 50% of treated eyes within ±0.50 D and 90% within ±1.00 D of plano at 1 year, whereas McDonald et al.[25] comment on the mean MRSE within ±0.50 D in 46%, within ±1.00 D in 93%, and within ±2.00 D in 100%. In our study with a 2.5-year follow-up,[31] 68% of the eyes were within ±0.50 D of plano.

Stability

Stability was evaluated as a mean diopter change in the MRSE during the follow-up period. No statistically significant difference was observed between the mean values over the follow-up period. The mean MRSE changed −0.05 D between 3 and 6 months postoperatively, −0.16 D between 6 and 12 months, and 0.02 D between 12 and 24 months. The change in MRSE between the postoperative visits did not exceed 0.50 D in any treated eye. The spherical equivalent refraction stabilized 6 months after surgery.

Compared with PRK corrections,[12–14,32] CK showed more stable results in the current study and in previously published CK studies.[21–23,25,31] Pietilä et al.[32] conclude that although most eyes were relatively stable at 3 months, regression was a constant finding with PRK for hyperopia.

Conductive keratoplasty achieved stability values similar to those of hyperopic LASIK[1–11]: Salz and Stevens[7] report change in MRSE ≤1.00 D in 100% of eyes from 1 to 3 months, in 97% from 6 to 9 months, and in 100% from 9 to 12 months. Ditzen et al.[6] observed that undercorrection and regression progressed until the third postoperative month and then stabilized. Many toric LASIK studies, however, have a limited follow-up of 6 or 9 months,[2–4,8,10] which makes the comparison difficult.

Conductive keratoplasty stability results are much higher than those achieved with LTK treatments.[16,33,34] Eggink et al.[33] report regression and low predictability of the effect. Instability of refraction persisted up to 1 year after treatment. Reports of regression were supported by the authors' next study.[16] Attia et al.[34] report LASIK for recurrent hyperopia after LTK performed in 50 eyes; regression was 100% in 15 eyes, 75% in 22 eyes, and 50% in 7 eyes.

With hot-needle thermal keratoplasty used to correct hyperopic astigmatism, Charpentier et al.[28] report intense regression early in the postoperative period and slower regression between 6 and 12 months, with a mean final correction of 64% of preoperative astigmatism.

With regard to sectoral thermal coagulation, Fedorov et al.[27] commented on the stability of the effect by 1 year but further regression (+0.50 D) in 10% of the treated cases.

A 2-year CK study by Lin and Manche[23] reports a low and decreasing regression rate of +0.024 D per month between 12 and 24 months. In our earlier study,[31] the

regression between 12 and 30 months was a mean total of +0.04 D. In a study by McDonald et al.,[20] the achieved levels of stability are similar to ours, but stability is achieved later in the follow-up period (by 6 months after surgery).

Safety

We did not observe sight-threatening complications in the course of the study. Complaints after surgery included discomfort and foreign-body sensation during the first 2 days, accompanied by light sensitivity in 39% of the treated patients.

By the end of the follow-up, no eye had lost ≥2 Snellen lines and all eyes had a BSCVA of 20/40 or better. Twenty-four months after surgery, 7.3% had an increase of 1 line of BSCVA and 24% experienced a loss of 1 line.

Compared with CK studies, in PRK studies, Nagy et al.[14] and Vinciguerra et al.[12] report a much higher percentage of ≥2 lines loss of BSCVA (9.1% and 7%, respectively).

In a study of a LASIK group by Arbelaez and Knorz,[1] 14% of the patients lost more than 2 lines of BSCVA. However, LASIK reports by El-Agha et al.,[8] Lindstrom et al.,[3] Pineda-Fernandez et al.,[4] and Lian et al.[5] comment on very low or no loss of BSCVA lines. Attia et al.[34] report significant line loss of 16% at 6 months after surgery performing LASIK treatments after previous LTK, which could explain these low safety results.

The reasons for BSCVA loss in the course of LASIK were microstriae and flap folds[10]; epithelial defects and diffuse lamellar keratitis[3,7]; small optical zones[11]; decentrations[1]; halos, double or ghost images[5–7]; epithelial ingrowth[4,6,7]; haze[3]; and irregular astigmatism.[3,6] Other complications included incomplete flap[11] and free cap[1,4] in LASIK cases and regression,[12] induced cylinder,[12,13] and corneal haze[8,12,13] with PRK.

Laser thermal keratoplasty studies[16–18,33] comment primarily on induced cylinder and rarely report loss of ≥2 Snellen lines.

In a 2-year CK study by Lin and Manche,[23] 12% had an induced cylinder of greater than +1.00 D; in no eye was it greater than +1.75 D. These results are similar to those we report: none of our patients had ≥1.50 D of induced cylinder. In a CK study conducted by McDonald et al.,[20] no patient experienced an increase of ≥2.00 D of cylinder, similar to that found in our study.

We find that the observed results in this study of the efficacy, stability, and safety of CK are satisfying. The predictability values could be improved by adjusting the nomogram through expanding the treatment zone to 9 mm, as described in Figure 1, to treat cylinder up to +1.75 D. It is also important to understand the limitations of this thermokeratoplasty procedure to treat cylinder greater than +1.75 D, which is the reason for the observed undercorrections. Careful patient selection in terms of age (should always be older than 40) and the attempted correction not higher than +1.75 D of cylinder is the key to success when treating hyperopic astigmatism with CK.

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