ARTICLE

Nonpenetrating femtosecond laser intrastromal astigmatic keratotomy in eyes having cataract surgery

Alexander C. Day, PhD, FRCOphth, Nicola M. Lau, FRCOphth, Julian D. Stevens, FRCOphth, FRCS

PURPOSE: To describe the effect of femtosecond laser intrastromal astigmatic keratotomy (AK) performed during cataract surgery.

SETTING: Moorfields Eye Hospital, London, United Kingdom.

DESIGN: Prospective case series.

METHODS: This study comprised patients having laser cataract surgery with concurrent astigmatism management by intrastromal AK. All eyes had greater than 0.7 corneal diopter (D) cylinder. An intrastromal AK nomogram with 8.0 mm diameter paired symmetric limbal centered arcs was used. Corneal keratometry was measured preoperatively and 1 month postoperatively using a KR8100PA topographer–autorefractor. Astigmatic analyses were performed using the Alpins method considering 3 vectors—target induced astigmatism (TIA), surgically induced astigmatism (SIA) and difference vector (DV)—and calculation of coupling measures.

RESULTS: In all, 196 eyes of 133 patients were analyzed. The mean TIA (equivalent to preoperative corneal cylinder) was 1.21 D $\pm$ 0.42 (SD) (range 0.75 to 2.64 D) and the mean SIA was 0.74 DC $\pm$ 0.40 (range 0.00 to 2.86). The mean difference vector was 0.74 $\pm$ 0.38 D (range 0.00 to 2.25 D). The mean correction index was 0.63 $\pm$ 0.32 (range 0.00 to 1.93), indicating that the mean astigmatism correction was 63%. Fourteen eyes (7.1%) and 7 eyes (3.6%) had an astigmatism correction of greater than 100% and greater than 120%, respectively. Overall 0%, 48.5%, and 51.5% of eyes had 0.50 D or less, 1.0 D or less, or greater than 1.0 D, respectively, preoperatively compared with 32.1%, 85.7%, and 14.3%, postoperatively. There were no cases of corneal endothelial perforation or inadvertent placement within the visual axis.

CONCLUSIONS: The intrastromal AKs were easily programmed as an integral part of laser-assisted cataract surgery without additional cost, significantly reduced corneal cylinder, and appeared to be safe through 1 month of follow-up.

Financial Disclosure: Dr. Day was supported by the National Institute for Health Research (NIHR) Biomedical Research Centre based at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology. Dr. Stevens has been a consultant to Optimedica Inc., now part of Abbott Medical Optics.

J Cataract Refract Surg 2016; 42:102–109 © 2016 ASCRS and ESCRS

Contemporary cataract surgery involves the correction or minimization of corneal astigmatic error to help achieve patients' expectations of best postoperative uncorrected visual acuity. Postoperative visual acuity[1] and undesirable visual symptoms such as halo effects[2] are worse in eyes with higher postoperative corneal astigmatism. Approximately one third[3] to almost one half[4] of eyes having cataract surgery have corneal astigmatism greater than 1.0 diopter (D), and 8%[3] to 13%[4] have greater than 2.0 D. There are many methods of correcting preexisting corneal cylinder during cataract surgery,[5] including operating on-axis, opposite clear corneal incisions, limbal relaxing incisions (LRIs), astigmatic keratotomy (AK), toric intraocular lens (IOL) implantation, and bioptics[6] (post–cataract surgery excimer laser

Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.jcrs.2015.07.045
0886-3350

refractive surgery). In addition to consistent capsulotomy creation[7] and lens fragmentation resulting in lower required effective phacoemulsification time,[8] femtosecond laser platforms for cataract surgery can produce corneal incisions including femtosecond laser AK, which can be either penetrating[9] or intrastromal AK.[10] For the latter, because the corneal epithelium is not opened, there is a theoretical elimination of the risk for infection and minimized postoperative pain.

To date, there are minimal data on the efficacy of intrastromal AK.[10,11] The purpose of this study was to determine astigmatic changes, by vector analysis of intrastromal AK performed during cataract surgery.

PATIENTS AND METHODS

The study was approved by the Research and Development department at Moorfields Eye Hospital. Analyses of this type do not require individual ethical permission because they are viewed as audits.[A] The study was conducted in accordance with the Declaration of Helsinki and the United Kingdom's Data Protection Act.

Data on patients having elective femtosecond laser-assisted cataract surgery with femtosecond laser intrastromal arcuate cylinders for astigmatism management were collected prospectively for continuous audit of surgical outcomes. Ocular biometry to measure axial length and anterior chamber depth (defined as corneal epithelium to anterior crystalline lens surface) was performed using partial coherence interferometry (PCI) (IOLMaster, Carl Zeiss Meditec AG). Preoperative and postoperative corneal keratometry were measuring using a KR8100PA topographer–autorefractor (Topcon Europe Medical BV). All postoperative data were recorded at standard follow-up at 1 month (mean 27 days).

All surgical procedures were performed between October 2013 and November 2014 using the Catalys laser system (Abbott Medical Optics, Inc.) at Moorfields Eye Hospital, London, using software version 2.20 or cOS 3.0. The programmed anterior capsulotomy size was 4.8 mm in all eyes, and crystalline lens fragmentation was performed using a standardized template. intrastromal AKs were performed in all eyes with preoperative corneal cylinder greater than 0.7 D for which bioptics (laser in situ keratomileusis or laser-assisted subepithelial keratectomy, following cataract surgery) was not planned. Manual alignment of the horizontal corneal meridian was made following docking and integral optical coherence tomographic guidance by the laser system to ensure that the intrastromal AKs were placed at the required corneal meridian. A personal nomogram was used for intrastromal AKs (v3[B]) (Table 1). All intrastromal AKs were 8.0 mm diameter paired symmetrical arcs and were limbal centered. The arcs were programmed to be intrastromal, nonpenetrating, with a depth between 20% and 80% of corneal pachymetry as measured locally by the laser system integral optical coherence tomography. Other intrastromal AK parameters were 90-degree side-cut angle; horizontal and vertical spot spacing of 5 μm and 10 μm, respectively; pulse energy of 5 μJ; anterior line density of 5; anterior line distance of 20 μm; and central line density of 4. Lens removal was completed by a standard phacoemulsification procedure using a Whitestar Signature phacoemulsification system (Abbott Medical Optics, Inc.). A 2.75 mm uniplanar clear corneal temporal main incision and two 1.5 mm side ports (each at 90 degrees to the main incision) were created using a disposable steel keratome. All patients had surgery by the same surgeon (J.D.S.).

Astigmatic analyses were performed using the Alpins method,[12–14] with calculation of 3 vector parameters: target induced astigmatism (TIA), surgically induced astigmatism (SIA), and difference vector. The TIA is defined as the intended correction in astigmatic magnitude and axis and is equivalent to the preoperative corneal cylinder magnitude with axis. The SIA is the amount and axis of astigmatism change achieved by surgery. The difference vector is the required astigmatism magnitude and correction to achieve the intended outcome.

Additional descriptor parameters are the correction index, coefficient of adjustment, magnitude of error, angle of error, and index of success. The correction index is the ratio of SIA to TIA with a value greater than 1.0 indicating overcorrection and less than 1.0 indicating undercorrection. The coefficient of adjustment is the modification required to the surgical treatment to achieve the ideal correction (ie, a correction index of 1.0). The coefficient of adjustment is calculated by TIA divided by SIA. The magnitude of error (SIA minus TIA) values greater than 0.00 and less than 0.00 indicate overcorrection and undercorrection, respectively. The angle of error is the difference in angle between SIA and TIA, with values less than 0 degrees and greater than 0 degrees indicating that the achieved correction was clockwise and counterclockwise, respectively, to the intended axis. The index of success is a measure of success with an ideal value of 0 and is calculated by the difference vector divided by TIA.

The coupling ratio, coupling constant, and total spherical shift were calculated according to Alpins et al.[15,C]

Although the femtosecond AK nomogram was intended to achieve only up to 70% correction to avoid potential overcorrection, for ease of interpretation of outcome data, the target corneal astigmatism was defined as an ideal outcome with 0 diopter (D) postoperative corneal astigmatism. Eyes with previous refractive or corneal surgery were excluded from analysis.

Data were entered into Excel software (Microsoft Corp.), and statistical analysis was performed using SPSS (SPSS Statistics, version 21, IBM Corp.). Comparative and descriptive statistical analyses included the Fisher exact test, chi-square test, and Student *t* tests.

Submitted: May 30, 2015.
Final revision submitted: July 13, 2015.
Accepted: July 31, 2015.

From Moorfields Eye Hospital (Day, Lau, Stevens), and the NIHR Biomedical Research Centre at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology (Day), London, UK.

Corresponding author: Alexander C. Day, PhD, FRCOphth, UCL Institute of Ophthalmology, 11-43 Bath Street, London EC1V 2PD, United Kingdom. E-mail: alex.day@ucl.ac.uk.

Table 1. Nomogram for laser system arc length.

Step 1	Step 2		Step 3		Step 4	
Preoperative Corneal Cylinder (D)	If value is, unadjusted arc length is:		Age adjustment, add:		Astigmatism type adjustment, add:	
Multiple value by 1.3	<0.50	0 degrees	<40 years	15 degrees	Against-the-rule	+5 degrees
	0.50 to 0.74	25 degrees	40-49 years	10 degrees	Oblique	0 degrees
	0.75 to 0.99	30 degrees	50 to 59 years	5 degrees	With-the-rule	−5 degrees
	1.00 to 1.24	40 degrees	60 to 69 years	0 degrees		
	1.24 to 1.49	50 degrees	70 to 79 years	−5 degrees		
	1.50 to 1.74	60 degrees	80 to 89 years	−10 degrees		
	1.75 to 1.99	65 degrees	90+ years	−15 degrees		
	2.00 to 2.24	70 degrees				
	2.25 to 2.49	75 degrees				
	2.50 to 2.74	80 degrees				
	2.75 to 2.99	85 degrees				
	3.00+	90 degrees				

Examples:

a) 50 years old, 1.0 diopters cylinder (DC) preoperatively at 90 degrees: Step 1: 1.0 × 1.3 = 1.3; Step 2: = 50 degrees unadjusted; Step 3: add 5 degrees = 55 degrees; Step 4: minus 5 degrees = program symmetric 50-degree paired arcs at 90-degree and 270-degrees meridian, at 8.0 mm diameter, limbus centering.

b) 50 years old, 1.5 DC preoperatively at 90 degrees: Step 1: 1.5 × 1.3 = 1.95; Step 2: = 65 degrees unadjusted; Step 3: add 5 degrees = 70 degrees; Step 4: minus 5 degrees = program symmetric 65 degrees paired arcs at 90-degree and 270-degree meridian, at 8.0 mm diameter, limbus centering.

c) 50 years old, 1.5 DC preoperatively at 180 degrees: Step 1: 1.5 × 1.3 = 1.95; Step 2: = 65 degrees unadjusted; Step 3: add 5 degrees = 70 degrees; Step 4: add 5 degrees = program symmetric 75 degrees paired arcs at 180-degree and 0-degree meridian, at 8.0 mm diameter, limbus centering.

RESULTS

During the 14-month study period, intrastromal AKs were performed in 196 eyes of 133 patients. The mean patient age was 62.1 years. Table 2 shows details of baseline case parameters and corneal astigmatism values. There was a statistically significant difference in the mean corneal cylinder between preoperatively and postoperatively ($P < .001$). There were no cases of cylinder arc posterior perforation or inadvertent placement within the visual axis. The intrastromal femtosecond arc creation time ranged from 1.3 to 2.6 seconds per arc.

Table 2. Case demographic and ocular biometric parameters (N = 196 eyes).

Factor	Mean ± SD	Range
Age (y)	62.1 ± 9.0	34, 83
Axial length (mm)	24.12 ± 2.37	16.68, 32.45
Anterior chamber depth (mm)	3.21 ± 0.38	2.33, 4.21
Predicted implant power (D)	19.5 ± 7.5	0.5, +54.0
Mean preoperative corneal keratometry (D)	43.42 ± 1.40	39.31, 46.31
Mean postoperative corneal keratometry (D)	43.41 ± 1.43	39.00, 46.50
Preoperative corneal cylinder (D)	1.21 ± 0.42	0.75, 2.64
Postoperative corneal cylinder (D)	0.74 ± 0.38	0.00, 2.25

Table 3 shows the vector analysis outcomes. Figure 1 shows the TIA versus SIA. Figure 2 shows the difference vector distribution, including the magnitude and axis. The mean correction index was 0.63 compared to the ideal value of 1.0, indicating mean undercorrection. Figure 3 shows the distribution of the correction index values. Fourteen eyes (7.1%) and 7 eyes (3.6%) had an astigmatism correction of greater than 100% and greater than 120%, respectively. The magnitude of error was −0.47, indicating undercorrection. The index of success (ideal value 0.00) was 0.63. The mean angle of error was 3 degrees, suggesting that the achieved correction axis was very slightly counterclockwise to that intended (ideal value 0 degrees). Tables 3 and 4 and Figure 4 show the preoperative and postoperative astigmatism values. Investigation into cases with astigmatism correction of greater than 100% found no significant differences in patient age, sex, or laser system intrastromal AK arc length compared with those with less than 100% astigmatism correction (all $P > .05$).

Table 3. Vector analysis parameter values (N = 196 eyes).

Parameter	Mean (SD)	Range
Target induced astigmatism (D)	1.21 ± 0.42	0.75, 2.64
Surgically induced astigmatism (D)	0.74 ± 0.40	0.00, 2.86
Difference vector (D)	0.74 ± 0.38	0.00, 2.25
Correction index	0.63 ± 0.32	0.00, 1.93
% astigmatism corrected	63 ± 32	0, 193
Coefficient of adjustment	2.07 ± 1.35	0.00, 9.33
Magnitude of error	−0.47 ± 0.43	−2.02, 1.24
Angle of error	3 ± 70	−175, 176
Index of success	0.63 ± 0.30	0.00, 1.99

There was no significant difference between the mean preoperative and mean postoperative corneal keratometry (mean difference −0.01 D; $P = .65$). The median coupling ratio was 0.56, indicating that the change in corneal power at the opposite meridian was 56% of the change at the treatment meridian.[15] The mean coupling constant was −0.01, meaning that each diopter change in astigmatism produced a −0.01 D change in spherical equivalent.[15] The median total spherical shift was 0.00 D.

DISCUSSION

Correction of corneal astigmatism is now an integral part of cataract surgery, with previous options limited to manual incisions including an on-axis incision (with or without opposite clear corneal incision), LRIs, AK, or toric IOL implantation. Femtosecond laser arcs have many potential advantages over manual incisions and are easily programmed and rapidly created as an integral part of laser-assisted cataract surgery without additional cost. This study showed that intrastromal AK significantly reduced preexisting corneal astigmatism and, using the version 3 nomogram,[B] the mean astigmatism correction was 63%, with 7% of eyes having any overcorrection. The nomogram was originally designed to provide a 70% astigmatic magnitude correction to minimize the risk for significant overcorrection and so is performing satisfactorily in this respect.

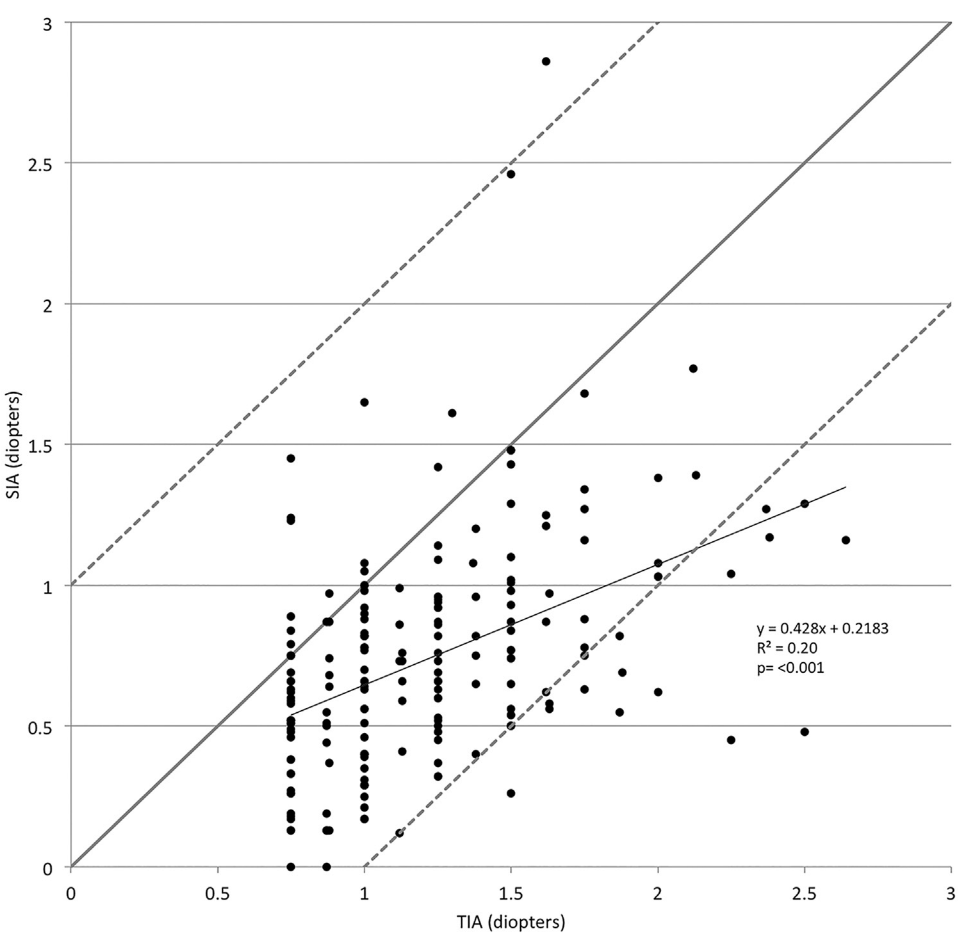

Figure 1. Attempted TIA versus achieved SIA (SIA = surgically induced astigmatism; TIA = target induced astimatism).

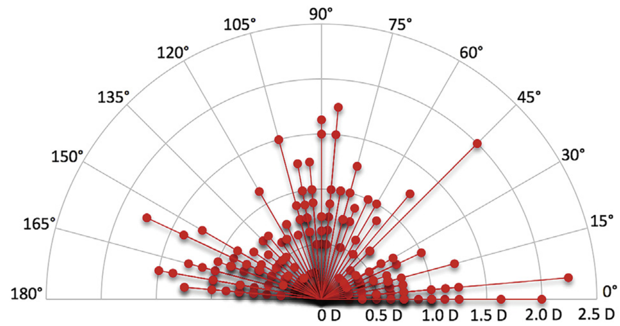

Figure 2. Difference vector showing the additional astigmatic change required to achieve the planned correction.

There are minimal published data on intrastromal AK for comparison, with those limited to a case report[11] or use of femtosecond laser platforms designed primarily for refractive corneal surgery rather than cataract surgery.[10] Data on 54 eyes having cataract surgery and penetrating femtosecond laser AK using the Victus system (Bausch & Lomb Inc.) was recently published.[9] This used a bespoke nomogram with a single AK paired with the main wound. There was a mean preoperative astigmatism of 1.33 D and a mean postoperative astigmatism of 0.87 D with a mean correction index of 0.86 $\pm$ 0.52. Although the correction index was higher compared with our findings (correction index 0.62 $\pm$ 0.32), there was greater variability in AK efficacy and a higher rate of overcorrection.

As seen in Figure 1, there were between-eye variances in astigmatism vector reduction, which was in part expected based on previous studies of manual astigmatic keratotomy.[16,17] Further understanding of the factors influencing intrastromal AK efficacy are required for nomogram refinement and to optimize outcomes. In our series, corneal cylinder overcorrection occurred in a low number of eyes, and we found no difference in age, sex, or laser system intrastromal AK arc length for those with astigmatism correction of greater than

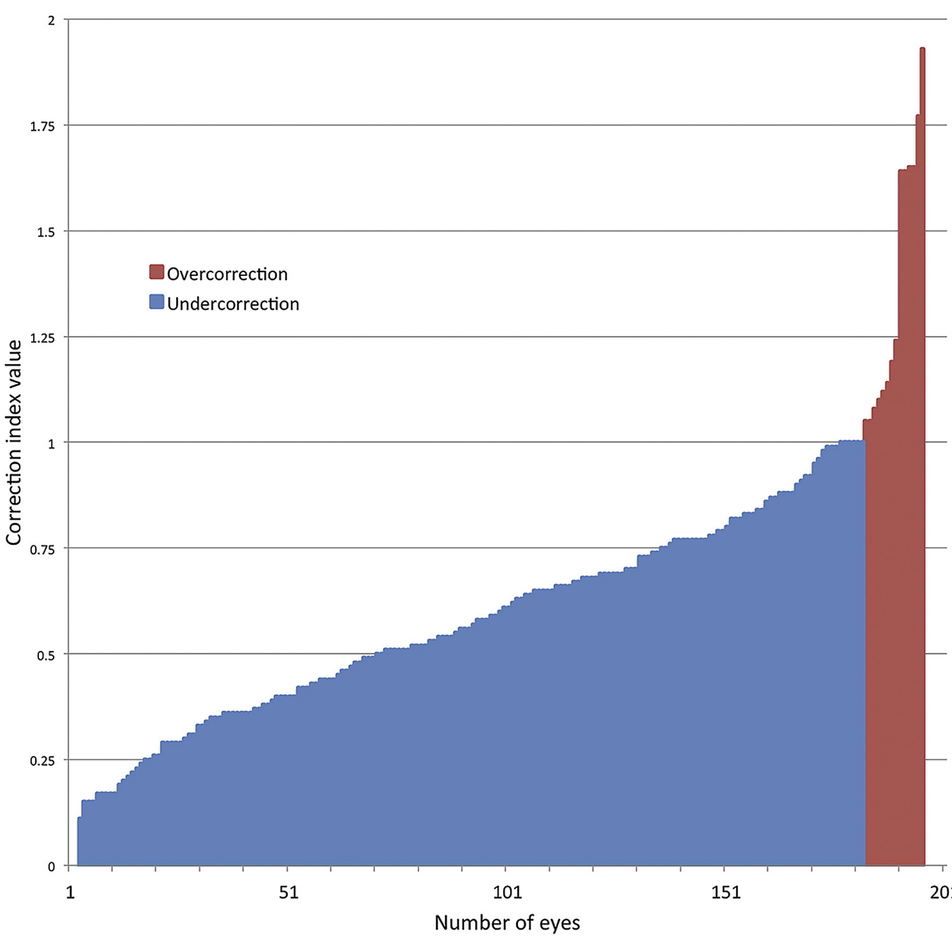

Figure 3. Correction index values by number of eyes (<1.0 indicates undercorrection, >1.0 indicates overcorrection).

Table 4. Percentage of eyes with corneal astigmatism by group.

Exam	≤0.50 D	≤1.0 D	>1.0 D
Preoperative	0	48.5	51.5
Postoperative	32.1	85.7	14.3

100% and those with less than 100% astigmatism correction. Corneal cylinder overcorrection following intrastromal AK has been previously reported for the laser system platform, presumed to be due to vertical gas breakthrough and anterior penetration of an arc.[18] Corneal internal perforation with a flat anterior chamber has also been reported, but we had no full-thickness intrastromal AK in our series.[19] In our analyses, the angle error interquartile range was 26 degrees, and this represents the angle between the intended axis and the axis of the actual incisional effect. This value is similar to that reported for manual LRIs[20] and is a result of imperfect intrastromal AK placement or variations in intrastromal AK construction or efficacy. In the recent study by Chan et al. of penetrating femtosecond AK using the Victus platform, the angle error was implicated as a cause of variability in AK efficacy.[9] Laser AK has the potential for more consistent creation as manual blade AKs are of nonuniform depth over their arc length.

Automated identification of the steep corneal meridian for femtosecond AK placement would be beneficial to improve astigmatic axis accuracy and future outcomes. Other factors that may contribute to angle error include variation in corneal pachymetry by location, with midperipheral corneal thickness being greater in the superior and nasal regions than in the inferior and temporal regions.[21]

For the coupling measures, we found that the intrastromal AK coupling ratio and coupling constant were 0.56 and −0.01, respectively, with a total spherical shift of 0.00 D. For comparison, Alpins et al.[15] found excimer laser treatments to have a coupling ratio of approximately 0 and a coupling

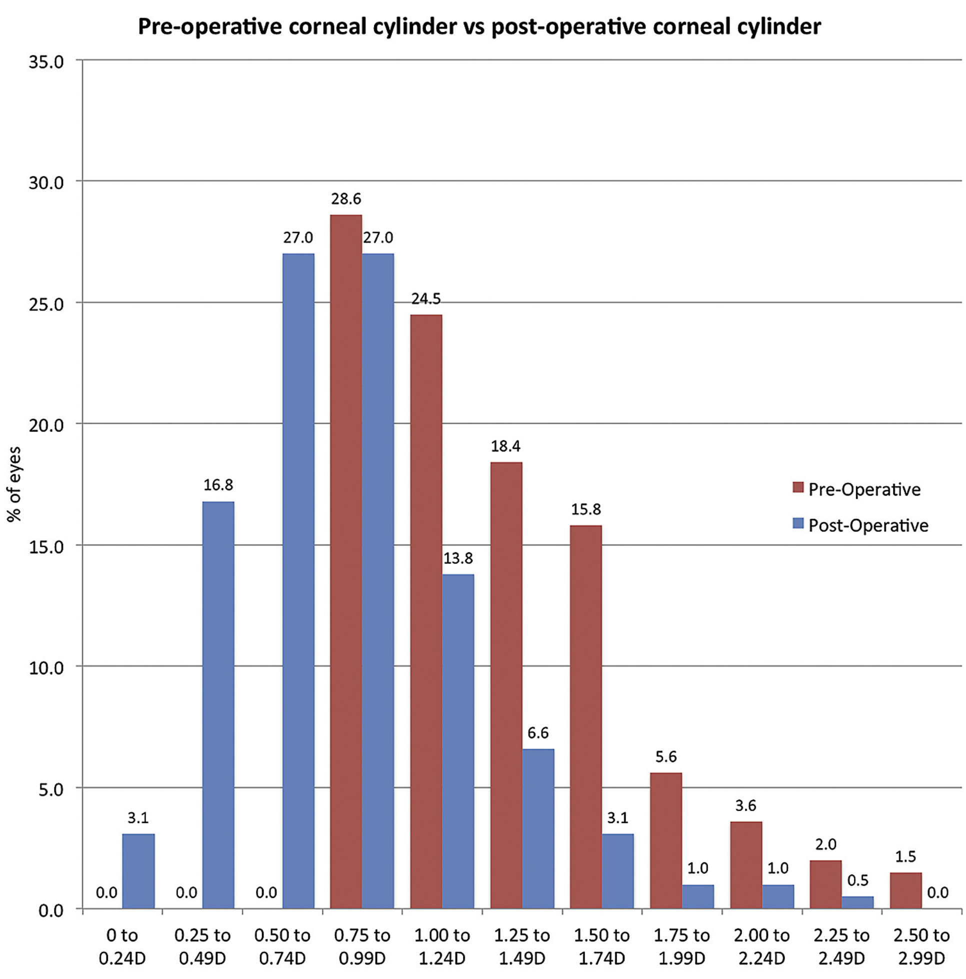

Figure 4. Preoperative and postoperative corneal astigmatism.

constant of approximately 0.5. For LRIs, the coupling ratio and constant were approximately 1.0 and 0, respectively. Alpins et al. observed large variability in the distributions of the coupling ratio and coupling constant values for LRIs, and we also found high variability in the values for intrastromal AK. We have calculated the coupling measures described using the Alpins method,[15] which is different from that described by, for example, Faktorovich et al.[22]

This study had a number of limitations. First, follow-up was limited to 1 month, and it is possible that the effect of intrastromal AK will progress or regress with time. As with any new procedure, long-term follow-up is needed. Progression of the intrastromal AK effect is thought to be unlikely due to intact Bowman and Descemet layers. In addition, for manually created peripheral corneal relaxing incisions, regression of the effect has been reported between 1 month and 6 months postoperatively,[23] with stability reported between 10 weeks and 3 years in a recent retrospective case series.[24] Another limitation of our study was that the clear corneal main wound incision and 2 side ports have their own SIA. Thus the SIA presented in this paper are those from the sum of the incisional SIA and the intrastromal AK. Exploration of individual intrastromal AK outcomes would require a representative control arm to isolate an intrastromal AK effect. Also, we considered only anterior corneal curvature to quantify corneal astigmatism that originates from both the anterior and posterior corneal surfaces. Intrastromal AKs are expected to have some potential issues, including transecting corneal nerves with consequent reduced corneal sensation within the arcs that may be associated with secondary induction of dry eye. Other potential issues include eye rotation or coronal *x*-*y* movement during femtosecond laser delivery following initial planning; possible incomplete cylinder creation due to tissue bridges or gas escape, resulting in no separation of the arc walls; and no effective astigmatic effect (null result). A tilted eye following docking will also result in femtosecond laser energy delivery such that arcs are not orthogonal to the surface. The nomogram that we present should be considered appropriate for astigmatic corrections in our particular patient group, and results may not be directly transferrable to other laser platforms, patient groups, or surgical sites.

Overall, intrastromal AK arcs are easily programmed as an integral part of laser-assisted cataract surgery, can significantly reduce corneal cylinder, and appear to be safe through 1 month of follow-up. The between-eye scatter in cylinder vector reduction was as expected based on previous studies of manual astigmatic keratotomy, and further understanding of the factors influencing intrastromal AK efficacy is required to optimize outcomes.

WHAT WAS KNOWN

- Femtosecond laser intrastromal AKs is effective at reducing astigmatism.

WHAT THIS PAPER ADDS

- Femtosecond laser intrastromal AKs performed during laser-assisted cataract surgery were easily and rapidly produced, significantly reduced corneal cylinder, and appeared to be safe through 1 month of follow-up.
- Between-eye variance in the astigmatism vector reduction was as expected, and further understanding of the factors influencing femtosecond laser intrastromal AK efficacy are required to optimize outcomes.

REFERENCES

1. Hayashi K, Manabe SI, Yoshida M, Hayashi H. Effect of astigmatism on visual acuity in eyes with a diffractive multifocal intraocular lens. J Cataract Refract Surg 2010; 36:1323–1329
2. Dick HB, Krummenauer F, Schwenn O, Krist R, Pfeiffer N. Objective and subjective evaluation of photic phenomena after monofocal and multifocal intraocular lens implantation. Ophthalmology 1999; 106:1878–1886
3. Hoffmann PC, Hütz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. J Cataract Refract Surg 2010; 36:1479–1485
4. Yuan X, Song H, Peng G, Hua X, Tang X. Prevalence of corneal astigmatism in patients before cataract surgery in Northern China. J Ophthalmol 2014:536412 Available at: http://downloads.hindawi.com/journals/joph/2014/536412.pdf. Accessed October 1, 2015
5. Amesbury EC, Miller KM. Correction of astigmatism at the time of cataract surgery. Curr Opin Ophthalmol 2009; 20:19–24
6. Zaldivar R, Davidorf JM, Oscherow S, Ricur G, Piezzi V. Combined posterior chamber phakic intraocular lens and laser in situ keratomileusis: bioptics for extreme myopia. J Refract Surg 1999; 15:299–308
7. Day AC, Gartry DS, Maurino V, Allan BD, Stevens JD. Efficacy of anterior capsulotomy creation in femtosecond laser–assisted cataract surgery. J Cataract Refract Surg 2014; 40:2031–2034
8. Abell RG, Kerr NM, Howie AR, Mustaffa Kamal MAA, Allen PL, Vote BJ. Effect of femtosecond laser–assisted cataract surgery on the corneal endothelium. J Cataract Refract Surg 2014; 40:1777–1783
9. Chan TCY, Cheng GPM, Wang Z, Tham CCY, Woo VCP, Jhanji V. Vector analysis of corneal astigmatism after combined femtosecond-assisted phacoemulsification and arcuate keratotomy. Am J Ophthalmol 2015; 160:250–255
10. Venter J, Blumenfeld R, Schallhorn S, Pelouskova M. Nonpenetrating femtosecond laser intrastromal astigmatic keratotomy in patients with mixed astigmatism after previous refractive surgery. J Refract Surg 2013; 29:180–186

11. Viswanathan D, Kumar NL. Bilateral femtosecond laser–enabled intrastromal astigmatic keratotomy to correct high post-penetrating keratoplasty astigmatism. J Cataract Refract Surg 2013; 39:1916–1920
12. Alpins NA. A new method of analyzing vectors for changes in astigmatism. J Cataract Refract Surg 1993; 19:524–533
13. Alpins N. Astigmatism analysis by the Alpins method. J Cataract Refract Surg 2001; 27:31–49
14. Alpins NA, Goggin M. Practical astigmatism analysis for refractive outcomes in cataract and refractive surgery. Surv Ophthalmol 2004; 49:109–122
15. Alpins N, Ong JKY, Stamatelatos G. Corneal coupling of astigmatism applied to incisional and ablative surgery. J Cataract Refract Surg 2014; 40:1813–1827
16. Agapitos PJ, Lindstrom RL, Williams PA, Sanders DR. Analysis of astigmatic keratotomy. J Cataract Refract Surg 1989; 15:13–18
17. Price FW, Grene RB, Marks RG, Gonzales JS; and the ARC-T Study Group. Astigmatism reduction clinical trial: a multicenter prospective evaluation of the predictability of arcuate keratotomy; evaluation of surgical nomogram predictability. Arch Ophthalmol 1995; 113:277–282
18. Kankariya VP, Diakonis VF, Kymionis GD, Yoo SH. Anterior gas breakthrough during femtosecond intrastromal astigmatic keratotomy (FISK) [letter]. J Refract Surg 2014; 30:511–513
19. Cherfan DG, Melki SA. Corneal perforation by an astigmatic keratotomy performed with an optical coherence tomography-guided femtosecond laser. J Cataract Refract Surg 2014; 40:1224–1227
20. Kaufmann C, Peter J, Ooi K, Phipps S, Cooper P, Goggin M; for the Queen Elizabeth Astigmatism Study Group. Limbal relaxing incisions versus on-axis incisions to reduce corneal astigmatism at the time of cataract surgery. J Cataract Refract Surg 2005; 31:2261–2265
21. Rüfer F, Schröder A, Arvani MK, Erb C. Zentrale und periphere Hornhautpachymetrie—Normevaluation mit dem Pentacam-System [Central and peripheral corneal pachymetry—standard evaluation with the Pentacam system]. Klin Monatsbl Augenheilkd 2005; 222:117–122
22. Faktorovich EG, Maloney RK, Price FW Jr; and the the ARC-T Study Group. Effect of astigmatic keratotomy on spherical equivalent: results of the Astigmatism Reduction Clinical Trial. Am J Ophthalmol 1999; 127:260–269
23. Hirnschall N, Gangwani V, Crnej A, Koshy J, Maurino V, Findl O. Correction of moderate corneal astigmatism during cataract surgery: toric intraocular lens versus peripheral corneal relaxing incisions. J Cataract Refract Surg 2014; 40:354–361
24. Lim R, Borasio E, Ilari L. Long-term stability of keratometric astigmatism after limbal relaxing incisions. J Cataract Refract Surg 2014; 40:1676–1681

OTHER CITED MATERIAL

A. Health Research Authority. Determine whether your study is research. Available at: http://www.hra.nhs.uk/research-community/before-you-apply/determine-whether-your-study-is-research/. Accessed October 1, 2015
B. Stevens J. Intrastromal AK nomogram calculator v3 2015. Available at: www.femtoemulsification.com. Accessed October 1, 2015
C. Alpins N. Planning and Outcomes with ASSORT: Alpins statistical system for ophthalmic refractive surgery techniques. Available at: http://www.assort.com/ASSORT-coupling-calculator.asp. Accessed October 1, 2015

First author:
Alexander C. Day, PhD, FRCOphth

Moorfields Eye Hospital, London, United Kingdom