# Simultaneous Correction of Unilateral Rainbow Glare and Residual Astigmatism by Undersurface Flap Photoablation After Femtosecond Laser-Assisted LASIK

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## ABSTRACT

**PURPOSE:** To report and document a case of successful rainbow glare correction using undersurface ablation of the LASIK flap.

**METHODS:** A 33-year-old woman was treated bilaterally for myopia using femtosecond laser-assisted LASIK with the FS200 femtosecond laser (Alcon Laboratories, Inc., Fort Worth, TX). Postoperatively, she complained of rainbow glare in her right eye, and presented some residual myopic astigmatism. Six months after the initial LASIK procedure, the right eye flap was lifted and a toric excimer correction was delivered on its stromal side.

**RESULTS:** Visual symptoms related to the rainbow glare disappeared immediately after the completion of the procedure and did not reoccur. Uncorrected visual acuity improved by two lines.

**CONCLUSIONS:** Rainbow glare following femtosecond laser-assisted LASIK can be successfully corrected by undersurface ablation of the flap.

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**R** ainbow glare is a rare optical side effect of femtosecond laser-assisted LASIK that was first described in 2008 by Krueger et al.<sup>1</sup> Patients affected by this describe seeing a spectrum of colored bands proceeding in rainbow-like fashion. The effect is most prominent in the dark when looking at pinpoint light sources, such as oncoming automobile headlights at night. The cause of the rainbow glare is thought to be the diffraction of light from the grating pattern created on the back surface of the LASIK flap after femtosecond laser use. To date, this complication has been reported with the **AQ1**FS60 (Abbott Medical Optics, Inc., Santa Ana, CA) and the Wavelight FS200 (Alcon Laboratories, Inc., Fort Worth, TX) femtosecond lasers.<sup>1-3</sup> We report the first case of successful rainbow glare surgical correction using undersurface ablation of the flap for LASIK re-treatment of low residual astigmatism.

## **CASE REPORT**

A 33-year-old woman was referred to our clinic for compound myopic astigmatism correction. Her preoperative corrected distance visual acuity (CDVA) was 20/20 in both eyes, with a refractive correction of -3.50 -1.25 × 180° in the right eye and -3.00 -1.75 × 5° in the left eye. An FS200 femtosecond laser was used to create superiorly hinged elliptical 9.3 × 7.8 mm flaps, followed by excimer laser ablation using the EX500 excimer laser (Alcon Laboratories, Inc.). The FS200 laser settings were identical in both eyes, with a planned interface depth of 130 µm. The bed spots and line separation was 8 µm and the energy was 0.82 µJ. The cornea image in the right eye taken by the FS200 laser camera immediately after the completion of the laser flap creation revealed a subtle raster pattern created by the cavitation bubbles. This was not observed on the left cornea (**Figure 1**).

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**Figure 1.** Energy and spot parameters used for the right eye flap creation with the FS200 femtosecond laser (Alcon Laboratories, Inc., Fort Worth, TX). The snapshot of the right eye taken immediately after the completion of the interface creation is evocative of a raster shot pattern.



**Figure 2.** Observation of hyperreflective zones in an equidistant arrangement, measuring only a few microns at the month 6 examination of the right eye of the patient. This aspect is evocative of the tissular response of the femtosecond laser impacts at the posterior side of the flap: the spacing of the impacts is approximately 8 microns. HRT II image (Heidelberg Engineering, GmbH, Dossenheim, Germany); original magnification, 400  $\times$  400  $\mu$ m.

One day postoperatively, uncorrected distance visual acuity (UDVA) was 20/25 in the right eye and 20/20 in the left eye. In the early postoperative period, the patient complained about colored radiating halos extending laterally and vertically around bright light sources, which were seen with the right eye only. The greatest perceived spectral intensity was noted when bright white light sources, such as the flash light feature of a smartphone, were visualized in a dark environment or against a uniform background. Each radiating band contained a typical rainbow-spectrum color pattern, extending from violetblue to red at its outermost extent. In addition, the patient reported slight blurring of her vision in the right eye. At 1 month postoperatively, UDVA was 20/25 in the right eye and CDVA was 20/20 with a plano (-1  $\times$  180°) lens.

Ocular wavefront and specular topography measurements were obtained using the OPD SCAN III (Nidek, Gamagori, Japan). Anterior axial curvature maps in the right and left eyes showed a central flattened zone without significant irregularities. In the right eye, simulated keratometry showed 1 diopter of with-the-rule astigmatism. High-order aberrations root mean square were 0.44 µm in the right eye and 0.37 µm in the left eye (5.5-mm optical zone). Confocal microscopy of the right and left corneas were obtained using the HRT II confocal microscope equipped with the Rostock corneal module (Heidelberg Engineering, GmbH, Dossenheim, Germany). The acquired two-dimensional image is defined by  $384 \times 384$  pixels covering an area of  $400 \times$ 400  $\mu$ m with lateral digital resolution of 1  $\mu$ m/pixel and digital depth resolution of 2 µm/pixel. On the right cornea, multiple rows of hyperreflective spots appeared at approximately 125 µm below the anterior corneal surface (Figure 2). The horizontal and vertical distances



**Figure 3.** Steps in undersurface of the flap re-treatment. (A) The right eye was draped in a sterile fashion and care was taken to keep the eyelashes out of the surgical field. The peripheral cornea and the corneal center of the entrance pupil were marked with a blunt tip stained with a gentian violet solution. (B) While the patient was asked to look downward, the hinged anterior corneal flap was temporarily elevated and reclined on a flat-domed spatula using a Merocel spongeAQ2. (C) The eye tracker of the EX500 excimer laser (Alcon Laboratories, Inc., Fort Worth, TX) was deactivated, and the photoablation was delivered on the stromal bed, manually centered on the entrance pupil center mark. (D) The laser-treated corneal flap was replaced on the cornea, and the interface irrigated with balanced saline solution before the flap was painted back into position with a wet Merocel sponge. (E) After the completion of the procedure, the patient was asked to describe her visual perception by looking at a bright white light source. The typical rainbow glare pattern, which was present before the surgery, had disappeared immediately after.



**Figure 4.** Disappearance of the hyperreflective spots at the interface depth level. HRT II image (Heidelberg Engineering, GmbH, Dossenheim, Germany); original magnification,  $400 \times 400 \ \mu$ m.

between these zones matched the distance between spots and lines programmed in the FS200 laser (8  $\mu$ m).

Six months later, it was decided to attempt to correct the persistent residual astigmatism and rainbow glare symptoms by performing undersurface ablation of the LASIK flap (Figure 3). A gentian violet pen was used to mark the center of the pupil on the cornea and create lateral marks to improve flap repositioning. A flap rhexis was followed by elevation and turn back of the flap. The patient was asked to look downward and the EX500 excimer laser delivered a 6.50-mm optical zone (9-mm outer diameter) toric ablation plano (-1.00 × 180°) on the stromal portion of the flap. The maximal depth of ablation was 16 µm. The flap was flipped with a cannula back into place, and irrigation of the flap was performed under the flap. A dripping wet MerocelAQ2 sponge was brushed over the surface of the flap to smooth it and remove any excess fluid from the interface. Immediately after the procedure, a white flash light was shone at 50 cm from the patient's right eye. The rainbow glare pattern was no longer perceptible. At days 1 and 30 postoperatively, UDVA was 20/20 with the right eye and the rainbow glare pattern perception did not reoccur. Confocal microscopy examination performed 1 week after undersurface ablation showed no evidence of the prior multiple spot patterns (Figure 4). Corneal toricity (sim-



Figure 5. Comparison between the (left) preoperative and (right) 1-month postoperative undersurface ablation axial curvature map (OPD SCAN III; Nidek, Gamagori, Japan), showing the reduction of the corneal toricity.

ulated keratometry) in the right eye was reduced to 0.54 diopters (Figure 5) and higher-order ocular root mean square was  $0.47 \mu m$ .

#### DISCUSSION

Even with the latest advances in femtosecond laser technology, rainbow glare remains a possible optical side effect related to diffraction of light from the grating pattern created on the back surface of the LASIK flap after femtosecond laser use.<sup>1,2</sup> The diffracted light is composed of the sum of interfering wave components, and the intensity of the pattern created on the retina is the result of the combined effects of interference and diffraction.

The image taken by the FS200 camera after the interface creation was suggestive of a raster pattern for the shot delivery in the right eye (Figure 1), whereas it was not apparent in the left eye. Using in vivo confocal microscopy, we have reported the presence of similar hyperreflective spots after LASIK in a symptomatic eye with rainbow glare in which flaps were also created with the FS200 femtosecond laser.<sup>3</sup> These features, which were still visible 6 months after femtosecond laser surgery, were attributed to tissular response to the femtosecond laser. It was presumed, but not confirmed, that these irregularities were located on the posterior side of the flap. In the current case, the disappearance of visual symptoms and hyperreflective shot pattern in the right eye after undersurface flap ablation reinforces the hypothesis that the uniform array of periodically aligned photodisruption defects are located at the posterior surface of the LASIK flap. Interestingly, preoperative confocal microscopy images of the left eye of our patient did not show any evidence of hyperreflective spots, and there are no clear reasons why rainbow glare occurred in the right eye only.

Maldonado reported in 2002 that undersurface ablation of the flap for LASIK re-treatment of low residual myopic and astigmatic refractive errors seemed safe and effective.<sup>4</sup> This method was primarily intended to prevent future keratectasia in cases where there is insufficient posterior stroma for additional treatment but adequate flap stroma. Other reports have confirmed that this method was effective for retreatments<sup>5,6</sup> or when combined with LASIK in eyes with high myopia and thin corneas.<sup>7,8</sup> Our observation suggests that undersurface ablation may be an effective method to suppress the symptoms related to rainbow glare.

Our approach to simultaneous correction of residual myopic astigmatism and rainbow glare was based on the assumption that the grating pattern on the back surface of the LASIK flap would be eliminated by the excimer photoablation. Our success suggests that undersurface ablation may be an effective method to reduce the symptoms related to rainbow glare. In eyes presenting with persistent and visually impairing rainbow glare symptoms, the deliverance of a planar ablation (eg, phototherapeutic keratectomy) on the stromal side of the LASIK flap may also be a valid option. Presumably, the depth of such photoablation would not need to be very high to smooth the femtosecond laser grating pattern. In this case, a maximal depth of ablation of 16 µm was sufficient to relieve visual symptoms.

We report the first case of successful undersurface ablation of rainbow glare occurring after femtosecond laser-assisted LASIK. Further cases are necessary to confirm these findings. Consequently, further investigation is necessary to evaluate its clinical impact and effect on the visual function, and to better understand the factors contributing to it.

#### **AUTHOR CONTRIBUTIONS**

Study concept and design (DG); data collection (DG, EG, HR, AS); analysis and interpretation of data (DG); writing the manuscript (DG); critical revision of the manuscript (DG, EG, HR, AS)

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# **AUTHOR QUERIES**

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