Comparison of visual and refractive outcomes following Intacs implantation in keratoconus eyes with central and eccentric cones

Mustafa Kapasi, (Hon)BSc, MD*, Guillermo Rocha, MD, FRCSC[†,‡]

ABSTRACT • RÉSUMÉ

Objective: To compare visual and refractive outcomes after Intacs implantation in keratoconus eyes with central and eccentric cones and to validate the current nomogram used to select Intacs size.

Design: Comparative study.

Participants: The charts of 20 patients in a single practice, who had symmetric (15 eyes) or asymmetric (16 eyes) implants, were retrospectively reviewed.

Methods: Intacs were implanted by a single surgeon using a femtosecond laser. Based on Scheimpflug imaging, central and eccentric cone patterns received symmetric and asymmetric Intacs, respectively. Uncorrected distance visual acuity (UDVA) and best-corrected distance visual acuity (CDVA), manifest refraction spherical equivalent (MRSE), and keratometry (K) values were measured pre- and postoperatively.

Results: The mean improvement in UDVA and CDVA in the symmetric group was 3.8 ± 0.9 and 0.6 ± 0.5 lines, and in the asymmetric group was 3.4 ± 0.7 and 1.8 ± 0.3 lines, respectively. The mean change in manifest refraction spherical equivalent (MRSE), refractive cylinder, and average K in the symmetric group was 2.40 ± 0.71 D, 0.02 ± 0.90 D, and −2.71 ± 0.50 D, and in the asymmetric group was 2.67 ± 1.21 D, 0.05 ± 0.47 D, and −2.35 ± 0.40 D, respectively. In CDVA, asymmetric Intacs showed statistically significant and better results than symmetric Intacs ($p = 0.0016$). There was no statistically significant difference between the means of symmetric and asymmetric implantation for UDVA, MRSE, average K, or corneal astigmatism ($p > 0.05$).

Conclusions: The implantation of symmetric and asymmetric Intacs segments in keratoconus eyes with central and eccentric cones, respectively, was found to have comparable visual and refractive outcomes except for CDVA, which improved significantly more in the asymmetric group. This study also demonstrates the validity of the nomogram used.

Objet : Comparaison entre les résultats visuels et réfringents après une implantation d'INTACS (?) dans les yeux atteints de kératocône centraux et excentriques, et validation des nomogrammes actuels servant à choisir la taille des INTACTS.

Nature : Étude comparative.

Participants : L'étude rétrospective a porté sur les dossiers de 20 patients d'une seule pratique, qui avaient des implants symétriques (15 yeux) ou asymétriques (16 yeux).

Méthodes : Les INTACS ont été implantés par un seul chirurgien en utilisant un laser femtoseconde. Fondés sur l'imagerie Scheimpflug, les cones ont reçu, selon leurs configurations centrées et excentriques, des INTACS symétriques ou asymétriques, respectivement. L'acuité visuelle non corrigée à la distance (AVNCD) et la meilleure acuité visuelle corrigée à la distance (MAVCD), l'équivalent sphérique de la réfraction manifeste (ÉSMR) et les valeurs de la kératométrie (K) ont été mesurés avant et après l'opération.

Résultats : La moyenne d'amélioration de l'AVNCD et de la MAVCD du groupe symétrique était de 3,8 ± 0,9 et 0,6 ± 0,5 lignes, et celle du groupe asymétrique, de 3.4 ± 0.7 et 1.8 ± 0.3 lignes, respectivement. Les moyennes des changements de l'équivalent sphérique de la réfraction manifeste (ÉSRM), du cylindre réfreingent et celle de K dans le groupe symétrique étaient de 2,40 + 0,71 D, 0,02 ± 0,90 D et -2,71 ± 0,50 D, et celle du groupe asymétrique était de 2,67 ± 1,21 D, 0,05 ± 0,47 D et -2,35 ± 0,40 D, respectivement. Pour ce qui est de la MAVCD, les INTACS asymétriques ont montré des résultats statistiquement significatifs et meilleurs que ceux des INTACS symétriques (p = 0,0016). Il n'y avait pas de différence statistiquement significative entre les implantations symétriques et asymétriques en ce qui a trait aux moyennes de l'AVNCD et de la MAVCD, la moyenne de K ou l'astygmatisme cornéen ($p > 0,05$).

Conclusions : L'implantation de segments INTACTS symétriques et asymétriques dans les yeux atteints de kératocône dans les cônes centraux et excentriques, respectivement, a donné des résultats visuels et réfractifs comparables, sauf pour la MAVCD qui s'améliorée davantage dans le groupe asymétrique. L'étude démontre aussi la validité du nomogramme utilisé.

Keratoconus is an asymmetric, bilateral, progressive, degenerative, and noninflammatory corneal ectasia caused by progressive biomechanical instability of the cornea.[1,2] Ever since the first report of the successful use of intracorneal ring segments (ICRS) (Intacs, Addition Technology, Des Plaines, Ill) to manage keratoconus, Intacs have been a helpful adjunct in the management of contact lens-intolerant keratoconus with no hydrops or scarring.[3-5] For the purpose of this study, contact lens intolerance is defined as the inability to tolerate contact lenses to maintain visual function on a daily basis. Functional visual acuity is unattainable through spectacle correction, and irritation prevents contact lens use despite possibly obtaining good visual capacity.

Intacs reshape the keratoconic cornea by placing 2 Intacs inserts of symmetric or asymmetric sizes in the mid-periphery, allowing for the correction of the refractive error as well as restoration of the prolate anatomy of cornea.[6] The decision to implant symmetric versus asymmetric Intacs segments is based on the cone location—symmetric segments are typically used to manage central ectatic con-

Oral presentation at Canadian Ophthalmology Society Annual Meeting and Exhibition in Quebec City, Q.C., June 26-29, 2010.

From the *Department of Ophthalmology, University of Ottawa, Ottawa, Ont.; the [†]Faculty of Medicine, University of Manitoba, Winnipeg, Man.; and [‡]ImagePlus Laser Eye Centre, Winnipeg, Man.

Originally received Sept. 29, 2011. Final revision Feb. 14, 2012. Accepted Mar. 29, 2012

Correspondence to Guillermo Rocha, GRMC Vision Centre, Suite 20, 144-6th Street, Brandon MB R7A 3N2; rochag@westman.wave.ca

Can J Ophthalmol 2012;47:354–359
0008-4182/11/$-see front matter
dx.doi.org/10.1016/j.jcjo.2012.04.001

ditions, whereas asymmetric segments are used for eccentric ectatic conditions.[7]

Such a treatment approach was designed to address the dissimilar optical properties of the keratoconus eyes with central and eccentric cones. Whereas eccentric cones tend to have larger higher order aberrations and astigmatism, central cones produce higher refractive error. Therefore, the quality of vision in the patients with the central cone is typically better than the ones with eccentric cones.[8] We wanted to know if the visual outcomes in central and eccentric cones are comparable. However, we did not find any answers in the currently published literature. Although there is extensive literature documenting the efficacy and safety of Intacs in reducing spherocylindrical error and corneal steepening with improved visual outcome,[4,5,9-12] no publication reported a comparison of visual outcomes after Intacs implantation in central and eccentric cones in keratoconus eyes. Furthermore, the nomograms presented in this study have never been validated with published safety, and postoperative visual and refractive outcome data.

We therefore undertook this study to compare the visual and refractive outcomes in keratoconus eyes with central cones implanted with symmetric segments versus eccentric cones implanted with asymmetric segments. We also sought to validate the current comprehensive nomogram and presurgical planning guide recommended by the manufacturer (Addition Technology) used for selecting Intacs size for keratoconus patients.

Methods

This study was approved by the Ottawa Hospital Research Ethics Board. This retrospective, nonrandomized, comparative chart review included 31 consecutive contact lens-intolerant keratoconus eyes of 20 subjects who had undergone Intacs implantation (Addition Technology) by a single surgeon (G.R.) at the GRMC Vision Centre, Canada, between October 28, 2005 and August 19, 2008. All subjects met the standard clinical protocol for Intacs implantation; i.e., central corneal thickness of at least 400 μm (μ), peripheral corneal thickness of at least 450 kcal at the incision site, and absence of apical scaring.

The eyes were categorized into 2 groups. Group I consisted of 15 eyes with central cone location. Group II consisted of 16 eyes with eccentric cone. The determination of the type of Intacs implantation was based on the comprehensive nomogram and presurgical planning guide recommended by the manufacturer—keratoconus eyes with central cones underwent symmetric Intacs implantation, and those with eccentric cones underwent asymmetric Intacs placement (Tables 1 and 2). The central cones were defined as those in which most of the posterior elevation on Scheimpflug imaging (Pentacam, Oculus, Wetzlar, Germany) was within the central 5 mm zone. Eyes with severe keratoconus (average keratometry of $\geq$ 56 D, usually corresponding to grade 4 classification on Pentacam analysis) were implanted Intacs SK implants.

Table 1—Nomogram used for symmetric Intacs size selection for patients with central cones as identified by Scheimpflug imaging

Symmetric	
Spherical equivalent	Intacs size
+1.00 to −1.75	0.250 mm
−2.00 to −2.75	0.300 mm
−3.00 to −3.75	0.350 mm
−4.00 to −4.75	0.400 mm
−5.00 to −5.75	0.450 mm
−6.00 to −7.75	0.400 mm SK
−8.00 and higher	0.450 mm SK

Table 2—Nomogram used for asymmetric Intacs size selection for patients with eccentric cones as identified by Scheimpflug imaging

Asymmetric		
Spherical equivalent	Inferior Intacs size	Superior Intacs size
+1.00 to −2.00	0.300 mm	0.210 mm
−2.00 to −3.00	0.350 mm	0.210 mm
−3.00 to −4.00	0.400 mm	0.210 mm
−4.00 and higher	0.450 mm	0.210 mm

The parameters studied included preoperative and postoperative uncorrected distance visual acuity (UDVA), best-corrected distance visual acuity (CDVA), manifest refraction spherical equivalent (MRSE), average keratometry (K), and corneal astigmatism. Both the groups were compared for changes in the above-mentioned parameters.

Surgical technique

All eyes underwent femtosecond-assisted Intacs implantation (Intralase FS, Abbott Medical Optics, Santa Ana, Calif) by a single surgeon (G.R.). The location of the incision was determined preoperatively based on the correlation of 3 parameters: the axis location of the plus cylinder on manifest refraction (that was given the most importance), the topographical meridian, and the shape and location of the cone on elevation imaging. Femtosecond settings for regular Intacs were depth of the channel 400 μm, internal diameter 6.8 mm, and external diameter 7.8 mm. For Intacs SK, depth of the channel was 380 μm, 6.0 mm internal diameter, and 7.0 mm external diameter. No modifications were made for segment thickness.

A Sinskey hook and Mendez dissector were used to open the incision. A dissector was used to open the channel at its origin. Next, the Intacs segments were placed either inferiorly or superiorly; preference was given to placing the thicker segment first. The segments were pushed into the channel until it was well clear of the incision. A 10-0 nylon suture was used to close the incision. Moxifloxacin hydrochloride 0.5% (Vigamox; Alcon, Canada, Mississauga, Ont.) and dexamethasone ophthalmic suspension 0.01% (Maxidex; Alcon) were instilled and continued 4 times a day for 1 week. A contact lens was not used. The suture was left in place until it became loose or until 2 months postoperatively. After 1 month, patients were encouraged to be fitted with either glasses or contact lenses.

Statistical analysis

Statistical analysis was carried out using SAS statistical software (Cary, NC). The Student's *t* test was used for numerical data and a multivariate analysis of variance was performed to control for type 1 error.

Results

The study population consisted of 10 males and 10 females with a racial distribution of 2 Hispanics, 1 Aboriginal Canadian, and 17 Caucasians. The mean age of the subjects in the symmetric implant group was 41 ± 4 years and in the asymmetric group was 42 ± 4 years. The mean follow-up period of symmetric implant group (n = 15 eyes) was 8.0 ± 1.5 (range, 0.5-18.5) months and asymmetric implant group (n = 16 eyes) was 10.3 ± 2.0 (range, 0.25-28) months. Some of the patients were lost to follow-up before the ideal 4-6 months stabilization period for Intacs. To account for this, a subset of eyes having > 6 months of follow-up (n = 22 eyes; 13 asymmetric eyes and 9 symmetric eyes) was analyzed separately. The mean follow-up period for eyes with more than 6 months of follow-up in the symmetric implant group (n = 9 eyes) was 13.1 ± 1.4 (range, 7.5-18.5) months, and in the asymmetric implant group (n = 13 eyes) was 12.5 ± 2.0 (range, 6-28) months.

Visual outcomes (UDVA and CDVA)

All eyes with symmetric implants (n = 15 eyes). The mean improvement in UDVA and CDVA for all symmetric eyes was 3.8 ± 0.9 lines (range, 0-9) and 0.6 ± 0.5 (range, −2 to 6), respectively (Fig. 1).

All eyes with asymmetric implants (n = 16 eyes). The mean improvement in UDVA for all asymmetric eyes was 3.4 ± 0.7 lines (range, 0-10), whereas the mean improvement in CDVA was 1.8 ± 0.3 lines (range, −1 to 4) (Fig. 1).

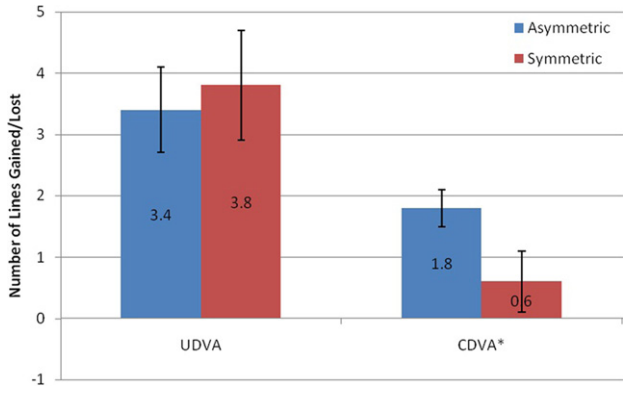

Fig. 1—Improvement in vision, comparing all asymmetric and symmetric implants. Uncorrected distance visual acuity (UDVA) and best-corrected DVA (CDVA). Mean values and standard error shown. *Indicates a statistically significant difference ($p = 0.0016$).

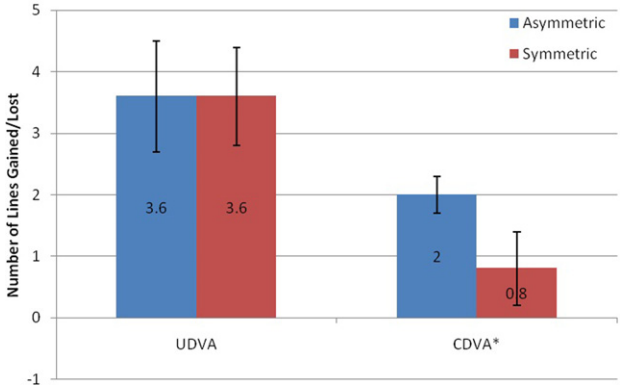

Fig. 2—Improvement in vision, comparing asymmetric and symmetric implants in eyes with > 6 months follow-up. Uncorrected distance visual acuity (UDVA) and best-corrected DVA (CDVA). Mean values and standard error shown. *Indicates a statistically significant difference ($p < 0.001$).

Eyes with symmetric implants with > 6 months follow-up (n = 9 eyes). For eyes with symmetric implants and > 6 months of follow-up, the mean improvement in UDVA and CDVA was 3.6 ± 0.8 lines (range, 0-8) and 0.8 ± 0.6 lines (range, −2 to 6), respectively (Fig. 2).

Eyes with asymmetric implants with > 6 months follow-up (n = 13 eyes). For eyes with asymmetric implants and > 6 months of follow-up, the mean improvement in UDVA was 3.6 ± 0.9 lines (range, 0-10), whereas mean improvement in CDVA was 2.0 ± 0.3 lines (range, −1 to 4) (Fig. 2).

Table 3 shows absolute values for preoperative and postoperative CDVA.

Functional visual capacity. All eyes were able to achieve functional vision post-Intacs implantation, with all eyes achieving adequate refractive correction through the use of spectacles.

Statistical analysis. There was no statistically significant difference (p value > 0.05) in improvement of UDVA between the symmetric and asymmetric implant eyes, whether the analysis was performed on all eyes operated or on those with 6 months follow-up. However, the improvement of CDVA was significantly better in the asymmetric group compared with the symmetric (p value = 0.0016, when comparison was performed on all eyes and p value < 0.001, when comparison was performed on eyes with > 6 months follow-up).

Refractive outcomes

All eyes with symmetric implants (n = 15 eyes). The mean change in MRSE for all symmetric eyes was 2.40 ± 0.71 (range, −5.12 to 5.25). The mean change in corneal astigmatism and average K in the same group was 0.60 ± 1.47 D (range, −4.25 to 15.1) and −2.71 ± 0.50 D (range, −5.08 to 1.44). The reading of 15.1 was a strong outlier in the corneal astigmatism data set; the mean change in corneal astigmatism without that data point was 0.02 ± 0.90 D (range, −4.25 to 6.75) (Fig. 3).

Table 3—Absolute values for CDVA for all symmetric and asymmetric implants

	Preoperative	Postoperative	Lines change (n)
Symmetric implants	20/200	20/40	6
	20/40	20/20	3
	20/20	20/20	0
	20/40	20/40	0
	20/40	20/40	0
	20/20	20/20	0
	20/30	20/25	1
	20/20	20/20	0
	20/30	20/30	0
	20/20	20/20	0
	20/20	20/30	−2
	20/60	20/60	0
	20/50	20/40	1
	20/50	20/50	0
	20/30	20/30	0
Asymmetric implants	20/70	20/40	3
	20/50	20/30	2
	20/40	20/25	2
	20/30	20/25	1
	20/60	20/30	3
	20/70	20/50	2
	20/30	20/20	2
	20/40	20/30	1
	20/40	20/20	3
	20/50	20/20	4
	20/20	20/25	−1
	20/40	20/25	2
	20/40	20/25	2
	20/30	20/25	1
	20/60	20/60	0
	20/60	20/40	2

Note: CDVA, best-corrected distance visual acuity.

All eyes with asymmetric implants (n = 16 eyes). The mean change in MRSE for the asymmetric group was 2.67 ± 1.21 (range, −8.88 to 12.25), whereas the mean change in corneal astigmatism for the same group was 0.05 ± 0.47 (range, −2.3 to 2.2) and the mean change in average K was −2.35 ± 0.40 (range, −4.62 to −0.12) (Fig. 3).

Eyes with symmetric implants with > 6 months follow-up (n = 9 eyes). The mean change in MRSE, corneal astigmatism, and average K for the symmetric group was 2.58 ± 0.56 (range, −1.25 to 4.25), 0.12 ± 0.87 (range, −3.87 to 4.38), and −2.56 ± 0.68 (range, −5.08 to 1.44), respectively (Fig. 4).

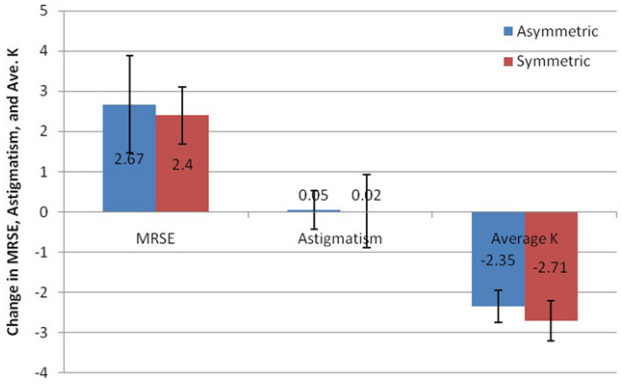

Fig. 3—Change in manifest refraction spherical equivalent (MRSE), astigmatism, and average keratometry (K). Comparing all asymmetric and symmetric implants. Mean values and standard error shown.

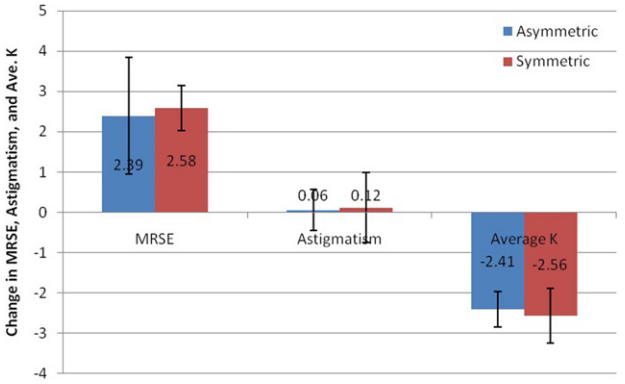

Fig. 4—Change in manifest refraction spherical equivalent (MRSE), astigmatism, and average keratometry (K). Comparing asymmetric and symmetric implants in eyes with > 6 months follow-up. Mean values and standard error shown.

Eyes with asymmetric implants with > 6 months follow-up (n = 13 eyes). For eyes with > 6 months of follow-up, the mean change in MRSE, corneal astigmatism, and average K for the asymmetric group was 2.39 ± 1.45 (range, −8.88 to 12.25), 0.06 ± 0.51 (range, −2.1 to 2.2), and −2.41 ± 0.44 (range, −4.62 to −0.12), respectively (Fig. 4).

Statistical analysis. There was no statistical difference (p value > 0.05) between the means of change in MRSE, average K, or corneal astigmatism, whether the comparison was performed on all eyes of symmetric and asymmetric group or the subgroup with > 6 months follow-up.

Safety

Overall (n = 31 eyes), 26 eyes (84%) gained lines in UDVA (15 [94%] asymmetric, 11 [73%] symmetric), and 18 eyes (58%) gained lines in CDVA (14 [88%] asymmetric, 4 [27%] symmetric). No eyes lost lines in UDVA, but a total of 2 eyes lost lines in CDVA (Figs. 5 and 6). No

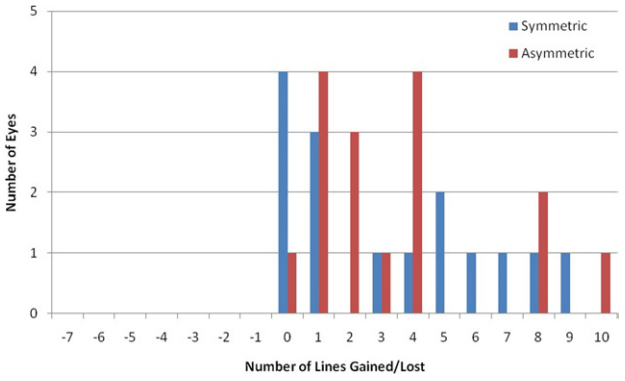

Fig. 5—Number of lines gained or lost in uncorrected distance visual acuity (UDVA) comparing all symmetric and asymmetric implants.

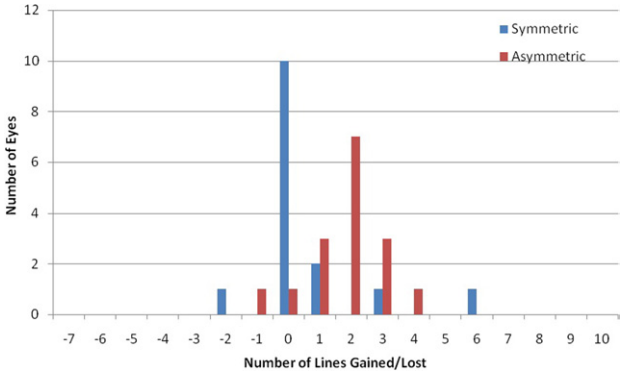

Fig. 6—Number of lines gained or lost in best-corrected distance visual acuity (CDVA) comparing all symmetric and asymmetric implants.

complications were recorded intraoperatively and postoperatively in the either group. One eye was found to have nonsymptomatic overlap of distal ends of the segments.

Discussion

The fundamental purpose of using ICRS Intacs specifically in our study is to create a more regularly shaped corneal surface that is better able to focus light through the correction of irregular astigmatism and improve tolerance for contact lenses.[13,14] To best achieve this purpose, the nomogram recommends use of symmetric implants in keratoconus with central cones and asymmetric implants in those with eccentric cones.

Our study was designed to find out how these 2 separate approaches compare for their respective indications. We found that there was no statistically significant difference in the improvement of UDVA, MRSE, corneal astigmatism, and average keratometry between the 2 groups. However, improvement in CDVA was statistically better in keratoconus eyes with eccentric cones. Because the changes in MRSE, average K, and corneal astigmatism were comparable between the 2 groups, it could be due possibly to significant decrease in the larger higher order aberrations associated with eccentric cones of keratoconus.

In terms of safety, 2 eyes lost lines in CDVA (Fig. 6). One asymmetric eye lost a single line of best-corrected vision due to possible corneal fluctuation as this was a case of post-LASIK ectasia. However, 4 lines were gained in UDVA and final CDVA was 20/25. One symmetric eye lost 2 lines of CDVA but gained 4 lines of UDVA. The reasoning behind this loss was not clear, but final CDVA was 20/30.

We found the results of our study to be comparable to the recently published literature. Improvement in UDVA of 3.6 lines and CDVA of 2.0 lines in the asymmetric group was similar to those reported by Colin et al,[14] who demonstrated an improvement of 2 lines in UDVA and 2 lines in CDVA. Similarly, increase in UDVA of 3.6 lines and CDVA of 0.8 lines in the symmetric group was similar to the Levinger et al.[15] publication that reported a mean improvement of 3.1 lines in UDVA but no improvement in CDVA with symmetric placement of implants.

The percentage of eyes demonstrating improvement in UDVA (94%) and CDVA (88%) was also comparable or better than those reported by Boxer Wachler et al.[11] (UDVA, 72%; CDVA, 24%) in the asymmetric group. However, in the symmetric group, although the improvement in UDVA in 73% of eyes was comparable to the 75% of eyes reported by Siganos et al.,[16] improvement in CDVA was found in 27% of eyes in our study compared with 45% by Siganos et al.[16] It is important to note that the comparisons drawn above are not directly comparable, as the criteria to recruit a subject and to decide implantation of symmetric versus asymmetric implants were not necessarily the same as used in our study.

One of the main weaknesses of this study was its retrospective nature. Follow-up was difficult, as some of the patients were from different provinces. A prospective study would have allowed a better control of subject recruitment, data collection, and, therefore, a more robust analysis.

We conclude that the implantation of symmetric and asymmetric ICRS Intacs specifically in our study, in keratoconus eyes with central and eccentric cones, respectively, was found to have comparable visual and refractive outcomes, except for CDVA, which improved significantly more in the asymmetric group. We also conclude that the current nomogram and presurgical planning guide recommended by the manufacturer (Addition Technology) used in selecting Intacs size based on spherical equivalent is valid, based on good safety and postoperative outcomes.

Disclosure: The authors have no proprietary or commercial interest in any materials discussed in this article.

References

1. Stabuc-Silih M, Strazisar M, Hawlina M, Glavac D. Absence of pathogenic mutations in VSX1 and SOD1 genes in patients with keratoconus. *Cornea.* 2010;29:172-6.
2. Bechrakis N, Blom ML, Stark WJ, Green WR. Recurrent keratoconus. *Cornea.* 1994;13:73-7.
3. Kymionis GD, Siganos CS, Tsiklis NS, et al. Long-term follow-up of INTACS in keratoconus. *Am J Ophthalmol.* 2007;143:236-44.
4. Colin J. European clinical evaluation: use of INTACS for the treatment of keratoconus. *J Cataract Refract Surg.* 2006;32:747-55.
5. Sharma M, Boxer Wachler BS. Comparison of single-segment and double-segment INTACS for keratoconus and post-LASIK ectasia. *Am J Ophthalmol.* 2006;141:891-5.
6. Ertan A, Colin J. Intracorneal rings for keratoconus and keratectasia. *J Cataract Refract Surg.* 2007;33:1303-14.
7. Wilson SE, Lin DT, Klyce SD. Corneal topography of keratoconus. *Cornea.* 1991;10:2-8.
8. Tan B, Baker K, Chen YL, et al. How keratoconus influences optical performance of the eye. *J Vis.* 2008;8:11-20.
9. Pinero DP, Alio JL, El Kady B, Pascual I. Corneal aberrometric and refractive performance of 2 intrastromal corneal ring segment models in early and moderate ectatic disease. *J Cataract Refract Surg.* 2010;36:102-9.
10. Alió JL, Shabayek MH, Belda JI, Correas P, Feijoo ED. Analysis of results related to good and bad outcomes of INTACS implantation for keratoconus correction. *J Cataract Refract Surg.* 2006;32:756-61.

11. Boxer Wachler BS, Christie JP, Chandra NS, Chou B, Korn T, Nepomuceno R. INTACS for keratoconus. *Ophthalmology.* 2003; 110:1031-40.
12. Alió JL, Artola A, Ruiz-Moreno JM, Hassanein A, Galal A, Awadalla MA. Changes in keratoconic corneas after intracorneal ring segment explantation and reimplantation. *Ophthalmology.* 2004;111:747-51.
13. Colin J, Cochener B, Savary G, Malet F. Correcting keratoconus with intracorneal rings. *J Cataract Refract Surg.* 2000. 26:1117-22.
14. Colin J, Cochener B, Savary G, Malet F, Holmes-Higgin D. INTACS inserts for treating keratoconus: one-year results. *Ophthalmology.* 2001. 108:1409-14.
15. Levinger S, Pokroy R. Keratoconus managed with INTACS: one-year results. *Arch Ophthalmol.* 2005. 123:1308-14.
16. Siganos CS, Kymionis GD, Kartakis N, Theodorakis MA, Astyrakakis N, Pallikaris IG. Management of keratoconus with INTACS. *Am J Ophthalmol.* 2003. 135:64-70.