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Evaluation of Femtosecond Laser Intrastromal Incision Location Using Optical Coherence Tomography

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Purpose: To use optical coherence tomography (OCT) to evaluate the femtosecond laser intrastromal incisions made during cataract surgery to reduce corneal astigmatism.

Design: Retrospective case series.

Participants: Seventy-seven eyes of 77 patients.

Methods: Paired intrastromal incisions were created using the Catalys femtosecond laser (Abbott Medical Optics, Inc., Santa Ana, CA). The planned intrastromal incision parameters were 20% uncut anterior, 20% uncut posterior, midpoint depth of 50%, and 90° side cut angle. Optical coherence tomography scans were obtained 3 weeks or more after surgery to assess these 4 parameters, and actual values were compared with intended values.

Main Outcome Measures: Percentages of uncut anterior and posterior tissue, midpoint depth, and degrees of side cut angle.

Results: The mean values were 17.2±5.8% (range, 7.2%−36.9%) for uncut anterior, 32.5±8.8% (range, 6.0%−57.9%) for uncut posterior, and 42.3±6.6% (range, 25.5%−65.4%) for midpoint depth, which all were significantly different from the planned parameters (all $P < 0.05$). The mean side cut angle was 88.5°±5.6° (range, 71°−114°) and was significantly different from the planned side cut angle of 90° ($P < 0.05$). In 50 eyes that had paired intrastromal incisions scanned by the OCT, there was no correlation between the paired incisions for midpoint depth and side cut angle (correlation coefficient, $r = -0.063$ and -0.067, respectively; $P > 0.05$).

Conclusions: The intrastromal incision midpoint depth was significantly more anterior than the planned depth of 50%. The locations of paired intrastromal incisions in each eye were not correlated. Further improvements are needed to ensure the precise location of the intrastromal incisions made with this device. *Ophthalmology 2017;■:1−6 © 2017 by the American Academy of Ophthalmology*

Optical coherence tomography (OCT) is a noninvasive and powerful imaging technology that can produce cross-sectional images of the anterior and posterior segments of the eye. Anterior segment OCT allows for the visualization of incisions made in the cornea and provides a means to analyze structural changes or the precise location of these incisions. Using anterior segment OCT, several studies have been performed to assess the architectural changes of clear corneal incisions after cataract surgery.[1−7]

Femtosecond laser−assisted corneal incisions have recently been used to reduce corneal astigmatism during femtosecond laser−assisted cataract surgery. The incision may be placed in 2 ways: (1) a penetrating incision penetrates the anterior corneal surface and (2) an intrastromal incision is placed in the stroma without penetrating the anterior and posterior corneal surfaces. The effectiveness of femtosecond laser−assisted penetrating arcuate keratotomy and intrastromal astigmatic keratotomy combined with cataract surgery have been reported previously.[8−10]

Haque et al[11] performed a video review of 28 consecutive eyes of 25 patients who underwent intrastromal limbal relaxing incisions using the Catalys laser (Abbott Medical Optics, Inc., Santa Ana, CA). and reported a high incidence of anterior microperforation in planned intrastromal incisions. Cherfan and Melki[12] reported a case in which a planned intrastromal arcuate incision (20% below the epithelium and 20% above the endothelium) ended up with a full-thickness incision along the entire length of the incision. We are unaware of any published studies evaluating femtosecond laser intrastromal incision location after surgery using OCT. In this study, using an OCT device (RTVue; Optovue, Inc., Fremont, CA), we assessed the location of the femtosecond laser−assisted intrastromal incisions after cataract surgery and compared the actual location with the planned location.

Methods

Participants

Institutional review board approval was obtained for the study, which followed the tenets of the Declaration of Helsinki. Retrospectively, we reviewed consecutive patients who underwent Catalys femtosecond laser−assisted cataract surgery combined with intrastromal incisions between July 2014 and July 2016. Inclusion criteria were (1) patients who had paired intrastromal

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incisions, and (2) at least 1 of the paired intrastromal incisions was visualized and scanned by OCT at 3 weeks or more after cataract surgery. One eye from each participant was included for analysis. If both eyes met the inclusion criteria, the first eye that underwent cataract surgery was included in this study.

Intrastromal Incisions

To determine the arc length of the intrastromal incision, we used the Intrastromal AK nomogram calculator proposed by Julian Stevens (http://femtoemulsification.com/) and modified it to take into account posterior corneal astigmatism. The paired intrastromal incision arc length ranged from 30° to 70°.

All procedures were performed by 1 surgeon (D.D.K.) using the Catalys laser. The laser treatment steps in sequence were capsulotomy (4.8-mm diameter), lens fragmentation (quadrants), and then the intrastromal incisions at the intended meridian. The programmed intrastromal incision parameters were 20% uncut anterior, 20% uncut posterior, and 90° side cut angle at an 8.0-mm optical zone (Fig 1A and B).

Intrastromal Incision Location Evaluation Using Anterior-Segment Optical Coherence Tomography

Three weeks or more after surgery, OCT was used to assess the location of the intrastromal incision in the corneal stroma. Optical coherence tomography scans were performed by 1 of 2 examiners (L.W. and a research coordinator). With the RTVue device, the cross-line scan mode was used to scan the intrastromal incision. The cross line (6 mm in length) first was rotated to the intrastromal incision meridian. For example, if paired intrastromal incisions were placed at 120°, the cross line was rotated along the semi-meridian of 120° to search for the intrastromal incision, with the center of the cross line aligned at the midperiphery of the cornea. In the first few eyes, we scanned the center and both ends of the incision, and we noted that the intrastromal incision architecture was similar at the center and at both sides of the incision; therefore, for subsequent cases, we obtained scans near the center of the incision only. Three scans were obtained for each intrastromal incision, and the one with the clearest image of the intrastromal incision was chosen for analysis.

Using RTVue's built-in calipers, we measured the distances between the following: (1) the anterior corneal surface and the most anterior aspect of the intrastromal incision, (2) the most posterior aspect of the intrastromal incision and the posterior corneal surface, and (3) the anterior corneal surface and the posterior corneal surface parallel to the intrastromal incision (Fig 1C). Additionally, we also measured the side cut angle by (1) placing a line overlapping the intrastromal incision (intrastromal incision line), (2) extending the intrastromal incision line passing the anterior corneal surface, (3) placing a line tangent to the anterior cornea at the point where the intrastromal incision line crosses the anterior corneal surface, and (4) measuring the angle between the intrastromal incision line and the tangent line toward the center of the cornea (Fig 1D). One examiner (the research coordinator) measured the distances and angles on all OCT scans.

Data Analysis

Parameters Evaluated. Based on the measurements obtained from the OCT scans, 4 parameters were evaluated. First, the percentage of intrastromal incision uncut anteriorly was calculated. The mean value was compared with the planned 20% uncut anterior. Second, the percentage of intrastromal incision uncut posteriorly was calculated. The mean value was compared with the planned 20% uncut posterior. Third, depth of the midpoint of the intrastromal incision from the anterior corneal surface was calculated. The mean value of the midpoint depth was compared with the planned value of 50%. Fourth, the angle of the intrastromal incision in degrees was recorded and compared with the planned angle of 90° relative to the corneal surface. For data analysis, all intrastromal incisions scanned by the OCT were included in the whole group. In the subgroup, one intrastromal incision from each eye was included. In eyes with both intrastromal incisions scanned, the first incision that was scanned by the OCT was included in this subgroup analysis.

Statistical Analysis. SPSS for Windows version 12.0 (IBM Corporation, Armonk, NY). was used, and $P < 0.05$ was considered statistically significant. Data distribution for normality was confirmed. A 1-sample *t* test was used to assess whether the mean values of percentage uncut anterior, percentage uncut posterior, percentage midpoint depth, and degree of side cut angle were significantly different from their planned values. Correlation analysis was performed to investigate the association of percentage midpoint depth and degree of side cut angle between the paired intrastromal incisions in each eye. For this analysis, the intrastromal incision located inferiorly, inferotemporally, or temporally was defined as intrastromal incision 1, and the other paired intrastromal incision was called intrastromal incision 2.

Results

We included 77 eyes of 77 patients. The mean age was 70±8 years (range, 47−85 years). Of the 77 eyes, 50 eyes had paired intrastromal incisions visualized and imaged by OCT, and 27 eyes had only 1 intrastromal incision scanned by OCT. In the entire group, 127 intrastromal incisions were scanned by OCT (2 incisions from each of the 50 eyes and 1 incision from the 27 eyes). The mean values were 17.2±5.8% for uncut anterior, 32.5±8.8% for uncut posterior, and 42.3±6.6% for midpoint depth (Table 1). These mean values all were significantly different from their planned values (all $P < 0.05$). Figure 2 shows that most eyes had a midpoint depth that was more anterior than the planned depth of 50%. The mean value for the side cut angle was 88.5°±5.6° and was significantly different from the planned value of 90° ($P < 0.05$). Figure 3 shows the distribution of the side cut angles. In the subgroup with 1 intrastromal incision from each eye, 77 intrastromal incisions from the 77 eyes were scanned by OCT. The mean values for uncut anterior, uncut posterior, and midpoint depth all were significantly different from their planned values (all $P < 0.05$). The mean value for side cut angle was not significantly different from the planned value of 90° ($P > 0.05$; Table 1). In eyes with paired intrastromal incisions scanned by the OCT, there was no correlation between the paired intrastromal incisions for midpoint depth and side cut angle (Pearson correlation coefficient, $r = -0.063$ and -0.067, respectively; both $P > 0.05$; Figs 4 and 5).

Discussion

The effectiveness of femtosecond laser−assisted penetrating arcuate keratotomy and intrastromal astigmatic keratotomy combined with cataract surgery have been reported.[8−10] In this study, we investigated the achieved intrastromal incision depth after surgery using anterior segment OCT and compared the achieved intrastromal incision location after surgery with the intended location.