Unilateral Rainbow Glare After Uncomplicated Femto-LASIK Using the FS-200 Femtosecond Laser

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ABSTRACT

PURPOSE: To report a case of rainbow glare following femtosecond laser-assisted LASIK (femto-LASIK) with the Wavelight FS-200 femtosecond laser (Alcon Laboratories, Inc., Fort Worth, TX).

METHODS: A patient was treated bilaterally for myopia with femto-LASIK using the FS-200 femtosecond laser. Postoperatively, he complained of rainbow glare in his right eye.

RESULTS: Three months postoperatively, the induced grating pattern (hyperreflective spot-like zones corresponding to the surgeon-programmed spot and line separation distance of the FS-200 femtosecond laser) was demonstrated with confocal microscopy at the level of the flap interface in the right eye.

CONCLUSIONS: This is the first report of rainbow glare following femto-LASIK with the FS-200 femtosecond laser documented with in vivo confocal microscopy.

Unilateral Rainbow Glare After Uncomplicated Femto-LASIK Using the FS-200 Femtosecond Laser

Rainbow glare is a mild optical side effect of femtosecond laser-assisted LASIK (femto-LASIK). It was first described in 2008 by Krueger et al. using the 15-kHz IntraLase femtosecond laser (IntraLase Corp., Irvine, CA). The cause of the rainbow glare was defined as the diffraction of light from the grating pattern created on the back surface of the LASIK flap after femtosecond laser exposure. The patients reported seeing a spectrum of colored bands radiating from a white-light source when viewed in a dark environment, as in a nighttime setting. The first study describing rainbow glare found an incidence of 19.07% with an older model of the laser, which included an increasing numerical aperture of the focusing optics, resulting in a smaller working distance under the cone. The incidence of rainbow glare with this model decreased to 2.32%. A subsequent study reported an incidence of rainbow glare of 5.8% with a newer generation model (IntraLase FS 60 kHz). We report the first case of rainbow glare with a different femtosecond laser platform (FS-200 Wavelight; Alcon Laboratories, Inc., Fort Worth, TX), in which the visual symptoms were correlated with the histopathology findings.

CASE REPORT

A 28-year-old man was referred to our office for the management of visual symptoms without loss of uncorrected distance visual acuity in the right eye after bilateral uneventful femto-LASIK. He had undergone uncomplicated bilateral LASIK at a private refractive surgery center for full correction of myopia with astigmatism 3 months prior to presentation.

The flap and the excimer laser parameters used for the LASIK correction were retrieved from the patient’s medical records at the private center. A FS-200 Wavelight femtosecond laser was used to create superiorly hinged 9-mm flaps followed with excimer laser ablation using the EX-500 excimer laser AQ1. The corrections entered in the EC-500 laser software were -3.75 -0.50 × 62° in the right eye and -3.75 -0.50 × 68° in the left eye. One day postoperatively, uncorrected distance visual acuity was 20/30 in the right eye and 20/20 in the left eye. One month postoperatively, uncorrected distance visual acuity was 20/20 in both eyes.

The FS-200 laser settings were identical in both eyes, with a planned interface depth of 100 µm and a flap diameter of 9.5 mm. The bed spots and line separation were 7.5 µm, and the energy 0.8 µJ. The image taken by the FS-200 laser camera immediately after the completion of the laser flap creation demonstrated a subtle raster pattern created by the cavitation bubbles on the right cornea; this was not observed on the left cornea (Figure 1).

In the early postoperative period, the patient complained about colored radiating haloes extending laterally and vertically around bright light sources. These disturbances were seen with the right eye only. The greatest perceived spectral intensity was noted when bright white light sources were visualized in a dark environment or uniform background. The patient volunteered to draw his subjective visual perception as he was watching an illuminated white bulb at a distance of 1 meter. Using image-creation software, the patient drew six lateral and two vertical equally spaced chromatic bands (Figure 2). Each radiating band contained...
a typical colored rainbow spectrum, which extends from violet-blue closer to the light source to red at its outermost extent.

Ocular and corneal wavefront measurements were obtained using the OPD SCAN III (Nidek, Gamagori, Japan). Left and right anterior axial curvature maps showed a central flattened zone without significant irregularities: high-order aberrations root mean square were 0.45 and 0.41 µm in the right and left eyes, respectively. Confocal microscopy of the right and left corneas were obtained using the HRT II confocal microscope equipped with the Rostock corneal module AQ1. The acquired two-dimensional image is defined by $384 \times 384$ pixels covering an area of $400 \times 400$ µm with lateral digital resolution of 1 µm/pixel and digital depth resolution of 2 µm/pixel. At approximately 40 µm below the epithelium basal layer on the right cornea, hyperreflective spots appeared in an equidistant horizontal arrangement, measuring only a few microns (Figure 3). The horizontal and vertical distances between these zones matched the distance between spots and lines programmed in the FS-200 laser (7.5 µm). Thus, the aspect found strongly suggested that it corresponded to tissular response to the femtosecond laser impacts. It was not possible to identify whether these presumed impacts were exactly located at the posterior side of the flap.

**DISCUSSION**

Rainbow glare is an optical side effect after LASIK primarily caused by the diffraction of light. It is believed to be caused by the grating pattern created on the back surface of the LASIK flap after femtosecond laser exposure. A diffraction grating is an optical component
with a periodic structure, which splits and diffracts light into several beams travelling in different directions. The directions of these beams depend on the spacing of the grating and the wavelength of the light, so that the grating acts as the dispersive element. As the incident light is refracted and diffracted by the cornea on the way from its source to the fovea, the gratings created by the femtosecond laser spots are of ‘transmission’ type. 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. A diffraction grating has a ‘zero-order mode’ (where \( m = 0 \)), in which there is no diffraction and a ray of light behaves according to the laws of refraction. The relationship between the grating spacing and the angles of the incident and diffracted beams (non-zero order modes, \( m \geq 1 \)) of light is known as the grating equation. When light is normally incident on the grating, the diffracted light will have maxima at angles \( \theta_m \) given by this equation: 

\[
d \sin \theta_m / \lambda = m \lambda/n,
\]

where \( \theta_m \) is the angle between the diffracted ray and the grating’s normal vector, \( d \) is the distance from the center of one slit to the center of the adjacent slit, and \( m \) is an integer representing the propagation mode of interest. When looking at a white-light source positioned at a distance of 1 m in a dark environment, our patient noted the spectral bands for red extended from a distance of 85.0 mm. Using the previous equation and \( \lambda = 640 \) nm, we calculated a grating pattern spacing of 7.90 \( \mu \)m, which is close to the programmed value of spot separation (7.50 \( \mu \)m), and corresponds to the spacing dimensions observed on confocal microscopy.

One morphologic study has reported the presence of a raster pattern at the interface after femto-LASIK flap creation, but others failed to demonstrate such pattern at the interface level or at the back of the flap.

Using in vivo confocal microscopy, similar hyper-reflective spots have been observed after LASIK in asymptomatic eyes in which flaps were created with the IntraLase femtosecond laser. These features, which disappeared between day 7 and month 2, were attributed to tissular response of the femtosecond laser impacts at the posterior side of the flap. In our patient, these images were still visible 3 months after femtosecond laser surgery.

The quality of the focused beam and numerical aperture of the focusing optics appears to be the most significant factor in minimizing the diffractive dispersion of light that leads to this symptom. In previous studies, the relationship between length of time from a service call and the incidence of rainbow glare emphasized the importance of a proper maintenance and alignment of the optical components used to focus the beam. Although we could not have access to this infor-
mation, it is intriguing that the occurrence of the rain-
bow glare symptoms was unilateral, despite identical
energy and spot separation parameters for the right and
left eyes. The image taken by the FS-200 camera after
the interface creation was suggestive of a raster pat-
tern for the shot delivery in the right eye (Figure 1B),
whereas it was not apparent in the left eye (Figure 1A).
How this immediate appearance after the interface cre-
ration relates to the occurrence and persistence of the
symptoms of our patient remains to be elucidated. The
presence of hyperreflective shot pattern in the right eye
and its absence in the left eye confocal microscopy ex-
amination reinforces the hypothesis that the uniform
array of periodically aligned photodisruption defects
acts as a likely source of the grating pattern, resulting
in diffractive light scatter.

We report the first case of rainbow glare occurring
after femto-LASIK using a FS-200 femtosecond laser.
The case was documented with in vivo confocal mi-
croscopy images evocative of a diffractive pattern cre-
ated by the raster spot pattern and consecutive tissular
response arrangement. Even with the latest advances
in femtosecond laser technology, rainbow glare re-
 mains a possible optical side effect. Consequently, fur-
ther 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 (EG, DG, HR, AS); analysis and interpretation of data (DG); drafting of the manu-
script (DG); critical revision of the manuscript (EG, DG, HR, AS);

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**AUTHOR QUERIES**

AQ1  Please provide the name and location of the manufacturer.