

Evaluation of intrastromal corneal ring segments for treatment of post-LASIK ectasia patients with a mechanical implantation technique

Zeki Tunc, Firat Helvacioğlu, Sadik Sencan

Aim: To evaluate the clinical outcomes of Keraring segment implantation in patients with post-laser-assisted *in situ* keratomileusis (LASIK) ectasia, using a mechanical implantation technique. **Materials and Methods:** Twelve eyes of 10 patients with post-LASIK ectasia were enrolled. Intracorneal ring segments (ICRS) were implanted after dissection of the tunnel using Tunc's specially designed dissector under suction. A complete ophthalmic examination was performed, including uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), spherical equivalent, keratometric (K) readings, inferosuperior asymmetry index (ISAI), and ultrasound pachymetry. All 3, 6, and 12-month follow-ups were completed, and statistical analysis was performed. **Results:** The mean preoperative UDVA for all eyes was 1.28 ± 0.59 logMAR. At 12 months, the mean UDVA was 0.36 ± 0.19 logarithm of the Minimum Angle of Resolution (logMAR) ($P=0.002$), and the mean preoperative CDVA was 0.58 ± 0.3 logMAR, which improved to 0.15 ± 0.12 ($P=0.002$) at 1 year. There was a significant reduction in cylindrical refractive and spherical equivalent refractive error from -5.29 ± 2.47 diopters (D) and -5.54 ± 5.04 D preoperatively to -1.47 ± 0.71 D and -0.74 ± 1.07 D ($P=0.001$, $P=0.002$), respectively, at 1 year. In the same period, the mean K-readings improved from 47.93 ± 4.84 D to 40.87 ± 2.36 D ($P=0.002$), and the mean ISAI improved from 5.34 ± 3.05 to 2.37 ± 1.68 ($P=0.003$). No significant changes in mean central corneal thickness were observed postoperatively. There were no major complications during or after surgery. **Conclusion:** ICRS implantation using a unique mechanical dissection technique is a safe and effective treatment for post-LASIK ectasia. All parameters showed improvement at 1-year follow-up.

Key words: Intrastromal corneal ring segments; keraring; post-LASIK ectasia

Corneal ectasia after laser-assisted *in situ* keratomileusis (LASIK) surgery is a rare but devastating complication that was first described by Seiler *et al.*,^[1] in 1998. Keratectasia is defined as a progressive steepening of the corneal curvature, with or without associated central and paracentral corneal thinning. Clinically, it presents as the initial appearance of low myopia that progresses over time to high myopia and irregular astigmatism, resulting in loss of uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA).^[2] Two major risk factors are thought to be responsible for this complication: operating on corneas with preexisting disposition to corneal ectasia, and removing too much corneal tissue.^[3] After LASIK, the cornea is structurally weakened not only by the laser central stromal ablation (depending on the attempted correction), but also by the creation of the flap itself.^[4] Despite the availability of this information, ectasia remains unpredictable.^[5]

This ectatic disorder has an estimated incidence that ranges from 0.04% to 0.6%.^[6] Treatment options for postoperative LASIK keratectasia include rigid contact lenses and lamellar or penetrating keratoplasty. Recently, intrastromal corneal ring segments (ICRS) and corneal collagen cross-linking have

added a new dimension to the management of keratectasia. Furthermore, long-term data on ICRS procedures indicate the possibility of deferring or even replacing keratoplasty in keratectasia patients.^[7]

Corneal tunnelization for ring segment insertion can be performed by mechanical dissection or by femtosecond laser technology. For mechanical dissection, there is already a 6 and 7 mm semiautomated dissector that operates under suction (Intacs, Addition Technology). However, in this study, 5 mm optical zone rings (Keraring) were implanted after dissection of the tunnel by using a semiautomated dissector operating under suction [Fig. 1], which was designed by Dr. Tunc, in patients with post-LASIK ectasia.

Materials and Methods

This prospective, non-comparative study was approved by the Ethics Board Committee and followed the tenets of the Declaration of Helsinki. All patients agreed to participate in the study and to return for the postoperative examinations. Written consent was obtained from every patient after the purpose and procedures of the study had been fully explained. Inclusion criteria were clear central corneas and no visual dysfunctions other than post-LASIK ectasia. A corneal thickness of 400 μ m at the site of segment implantation was considered the minimum acceptable for the study. Exclusion criteria were additional severe ocular pathologies (e.g., glaucoma, cataract, diabetic retinopathy, and age-related macular degeneration). All operations were performed by the same surgeon (ZT) at the Department of Ophthalmology, Maltepe University School of Medicine, Istanbul, Turkey

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During each surgery session, only one eye of each patient was implanted with the Keraring; if patients needed ring segment implantations for both eyes, each eye was implanted during a different session. A complete ophthalmic examination was performed preoperatively and postoperatively, including UDVA, CDVA, spherical equivalent (SE), keratometric (K) readings, the inferosuperior asymmetry index (ISAI), and ultrasound pachymetry. ISAI was calculated as the difference between the dioptric powers at 3 mm, of the corneal geometric center using EyeSys Vision, Inc V 4.5. Posterior ectasia and corneal thickness were measured using the Orbscan II Slit Scanning Corneal Topography/Pachymetry System (version 3.10.27, Orbtex Inc.) and the DGH-500 ultrasound pachymeter (DGH, Paghette 2). ICRS placement was analyzed by Fourier-domain optical coherence tomography (OCT) (Optovue RTVue with Cornea/Anterior Module (CAM)). Visual acuity was measured using Snellen notation and then converted to logMAR for statistical analysis.

The diagnosis of corneal ectasia was based on the following criteria: (1) various degrees of progressive significant myopic

regression after LASIK; (2) loss of one or more Snellen lines of CDVA after LASIK; (3) ISAI more than 1.2; (4) a maximum posterior surface elevation from the best-fit sphere of 0.071 mm; (5) a maximum anterior surface elevation from the best-fit sphere of 0.042 mm; and (6) progressive corneal thinning or pachymetry less than 400 μ .^[7,8] At least 4 of the above mentioned criteria were required to be present for the diagnosis of ectasia.

Twelve eyes of 10 patients with post-LASIK ectasia underwent 5 mm intrastromal corneal ring (Keraring, Mediphacos, Belo Horizonte, Brazil) implantation [Figs. 2A and 2B]. The mean age of patients was 25.90 ± 7.89 years, and there were 6 female and 4 male patients. The mean time to operation after LASIK was 5.6 ± 1.64 years. Preoperatively, the location of the iatrogenic cone was central in 5 eyes (41.6%), inferior in 2 eyes (16.8%), and inferotemporal in 5 eyes (41.6%). The follow-up period for all patients was at least 12 months. Corneal tunnels were made manually by using a special dissector under suction that was designed by Dr. Tunc. The



Figure 1: Intraocular dissector for a 5.0 mm diameter implantation zone with suction ring

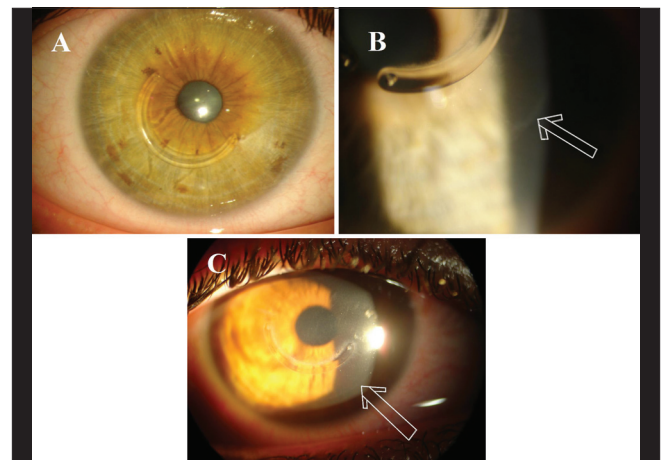


Figure 2: (A) A slit lamp photograph of a post-LASIK eye with ectasia after implantation of a new 210° Keraring segment. (B,C) Adequate distance between the Keraring segment and the post-LASIK flap border.

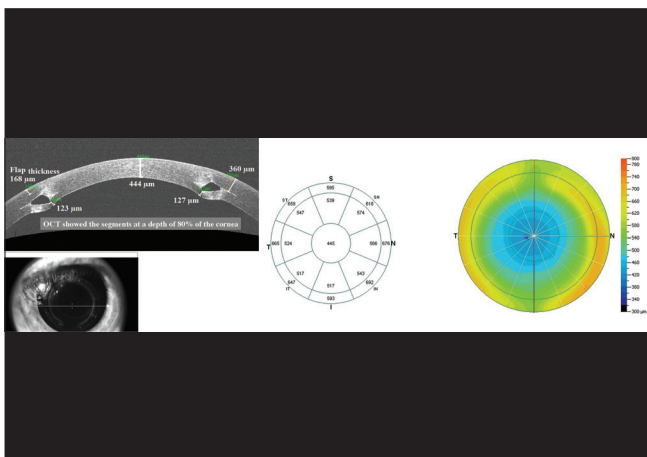


Figure 3: (A) Fourier-domain optical coherence tomography (OCT) showing the precise cross-sectional visualization and ICRS (OCT) at the adequate depth of the cornea and (B) the pachymetry map

		Nomogram			
		0% / 100%	25% / 75%	33% / 66%	50% / 50%
Eq. Esf					
	Over -10 D	25/30	25/30	30/30	30/30
	-8 a -10 D	15/30	20/30	25/30	30/30
	-6 a -8 D	0/25	15/25	20/25	25/25
	-2 a -6 D	0/20	0/20	15/20	20/20
Until -2 D	0/15	0/15	15/15	15/15	

Figure 4: Keraring segment implantation nomogram, which describes the implantation of one or two segments according to the localization of the ectasia in the corneal topography map

technique used to place the Keraring segments in these post-LASIK corneas was identical to that used in the unoperated eyes. Because the typical flap diameter is 8.5 to 9.0 mm, and Keraring inserts had an inner diameter of 4.7 mm and an outer diameter of 5.4 mm, the inserts were positioned away from the flap border [Figs. 2B and 2C].

All surgical procedures were performed under topical anesthesia. Proparacaine hydrochloride 0.5% (Alcaine, Alcon) drops were used for topical anesthesia. The operation microscope (Carl Zeiss Meditec, Jena, Germany) was used to mark the Purkinje reflection as the central point of intrastromal corneal ring implantation. After marking the center, intraoperative ultrasonic pachymetry was performed at the site of the future incision. The diamond blade was set at 80% of the measured corneal thickness and was used to create a single radial incision of 1.2 mm at the steepest meridian [Figs. 3A and 3B]. The mean depth of implantation was 407.58 ± 23.28 μm (range 375 μm to 442 μm). A surgical pocket for each eye was created using a micro-dissector and Suarez spreader. The intrastromal dissection was created to the full depth of the incision, and the pocket was extended along its full length. All eyes were fixed using a suction ring that was placed around the limbus and was guided by the previously marked geometric center of the cornea. The tunnels were created by using left and right Dr. Tunc's special dissectors. As a result, two 180-degree or one 240-degree semicircular dissections into the stroma with an approximate diameter of 5 mm were achieved. After the suction device, which was the same device used in Intacs segment implantation, was removed, the 1 or 2 Keraring segments were inserted into each of the semicircular channels using Albertazzi forceps [Table 1]. The 5-mm diameter Keraring with appropriate arc length and thickness was implanted in each eye according to

the manufacturer's nomogram [Fig. 4]. The decision to perform asymmetrical implantation was made according to the corneal topography.^[9] The radial incision was closed with 1 embedded 10-0 nylon suture. All operations were uneventful. The corneal suture was removed 1 week after surgery to minimize the potential for induced astigmatism, and to minimize the risk of keratitis. Postoperative medications included a topical tobramycin 0.3% (Tobrex, Alcon), fluorometholone 5% (Flarex, Alcon), and hydroxypropyl methylcellulose 0.003% (Tears Naturale Free, Alcon) 4 times a day for 2 weeks.

Statistical Method

Statistical calculations were performed with the Number Cruncher Statistical System (NCSS) 2007 program for Windows. In addition to the standard descriptive statistical calculations [mean, standard deviation, and median interquartile range (IQR)], Friedman's repeated-measures test was used to determine the differences in measurement at each time point, and Dunn's multiple comparisons post-hoc tests were used for pair wise comparisons. The statistical significance level was established at $P < 0.05$.

Results

Twelve eyes of 10 patients underwent Keraring implantation. There were no intraoperative complications, such as anterior chamber perforation; postoperatively, all eyes showed excellent corneal tolerance with intrastromal segments. Some of the eyes showed subconjunctival hemorrhage due to the suction ring of the dissector, which dissolved spontaneously and completely after 1 week.

The mean UDVA increased significantly from 1.28 ± 0.59 logMAR preoperatively to 0.37 ± 0.2 logMAR ($n=12$) ($P=0.002$) 3 months after implantation, and at 12 months the mean UDVA was 0.36 ± 0.19 logMAR ($n=12$) ($P=0.002$) [Fig. 5A]. The mean preoperative CDVA was 0.58 ± 0.3 logMAR. The mean CDVA improved to 0.16 ± 0.14 logMAR ($n=12$) ($P=0.002$) at three months after implantation. One year postoperatively, the mean CDVA was 0.15 ± 0.12 logMAR ($n=12$) ($P=0.002$) [Fig. 5B]. There was a significant reduction in cylindrical refractive and spherical equivalent refractive error from -5.29 ± 2.47 diopters (D) and -5.54 ± 5.04 D preoperatively to -1.47 ± 0.71 D and -0.74 ± 1.07 D ($P=0.001$, $P=0.002$) respectively at 1 year [Table 2]. In the same period, the mean K readings improved from 47.93 ± 4.84 D to 40.87 ± 2.36 D ($P=0.002$) [Figs. 6A and 6B] and the mean ISAI from 5.34 ± 3.05 to 2.37 ± 1.68 ($P=0.003$). No significant changes in preoperative mean central corneal thickness (439 ± 52 μm) were observed 1 year postoperatively (440 ± 50 μm). Table 3 shows the means, standard deviation and median interquartile range (IQR) of all data. Significant improvements were observed postoperatively for UDVA and CDVA, and corneal ectasia, keratometry, SE, and ISAI were significantly reduced. Moreover, according to Dunn's multiple comparisons tests, 3, 6, 12-month postoperative UDVA, CDVA, keratometry, and SE values showed significantly improved results from the preoperative values. Additionally, 3, 6, and 12-month results showed that there was no significant difference in refraction stability [Table 4].

The patients were subdivided into two groups: Those with one (group 1, $n=5$) and two (group 2, $n=7$) segment implantations. The outcomes were further analyzed for these groups. The preoperative central pachymeter and incision

Table 1: Data of implanted rings and preoperative corneal status

Case (eye)	Central pachymetry	Incision depth	Cone position	Ring	Ring number
1 (OD)	447	442	Central	200 μm /200 μm 160°	Double
1 (OS)	340	420	Central	300 μm /300 μm 160°	Double
2 (OD)	485	440	Temp inf	300 μm 210°	Single
2 (OS)	471	404	Temp inf	250 μm 210°	Single
3 (OS)	437	430	Central	300 μm /300 μm 160°	Double
4 (OS)	478	420	Inferior	150 μm 160°	Single
5 (OD)	422	380	Central	300 μm /300 μm 160°	Double
6 (OS)	389	375	Central	250 μm 210°	Single
7 (OS)	485	405	Inferior	200 μm 210°	Single
8 (OD)	356	380	Temp inf	300 μm /300 μm 160°	Double
9 (OS)	490	390	Temp inf	150 μm /250 μm 160°	Double
10 (OS)	466	405	Temp inf	150 μm /200 μm 160°	Double

Where, OD = Right Eye, OS = left eye

Table 2: Preoperative and postoperative 3, 6, and 12-month follow-up data

Case (eye)	Preoperative												3 months postoperative						6 months postoperative						12 months postoperative									
	UDVA	CDVA	RS	RC	SE (D)	SE (D)	AvK (D)	UDVA log-MAR	CDVA log-MAR	RS	RC	SE (D)	SE (D)	AvK (D)	UDVA log-MAR	CDVA log-MAR	RS	RC	SE (D)	SE (D)	AvK (D)	UDVA log-MAR	CDVA log-MAR	RS	RC	SE (D)	SE (D)	AvK (D)	UDVA log-MAR	CDVA log-MAR	RS	RC	SE (D)	SE (D)
1 (OD)	0.60	0.40	-1.50	-3.50	-3.25	43.74	0.30	0.10	+0.0	-1.25	-0.62	38.61	0.30	0.10	-0.25	-1.25	-0.87	38.57	0.30	0.10	0	-1.0	-0.50	38.57	(OD)									
1 (OS)	2.00	1.00	-10.00	-4.50	-12.25	56.61	0.50	0.40	-0.25	-3.0	-1.50	36.98	0.50	0.40	-0.5	-3.0	-0.20	36.97	0.50	0.40	-0.25	-3.00	-1.75	36.97	(OS)									
2 (OD)	0.80	0.30	-0.75	-3.75	-2.62	43.98	0.10	0.00	0.00	-0.5	-0.25	39.96	0.10	0.00	0	-0.5	-0.25	40.49	0.10	0.00	0	-0.50	-0.25	40.29	(OD)									
2 (OS)	0.80	0.30	-1.25	-1.50	-2.00	43.60	0.18	0.10	0.00	-0.75	-0.37	39.35	0.18	0.10	0	-0.75	-0.37	39.29	0.18	0.10	0	-0.75	-0.37	39.35	(OS)									
3 (OS)	2.00	1.00	-8.50	-2.75	-9.87	49.13	0.40	0.20	-1.5	-1.00	-2.00	42.31	0.40	0.18	-1.5	-0.75	-1.62	41.82	0.40	0.18	-1.5	-0.75	-1.62	42.41	(OS)									
4 (OS)	1.00	0.30	+3.00	-3.50	+1.25	45.97	0.40	0.10	+2.25	-1.5	+1.75	42.43	0.40	0.10	+2.25	-1.5	+1.75	42.67	0.40	0.10	+2.25	-1.00	+1.50	42.95	(OS)									
5 (OD)	2.00	0.70	-8.50	-8.50	-7.50	49.98	0.60	0.30	-1.0	-1.5	-1.75	37.46	0.60	0.30	-1.0	-1.5	-1.50	38.02	0.60	0.30	-0.75	-1.5	-1.50	38.00	(OD)									
6 (OS)	1.60	0.70	-1.25	-6.00	-4.25	46.71	0.60	0.10	-0.75	-2	-1.75	42.36	0.60	0.10	-0.75	-2	-1.75	42.36	0.60	0.10	-0.75	-2	-1.75	40.67	(OS)									
7 (OS)	1.00	0.70	-0.75	-5.00	-3.25	47.24	0.30	0.10	+0.75	-1.0	+0.25	44.22	0.30	0.10	+1.0	-1.50	+0.25	44.47	0.30	0.10	+1.0	-1.50	+0.25	44.22	(OS)									
8 (OD)	2.00	1.00	-12.0	-9.0	-16.50	58.04	0.70	0.40	-1.50	-1.75	-2.37	44.74	0.70	0.40	-1.50	-1.50	-2.20	44.53	0.60	0.30	-1.25	-2.00	-2.25	44.29	(OD)									
9 (OS)	0.70	0.20	+0.75	-7.25	-2.87	44.78	0.10	0.00	+0.5	-1.75	-0.37	41.56	0.10	0.00	+0.5	-1.5	-0.25	41.49	0.10	0.00	+0.75	-2.00	-0.25	41.32	(OS)									
10 (OS)	0.80	0.40	+0.75	-8.25	-3.37	45.34	0.20	0.10	+0.5	-2.0	-0.50	41.38	0.20	0.10	+0.5	-1.75	-0.37	41.23	0.20	0.10	+0.5	-1.75	-0.37	41.35	(OS)									

Where, OD = Right Eye, OS = left eye, UDVA = uncorrected distance visual acuity, CDVA = corrected distance visual acuity, RS = refraction spherical, RC = refraction cylinder, SE = spherical equivalent, AvK = average keratometric readings, D = diopter.

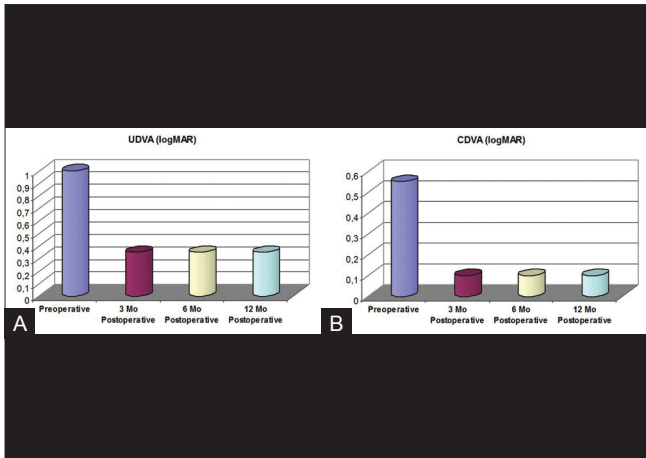


Figure 5: Graphs showing the comparison of (A) uncorrected distance visual acuity (UDVA) and (B) corrected distance visual acuity (CDVA) values between the preoperative test and the 3, 6, and 12-month postoperative follow-ups

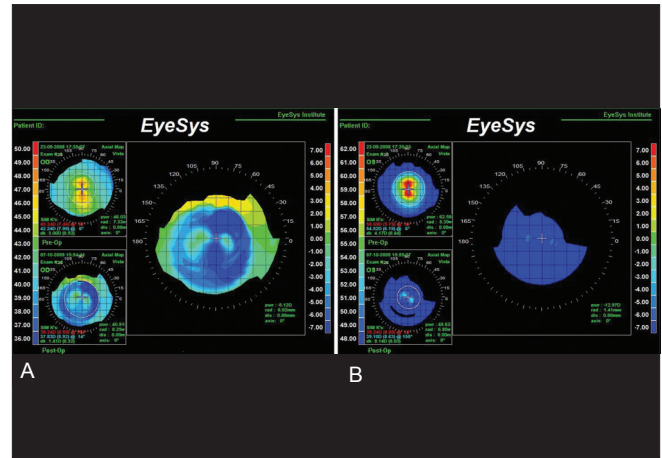


Figure 6: (A,B) The topography of the eye with post-LASIK irregular astigmatism before (top left) and 12 months after (bottom left) ICRS implantation and the difference map (right)

Table 3: Statistical calculations of preoperative and postoperative 3, 6, and 12-month follow-up data with Friedman’s test

	UDVA (logMAR)		CDVA (logMAR)		SE(D)		AvK(D)		ISAI	
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)
Preoperative	1.28±0.59	1 (0.8–2)	0.58±0.3	0.55 (0.3–0.93)	-5.54±5.04	-3.31 (-9.28 to 2.68)	47.93±4.84	46.34 (44.18–49.77)	5.34±3.05	5.2 (2.93–7.64)
3 Mo postoperative	0.37±0.2	0.35 (0.19–0.58)	0.16±0.14	0.1 (0.1–0.28)	-0.79±1.15	-0.56 (-1.75 to 0.28)	40.95±2.5	41.47 (38.8–42.41)	2.58±2	2.23 (0.85–3.5)
6 Mo postoperative	0.37±0.2	0.35 (0.19–0.58)	0.16±0.14	0.1 (0.1–0.27)	-0.62±1.07	-0.37 (-1.59 to 0.21)	40.99±2.42	41.36 (38.75–42.59)	2.54±1.86	2.09 (1–3.76)
12 Mo postoperative	0.36±0.19	0.35 (0.19–0.58)	0.15±0.12	0.1 (0.1–0.27)	-0.74±1.07	-0.44 (-1.72 to 0.25)	40.87±2.36	41 (38.77–42.82)	2.37±1.68	2.21 (0.86–3.44)
Fr	34.68		33.58		28.21		23.09		16.21	
P	0.0001		0.0001		0.0001		0.0001		0.001	

UDVA = uncorrected distance visual acuity, CDVA = corrected distance visual acuity, SE = spherical equivalent, AvK = average keratometric readings, D = diopter, ISAI = inferosuperior asymmetry index. The statistical significance level was established at $P < 0.05$.

Table 4: Evaluation of the postoperative results and the refraction stability with Dunn’s multiple comparisons test

Dunn’s multiple comparisons test	UDVA (log-MAR)	CDVA (log-MAR)	SE (D)	AvK (D)	ISAI
Preoperative vs. 3 mo	0.002	0.002	0.002	0.002	0.003
Preoperative vs. 6 mo	0.002	0.002	0.002	0.002	0.003
Preoperative vs. 12 mo	0.002	0.002	0.002	0.002	0.003
3 mo vs. 6 mo	1	0.317	0.108	0.790	1
3 mo vs. 12 mo	0.317	0.180	0.396	0.959	0.135
6 mo vs. 12 mo	0.317	0.317	0.465	0.575	0.136

UDVA = uncorrected distance visual acuity, CDVA = corrected distance visual acuity, SE = spherical equivalent, AvK = average keratometric readings, D = diopter, ISAI = inferosuperior asymmetry index. The statistical significance level was established at $P < 0.05$.

depth of the groups were 461.60 ± 40.99 and 422.57 ± 55.50 μm , respectively, and 408.80 ± 23.86 and 406.71 ± 24.74 μm , respectively and statistical analysis showed no significant difference for these parameters ($P_1=0.214$ $P_2=0.887$). The preoperative mean UDVA of groups 1 and 2 were 1.04 ± 0.32 and 1.44 ± 0.69 logMAR, respectively which were not significantly different ($P=0.262$). The preoperative mean CDVA of groups 1 and 2 were 0.46 ± 0.21 and 0.67 ± 0.34 logMAR, respectively ($P=0.253$). The preoperative mean spherical equivalent refractive errors of the groups 1 and 2 were 2.67 ± 1.15 D and 7.94 ± 5.23 D, respectively, and group 2 had a significantly higher refractive error than group 1 ($P=0.038$). The preoperative mean cylindrical refractive errors of the groups 1 and 2 were -3.95 ± 1.69 D and -6.25 ± 2.59 D, respectively, and group 2 had a insignificantly higher refractive error than group 1 ($P=0.116$). The preoperative mean K readings of the groups were $45.50 \pm$

1.63 D and 49.66 ± 5.72 D, respectively. The mean K readings of group 2 were slightly but not significantly higher than the K readings of group 1, ($P=0.150$). The preoperative mean ISAI of the groups were 5.62 ± 2.99 and 5.13 ± 3.30 ($P=0.798$), respectively. Improvements in all of the parameters in both groups were observed at 12 months [Tables 2 and 4]. The 12-month postoperative mean UDVA and CDVA of group 1 and 2 were 0.31 ± 0.19 and 0.38 ± 0.19 logMAR, respectively, and 0.08 ± 0.04 and 0.19 ± 0.14 logMAR, respectively ($p_1=0.558$, $p_2=0.108$). The 12-month postoperative mean spherical equivalent refractive errors of the groups 1 and 2 were 0.82 ± 0.73 D and 1.17 ± 0.79 D, respectively ($P=0.452$). The 12-month postoperative mean cylindrical refractive errors of the groups 1 and 2 were -1.15 ± 0.60 D and -1.71 ± 0.74 D, respectively ($P=0.192$). The 12-month postoperative mean K readings of the groups were 41.49 ± 2.01 D and 40.41 ± 2.63 D, respectively ($P=0.462$). The 12-month postoperative mean ISAI of the groups were 2.63 ± 1.11 and 2.17 ± 2.05 , respectively ($P=0.659$).

Discussion

Ectasia after LASIK is an uncommon, but potentially visually disabling complication.^[10] Despite the number of studies that support the efficacy of LASIK,^[11] concerns about the occurrence of postoperative keratectasia are growing. Even though corneal ectasia is a rather rare complication after LASIK, it can have a profoundly negative effect on the refractive properties of the cornea. One of the possible alternatives to manage post-LASIK corneal ectasia is the implantation of ICRS, which were initially developed for the correction of myopia.^[12,13] Recently, corneal collagen cross-linking with riboflavin and ultraviolet-A light with or without ICRS implantation is used to slow down the progression of ectasia.^[14] ICRS were designed to achieve a refractive adjustment by flattening the central corneal curvature while maintaining clarity in the central optical zone. Because of the removable and tissue-saving nature of this technique, its application could be expanded to patients with corneal thinning disorders. Several reports have demonstrated the efficacy of Intacs in correcting keratoconic eyes,^[15-18] and preliminary studies show encouraging results in eyes with post-LASIK corneal ectasia.^[7,8,19-21] The magnitude of this flattening effect is in direct proportion to the thickness of the implant and in inverse proportion to its diameter.^[22] Furthermore, soft-ectasia corneas show more flattening than healthy corneas.^[16] The goal of implanting intracorneal rings for keratectasia after LASIK is to reduce the corneal steepening, which results in a favorable visual outcome and eliminates or delays the need for corneal grafting.

The 3 main ICRS in the market are Intacs (Addition Technology, Inc.), Ferrara (Ferrara Ophthalmics Ltd.), and Keraring (Mediphacos Ltd.). Kerarings are made of polymethylmethacrylate (PMMA) and are characterized by a triangular cross-section that induces a flattening effect on the cornea. Their apical diameter is 5 mm, and the flat basis width is 0.6 mm, with variable thickness (0.15 to 0.35 mm with 0.05-mm steps) and arc length (90 degrees, 160 degrees, and 210 degrees). The optical zone provided by Keraring segments is 5.0 mm in diameter.

The surgical technique for tunnel creation in Keraring and Ferrara procedures differs from the mechanical tunnel creation technique used in Intacs. While a suction device is used in

Intacs, the tunnels of Keraring and Ferrara are prepared by the Ferrara double spatula. Implantation of ICRS without the use of a suction device is a more surgeon dependent technique, which has increased risk of complications while the surgeon is in the learning curve of the procedure. Additionally, Kwitko and Severo reported decentration of Ferrara ICRS in 3.9% of cases, segment extrusion in 19.6%, and bacterial keratitis in 1.9%.^[23] The authors suggest that most of the complications related to surgical technique were caused by the surgeon's learning curve, and the differing healing processes of keratoconic corneas. Siganos *et al.* reported superficial implantation and asymmetric placement of the segments in 7.7% of cases. A vacuum was not used to create the channels in their series, and these complications were associated with implantation of the Ferrara rings.^[24]

Making the tunnels in the 5 mm optical zone gives the surgeon the ability to correct the higher amount of refractive error with thinner ICRS implantation. However, this procedure requires precision because the cornea in this area is thinner than the periphery of the cornea and is close to the optical axis [Figs. 3A and 3B]. Recently, Kubaloglu *et al.* used suction rings (Moria) to minimize decentration during the implantation of Keraring segments.^[25] Unfortunately, this suction ring only fixes the eye but cannot prevent uncontrolled movements of the dissector. Although the operations were performed by an experienced surgeon, corneal perforation and superficial segment implantation was observed in 6% of the cases who had mechanical implantation.^[26] We believe that fixating the eye under a suction during intrastromal dissection is essential to be able to create a tunnel at the adequate depth preoperatively. In our cases, the intrastromal dissection was created to the full depth of the incision. The suction ring not only served to fix the eye but also prevented uncontrolled movement of the dissector during rotational movement (counterclockwise and clockwise) by holding the dissector (like the semiautomated suction ring of Intacs). The tunnels were created by using left and right special dissectors with a device containing a semiautomated suction ring. As a result, two 180-degree or one 240-degree semicircular dissections into the stroma with an approximate diameter of 5 mm were achieved at the adequate depth and with proper centralization [Fig. 3A]. All operations were uneventful. There was no incidence of delayed complications. The integrity of the cornea was well preserved in all eyes, and there was no extrusion of the rings. In contrast, standard mechanical stromal dissection of the Keraring could cause a higher rate of extrusion.^[23-26]

Alio' *et al.* found significant improvement in visual acuity after Intacs segment implantation in three eyes with ectasia. In 2 eyes, the UDVA was 20/40 postoperatively. In the third eye, there was a residual refractive error; and, the UDVA was 20/50, and the CDVA was 20/40.^[7] In a post-LASIK ectasia study, Kymionis *et al.* implanted Intacs segments in eyes with a mean preoperative UDVA of 20/100. At the last follow-up examination, 6 (75%) of 8 eyes had a UDVA 20/40 or better. At the end of the first postoperative year, UDVA, CDVA, and topography were stable and remained so during the follow-up period.^[19] In a recent study of single Ferrara segment implantation in patients with corneal ectasia after refractive surgery by Torquetti *et al.*, both UDVA and CDVA increased significantly after surgery ($P=0.005$, $P=0.008$). Manual implantation technique was used in their surgeries and very experienced surgeons performed

the operations. No complications was seen in their series of 25 eyes.^[27] Our study has potential limitations, such as the small sample of treated eyes, the lack of higher-order aberration analysis and the lack of a comparative group. However, the results are similar to those in a post-LASIK study in which ICRS were used for treatment.^[27]

Our postoperative results reveal a significant reduction in the magnitude of corneal steepening, an increase in topographical regularity, and an improvement in the UDVA due to the improved ISAI and simultaneous partial correction of the spherical and cylindrical refractive errors. Tunc's dissector for the preparation of the tunnel facilitates the procedure and adds to the safety of the surgery in patients with post-LASIK ectasia. Further follow-up and additional cases are needed to draw final conclusions about the efficacy of this surgical technique.

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