ARTICLE

Refractive outcomes after limbal relaxing incisions or femtosecond laser arcuate keratotomy to manage corneal astigmatism at the time of cataract surgery

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Purpose: To compare the results of manual limbal relaxing incisions (LRIs) performed during conventional phacoemulsification surgery with those of nonpenetrating femtosecond laser arcuate keratotomies performed during femtosecond laser–assisted cataract surgery to manage corneal astigmatism.

Setting: Guy's and St. Thomas' NHS Foundation Trust, London, United Kingdom.

Design: Randomized case-controlled trial.

Methods: This was a secondary outcome of a randomized controlled trial comparing 400 patients treated with conventional phacoemulsification surgery or femtosecond laser–assisted cataract surgery. All patients with corneal astigmatism greater than 0.9 diopter (D) were offered LRIs or femtosecond laser arcuate keratotomy based on the original randomization. Visual acuity, postoperative refraction, and corneal topography were recorded 4 weeks postoperatively. Vector analysis was performed using the Alpins method.

Results: Fifty-one eyes of 51 patients received LRIs, and 53 eyes of 53 patients received femtosecond arcuate keratotomies. The mean target induced astigmatism was 1.50 D and 1.38 D, respectively, with 1.02 D and 1.23 D surgically induced astigmatism ($P = .21$), resulting in the femtosecond arcuate keratotomy group having a smaller difference vector (1.17 D versus 0.89 D; $P = .02$) and a greater correction index (0.48 versus 0.73; $P = .02$). Forty-four percent of patients in the femtosecond arcuate keratotomy group and 20% in the LRI group attained a postoperative cylinder of less than 0.50 D ($P = .01$).

Conclusions: The femtosecond arcuate keratotomy group achieved a higher correction index and a smaller difference vector. The femtosecond arcuate keratotomy patients showed less postoperative cylinder than LRI patients.

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Corneal astigmatism in patients having cataract surgery is common, with approximately 40% of patients having more than 1.0 diopter (D) and 10% more than 2.0 D of corneal astigmatism.[1] Various techniques have been introduced to decrease corneal astigmatism at the time of cataract surgery and thus reduce postoperative spectacle dependence and maximize uncorrected distance visual acuity (UDVA). These include on-axis incisions supplemented with opposite clear corneal incisions if indicated, limbal relaxing incisions (LRIs), femtosecond laser arcuate keratotomies, toric intraocular lenses (IOLs), and refractive surgery after cataract surgery (bioptics).[2–6]

Limbal relaxing incisions or femtosecond arcuate keratotomies have been found to be efficacious in the management of low to moderate astigmatism (<2.5 to 3.0 D) but are less suitable for moderate to high astigmatism, which requires toric IOLs or bioptics.[7,8] To our knowledge, there are no trials comparing the effectiveness of LRIs with that of femtosecond arcuate keratotomies in the management of low-to-moderate corneal astigmatism at the time of cataract surgery. The purpose of this study was to determine

whether there are differences between laser-delivered and manually delivered keratotomies using vector analysis.[9–12]

PATIENTS AND METHODS

This analysis of refractive outcomes of patients treated with LRIs or femtosecond arcuate keratotomies was performed as a secondary outcome of a prospective randomized interventional case-controlled study at Guy's and St. Thomas' Hospital NHS Foundation Trust, London, United Kingdom. The study was approved by local Research and Development and Cambridge South Research Ethics Committee (reference 16/EE/0180). This study adhered to the tenets of the Declaration of Helsinki.

Specific to this subgroup analysis, any patient with corneal astigmatism greater than 0.9 D based on Scheimpflug tomography (Pentacam, Oculus Optikgeräte GmbH) were offered LRIs or femtosecond arcuate keratotomy as part of their cataract operation based on the initial randomization. Eyes with previous refractive or corneal surgery or corneal pathology were excluded. Partial coherence interferometry (PCI) (IOLMaster 500, Carl Zeiss Meditec AG) was performed to obtain keratometry (K) measurements for IOL formula calculation. Corneal astigmatism was measured using Scheimpflug tomography, and the measurements were used for preoperative astigmatism planning and postoperative analysis. When biometry was not possible on PCI because of the density of a cataract, A-scan ultrasound biometry (Carl Zeiss Meditec AG) was performed. All postoperative results were recorded at the 4-week follow-up.

Surgical Technique

The methods of the study are described in the publication of the main study findings.[A] Eyes were randomized to receive femtosecond laser–assisted cataract surgery or conventional phacoemulsification surgery. Manual limbal markings at 0 degree and 180 degrees were made on all eyes preoperatively with patients a sitting position at the slitlamp. For the markings, a needle was used scratch the corneal epithelium at the limbus; this was followed by the use of a sterile marker pen.

Femtosecond laser–assisted cataract surgery was performed using the Lensx femtosecond laser (Alcon Surgical, Inc.). The femtosecond laser was used to create the capsulotomy and fragment the lens in all patients and intrastromal femtosecond arcuate keratotomy was performed when appropriate. All cataract surgeries were performed using local anesthesia. After the femtosecond laser treatment, the patient was transferred to the operating room for the remainder of the cataract extraction. Phacoemulsification was performed using the Infiniti machine (Alcon Surgical, Inc.) in both groups. Patients having conventional phacoemulsification surgery were prepared for surgery in the same way as those in the laser arm. Instead of receiving laser pretreatment, they were brought straight to surgery and received LRIs at the start of the cataract operation. All operations were performed by experienced surgeons who had completed at least 30 femtosecond laser–assisted cataract surgery procedures (H.W.R., V.K.W., D.P.S.O.).

Limbal Relaxing Incision Group Limbal relaxing incision parameters were calculated based on Donnenfeld's nomogram via an online software program[B] based on the K readings from the Scheimpflug tomographer and the individual surgeon's surgically induced astigmatism (SIA) values. Target induced astigmatism (TIA) was always aimed at 100% correction. Paired arcuate LRIs were always performed; when the surgeon's preference was to operate on axis, the 2.4 mm main wound was positioned in the middle of the LRI. When anatomy or comfort dictated an off-axis approach, the surgeon's SIA was used to modify the LRIs.

A Mendez-style ring was used to mark the steep meridians at the start of the surgery. The LRI incision was made before the commencement of phacoemulsification using a 2.4 mm keratome to incise through epithelium and Bowman layer. Next, a 600 μm guarded diamond knife was used to incise through the stroma. No corneal sutures were placed during the surgery.

Femtosecond Arcuate Keratometry Group Femtosecond arcuate keratotomy parameters were determined by a nomogram previously reported by Day et al.[7] The settings of the femtosecond laser for the arcuate intrastromal incisions were also maintained. Although this nomogram was intended to achieve up to 70% correction only, for ease of interpretation of outcome data, the TIA was defined as a 100% correction with no residual postoperative corneal astigmatism. After the femtosecond laser was docked, the horizontal meridian was manually adjusted in cases of cyclorotation.[13] In cases in which either of the arcuate keratotomies overlapped with the surgeon's planned manual wound, the main section was positioned more peripherally than the arcuate keratotomy so that it would not be involved.

Statistical Analysis

Baseline characteristics were summarized for each treatment arm. Results were analyzed primarily as per intention to treat. For all evaluations of visual acuity as an outcome, patients with visually significant ocular comorbidities were excluded prospectively and those opting for a refractive target other than emmetropia were excluded from analysis of refractive outcome. Snellen visual acuities were converted to logarithm of the minimum angle of resolution notation for analysis.[14] Comparative and descriptive statistical analyses included the Fisher exact test, chi-square test, and Student t tests. All statistical tests used a 2-sided P value of α equal to 0.05 unless otherwise specified. Excel software (Microsoft Corp.) was used for data entry, analysis, and graphic representation. Intraoperative or postoperative complications were defined as any event that involved unintentional trauma to an ocular structure, requiring additional treatment, or having a negative effect on the patient's eyesight.

Analysis of corneal astigmatic outcomes based on corneal topography measurements before and after surgery was performed using the Alpins method,[9–11] with calculation of the 3 following vector parameters: TIA, SIA, and difference vector. Results are presented based on the standardized graphs for reporting the outcomes of refractive surgery and IOL-based refractive surgery.[12,15] Additional parameters calculated included the correction index, coefficient of adjustment, magnitude of error, angle of error, and index of success. The axis of the steep meridian was used throughout.

RESULTS

Four hundred twenty-seven patients were recruited to the study between August 2016 and June 2017 as per the inclusion and exclusion criteria. Twenty-seven patients withdrew from the trial before surgery. Four hundred eyes of 400 patients received surgery between November 2016 and June 2017 (200 conventional phacoemulsification surgery; 200 femtosecond laser–assisted cataract surgery).

Fifty-one eyes of 51 patients in the conventional phacoemulsification group received LRIs, of which 8 were excluded from the UDVA analysis because of visual comorbidities (6 age-related macular degeneration [AMD], 1 amblyopia, and 1 chronic central serous chorioretinopathy). Fifty-three eyes of 53 patients in the femtosecond laser–assisted cataract surgery group received femtosecond arcuate keratotomy, of which 9 were excluded for visual comorbidities (4 AMD, 2 amblyopia, 1 previous retinal detachment, 1 vitreomacular traction, and 1 central retinal vein occlusion).