Characteristics of Straylight in Normal Young Myopic Eyes and Changes before and after LASIK

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PURPOSE. To investigate the characteristics of straylight and relevant factors in normal young myopic eyes and to assess changes in straylight and possible influencing factors before and after laser in situ keratomileusis (LASIK).

METHODS. In this prospective nonrandomized study, 105 eyes of 105 patients were included. The level of straylight was measured with a straylight meter, and relationships with some optic parameters were analyzed in normal young myopic eyes. The difference between postoperative and preoperative straylight and the relationship with ablation were studied before and 1, 4, and 10 months after LASIK surgery.

RESULTS. For normal eyes, sphere, astigmatism, keratometric (K) value, corneal central thickness (CCT), and anterior chamber depth (ACD) showed no significant correlation with straylight. However, straylight values showed a statistically significant increase 1 and 4 months after surgery (P < 0.05) but returned to preoperative levels at 10 months after surgery (P > 0.05) in LASIK eyes. No statistically significant relationship was found between straylight values and ablation depth, ablation ratio, residual bed thickness (RBT), or RBT/CCT (P > 0.05) after surgery.

CONCLUSIONS. Specific optic parameters (refractive power, K value, CCT, and ACD) have no significant correlation with straylight. Although straylight increased during the early postoperative period, the parameter returned to preoperative levels over time. (Invest Ophthalmol Vis Sci. 2011;52:3069–3073) DOI:10.1167/iovs.10-6270

In recent years, more and more studies have focused on visual performance and optic quality after various surgeries, especially after refractive surgery. The complicated combination of many factors set the optical quality of the visual system, including ocular aberrations, diffraction, and scatter. Many studies have focused on wavefront aberrations and the influence on the quality of vision, whereas intraocular light scatter has rarely been studied. We concentrated our study on light scatter.

Straylight is a functional measure of the effect of light scatter across the retina. The phenomenon is complex and depends on the level and the turbidity of the ocular media. All light reaching the eye is scattered to some extent when it passes through the structures of the eye. This scattering causes a veil of light called straylight, resulting in a degraded quality of vision. In short, straylight corresponds to the light that reaches the retina but does not contribute to normal image formation. It can also be described as being related to the point spread function (PSF): A large-angle domain >1° creates a veiling luminance over the entire retina, which results in glare. The central peak of PSF is mostly affected by optical aberrations, such as defocus, astigmatism, and other higher order aberrations. The direct measurement of light scatter is difficult in the living eye. An instrument using a psychophysical method proposed by Van den Berg (in Franssen et al.) for clinical use has facilitated the study of intraocular straylight. Use of this technique has shown straylight to increase with age and to depend on pigmentation in normal eyes. A recent study investigated the dependency of straylight on ocular biometry and found that it increases with axial length but has no correlation with keratometry and corneal astigmatism or with iris color.

A few studies of intraocular straylight have been performed after corneal refractive surgery, and no significant increases were observed after LASIK. Theoretically, alterations to the corneal structure and flap-related optical imperfections after corneal refractive surgery should increase straylight. In a previous study, we found a significant increase in straylight values during the early postoperative period after LASIK. It could increase dramatically in eyes with complications of corneal refractive surgery in ways that impair corneal transparency (e.g., epithelial ingrowth and corneal subepithelial haze) and in patients with other ocular diseases, such as cataract, retinitis pigmentosa, and choroideremia.

The factors contributing to intraocular straylight have not been extensively investigated. The influence of corneal refractive surgery on straylight should be clarified and further investigated. This study was therefore designed to determine the effect of various optic parameters on straylight and to investigate changes in straylight after LASIK.

METHODS

Patients

This study was a prospective nonrandomized study of 105 patients (60 women and 45 men; age 23.97 ± 5.51 years [mean ± SD], range, 18–36), 60 of whom were scheduled to undergo LASIK. The protocol adhered to the tenets of the Declaration of Helsinki and received approval from an institutional review board. Informed consent was obtained from each subject after a thorough discussion of the benefits and the known risks of the procedure. In 105 young myopia patients, the mean preoperative spherical equivalent (SE) of refraction was −5.40 ± 1.76 D (range, −10.25 to −1.63), with mean astigmatism of −0.62 ± 0.53 D (range, −2.00 to 0). The mean keratometric value, central corneal thickness (CCT), and anterior chamber depth (ACD) were 43.50 ± 1.37 D (range, 38.10–46.20), 545.39 ± 24.10 μm (range, 486–601), and 3.26 ± 0.25 mm (range, 2.47–3.71), respectively. In 60 patients who underwent the LASIK procedure, the mean ablation depth was 78.55 ± 12.99 μm (range, 29–105). The ablation ratio, residual bed thickness (RBT), and RBT/CCT were calculated.
according to ablation depth and CCT. The preoperative examination included uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA), manifest and cycloplegic refraction, intraocular pressure (IOP), topography, slit lamp microscopy, and dilated indirect funduscopes. The preoperative values for keratometry, CCT, and ACD were acquired by the Scheimpflug tomography system (Pentacam; Oculus GmbH, Wetzlar, Germany). All enrolled patients were confirmed to have stable refraction and to be free of ocular and systemic disease. Contact lens wear was discontinued 2 weeks before LASIK for soft lenses or 4 weeks before LASIK for hard lenses.

**Straylight Examination**

The straylight meter (C-Quant; Oculus GmbH) is a newly developed instrument used to measure retinal straylight. It uses the compensation comparison method proposed by Van den Berg. It is a modification of previous versions of the instrument and implements the direct compensation method. This apparatus provides direct information about intraocular forward light scatter. The test field is divided into halves: Compensation light is presented to one (randomly chosen) half of the test field, while no compensation light is presented to the other half. There is a bright, ring-shaped, flickering light source corresponding to a 7° scattering angle. Because of light scattering in the eye, part of the flickering light from this ring also reaches the center of the retinal projection of the ring. As a result, two flickers are perceived that differ in modulation depth: One results from straylight only, and the other is a combination of straylight and compensation light, flickering in counterphase with the straylight. Because of a change in average luminance of the stimulus and counterphase modulating light, the straylight value of the respective eye is approached when the halves are balanced. The subject’s responses are recorded by a two-alternative, forced-choice procedure. A psychometric curve is fitted to the subject’s responses, from which the log (straylight parameter), estimated standard deviation (ESD), and quality factor (Q) can be deduced. The measurement can be considered reliable when ESD and Q are lower than 0.08 and higher than 1.00, respectively. Straylight values are expressed as log(s). Higher values indicate more straylight.

All measurements were performed under low-mesopic conditions. Each eye was measured with pupils undilated and with compensation of refractive error. During the test, a series of limited-duration stimuli were presented. The task for the subject was to decide, for each stimulus, which half of the test field flickered more strongly. The subject’s response was recorded by pushing one of two buttons, representing the left and right test fields.

**Surgical Technique**

All LASIK procedures were performed in eyes under topical anesthesia. A microkeratome (model M2; Moria SA, Antony, France) was used to create a superior-hinged, 110-µm flap measuring 9.0 mm in diameter. The flap was superiorly reflected, and the stromal bed was ablated with an excimer laser system (Star S4; VISX, Inc., Santa Clara, CA). After photoablation, the flap was replaced on the stromal bed, and the interface was irrigated. An optic zone of 6.0 or 6.5 mm with an 8-mm transition zone was applied in all cases.

**Postoperative Treatment**

Patients who underwent LASIK had follow-up examinations at 1, 4, and 10 months after surgery. The postoperative assessment included measurements of uncorrected and best spectacle-corrected visual acuity, manifest refraction, topography, and straylight, as well as slit lamp microscopy. Postoperative medication included a combination of topical antibiotic eye drops (ofloxacin 0.5% for 1 week) and topical steroid eye drops (fluorometholone 0.1% for 4 weeks). The fluorometholone was administered as 1 drop four times daily for the first week, three times daily for the second week, twice daily for the third week, and once daily for the last week.

**Statistical Analysis**

Monocular data (right eye) were analyzed and are presented as the mean ± SD (SPSS ver. 13.0; SPSS, Chicago, IL). The Kolmogorov-Smirnov test was used to check the normality of all data; only astigmatism failed normality testing. Comparisons of the preoperative and postoperative straylight values were performed with one-way analysis of variance (ANOVA). The Pearson (r) or the Spearman (p) correlation coefficient was used to evaluate the correlations between variables. P < 0.05 was regarded as statistically significant.

**RESULTS**

In 105 young myopia patients, the analysis showed that the mean straylight was 0.93 ± 0.14. The correlations between straylight values and sphere, astigmatism, SE, K value, CCT, and ACD were analyzed. There was no association between any two of these variables (P > 0.05). Table 1 shows the mean values for parameters and the correlation coefficient for the amount of straylight. To exclude the influence of age and other ocular diseases, we included only young and healthy myopic eyes. Figure 1 shows the distribution of straylight in the normal young myopic eyes.

Table 2 shows the pre- and postoperative straylight outcomes in LASIK eyes. The preoperative straylight log values differed significantly with respect to values measured at 1 month and 4 months (P < 0.0001 and P < 0.0001), but not at 10 months (P = 0.45) after surgery. No significant difference was noted between value sets obtained at 1 and 4 months after surgery (P = 0.15). Both the 1- and 4-month measurements were significantly higher than the 10-month postoperative values (P = 0.01 and P = 0.0001). The dependency of straylight on time after LASIK surgery is shown in Figure 2. Figure 3 shows 10-month postoperative straylight values versus preoperative values. Figure 4 shows the time curves for straylight increases of more than 0.2 log units at 4 months after LASIK.

Table 3 shows the data for ablation depth, ablation ratio, RBT, and RBT/CCT. After investigating the correlation of postoperative straylight values and related changes with ablation depth, ablation ratio, RBT, and RBT/CCT, respectively, we found no statistically significant relationship (P > 0.05).

### Table 1. Preoperative Data and the Correlation with the Amount of Straylight

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>r (p)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphere, D</td>
<td>−5.09 ± 1.67</td>
<td>−9.25 to −1.50</td>
<td>−0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>Astigmatism, D</td>
<td>−0.62 ± 0.55</td>
<td>−2.00 to 0</td>
<td>−0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Spherical equivalent, D</td>
<td>−5.40 ± 1.76</td>
<td>−10.25 to −1.63</td>
<td>−0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>Keratometric value, D</td>
<td>43.30 ± 1.37</td>
<td>38.10 to 46.20</td>
<td>−0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>Central corneal thickness, mm</td>
<td>545.39 ± 24.10</td>
<td>486 to 601</td>
<td>0.11</td>
<td>0.26</td>
</tr>
<tr>
<td>Anterior chamber depth, mm</td>
<td>3.26 ± 0.25</td>
<td>2.47 to 3.71</td>
<td>0.17</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Straylight in Normal Young Myopic and Post-LASIK Eyes

No significant clinically visible complications existed in any case. The mean postoperative visual acuity was 20/20 or better in each eye.

DISCUSSION

Straylight is scattered over the retina by intraocular structures, such as the cornea, lens, iris, and intraocular media. Lens scatter increases with age and increases in patients with cataracts.23 Corneal light scatter is constant with age10 but may change with corneal defects or after corneal refractive surgery.

In normal eyes, there are many factors that may be associated with straylight. Previous studies found intraocular straylight to increase with age and to depend on eye pigmentation. Rozema et al.13 recently concluded that retinal straylight increases with axial length but found no correlation with keratometry or corneal astigmatism. Based on our findings, there seemed to be no strong association between straylight and K value or astigmatism, in agreement with the findings of Rozema et al. Furthermore, we detected no correlation with SE, CCT, or ACD.

After LASIK surgery, we detected a significant increase in the mean straylight values 1 and 4 months after LASIK; however, these values returned to preoperative levels 10 months after LASIK. Our results were inconsistent with those described by Beerthuizen et al.15 and Lapid-Gortzak et al.14 In the study by Beerthuizen et al., for which the sample size was smaller than that in the present study, the authors evaluated 12 eyes that had undergone LASIK. These eyes revealed no significant change in straylight values 1 month after surgery; however, four eyes in the group displayed an increase in straylight of more than 0.15 log units. Recently, Lapid-Gortzak et al. showed that straylight values 3 months after LASIK were slightly lower than baseline, on average. One consideration is that the mean preoperative level of straylight was higher than that observed in a normal population, because most patients wore contact lenses up to a few days before preoperative testing. Contact lens wear may cause increased straylight measurements, even after the lenses have not been worn for a while.24 In the present study, few patients had worn contact lenses, and so no preoperative elevation was present.

For patients who underwent LASIK, it is assumed that the changes in straylight values after LASIK were caused by the following factors. First, the cornea retains its transparency as a result of a regular collagen fiber lattice arrangement that compensates for light scattering.25 The creation of a corneal flap, laser ablation on the stromal bed, and corneal wound healing may disturb the lattice arrangement of the fibers and the cells of the cornea, causing elevated levels of straylight. A combination of stromal remodeling, the mismatch between flap and stromal areas,26 and changes in the cellular and molecular morphology after surgery may be responsible for increased light scatter. Second, the presence of microfolds and particles at the interface level after LASIK has been described in many studies based on confocal microscopy.27–29 Confocal microscopy has revealed regular alterations after surgery, including microfolds (most often found on Bowman’s layer and sometimes in the anterior stroma) as well as particles located at the interface level with variable reflectivity. The microfolds, which are not clinically visualized, may result from stretching of the flap during surgery or from impaired compatibility of the flap to the reformed stromal bed.27 The potential origin of the material in the flap interface includes sources such as metal from the microkeratome blade, cotton from the swabs, lipids

Table 2. Pre- and Postoperative Straylight Values

<table>
<thead>
<tr>
<th>Log(s)</th>
<th>Pre- (n = 60)</th>
<th>Post 1 mo (n = 57)</th>
<th>Post 4 mo (n = 39)</th>
<th>Post 10 mo (n = 26)</th>
<th>Post 1 m – Pre</th>
<th>Post 4 m – Pre</th>
<th>Post 10 m – Pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>0.94 ± 0.14</td>
<td>1.06 ± 0.13</td>
<td>1.10 ± 0.13</td>
<td>0.97 ± 0.14</td>
<td>0.11 ± 0.16</td>
<td>0.16 ± 0.17</td>
<td>−0.01 ± 0.16</td>
</tr>
<tr>
<td>Range</td>
<td>0.63–1.37</td>
<td>0.80–1.40</td>
<td>0.83–1.34</td>
<td>0.68–1.28</td>
<td>−0.20–0.70</td>
<td>−0.21–0.54</td>
<td>−0.30–0.31</td>
</tr>
</tbody>
</table>

* P < 0.05, changes in straylight values at 10 postoperative months were significant compared with values at 1 and 4 months. Post 1 m – Pre, Post 4 m – Pre, Post 10 m – Pre were calculated by subtracting straylight values before surgery from those at 1, 4, and 10 months after surgery, respectively.
or inflammatory cells from the tear fluid, or epithelial remnants carried to the interface by the microkeratome. Lapid-Gortzak et al. also evaluated some cases of increased straylight. Biomicroscopy revealed physical findings (e.g., microstriae of the flap, haze, and interface debris) that may explain the increase in straylight levels.

The results of our study confirmed that visual acuity, slit lamp examination results, and backward light scatter are not directly related to straylight. Although both the 1- and 4-month measurements were significantly higher than the preoperative values, mean postoperative visual acuity was 20/20 or better in all cases. One reason for this finding is that straylight is caused by irregularities, with magnitudes on the order of the wavelength of visible light. Small irregularities (in the micrometer range) influence straylight but not visual acuity. Van den Berg also showed that visual acuity correlates rather weakly with the amount of scatter. The evaluation of visual acuity sometimes leads to overestimations of visual quality, especially in cases of media turbidity. In addition, slit lamp examination revealed no clinically visible complications in our patients, despite elevations in straylight levels. Clinical slit lamp examination is a rather poor tool with which to evaluate stromal alterations after LASIK. Moreover, backward light scatter (from the eye toward the light source), which can be assessed by slit lamp examination, is distinct from forward light scatter (from the light source toward the eye), which can cause reduced vision. Backward scatter has little relationship with forward scatter. Straylight measurement provides an indication of the amount of forward light scatter. Forward and backward light scatter are therefore not expected to exhibit close correlation.

It can be concluded that certain aspects of optical quality may be affected subclinically after LASIK, although corneas may appear transparent clinically. This change may not be noticed by the patient. Patients may report visual disturbance after surgery that resulted in improved UCVA. Scattered light could reduce vision in two ways. First, light from the object is scattered and reduces the contrast of the retinal image. Second, glare symptoms are generally caused by wide-angle light scatter from a peripheral glare source; this glare produces a veiling luminance on the retina and further reduces the contrast of the retinal image.

In our study, an increase in intraocular straylight was experienced during the early post-LASIK period, followed by a gradual return to preoperative values. Morphologic changes at the flap interface after surgery may be responsible for the straylight shift after LASIK. However, this study did not include ultrastructural or histologic evaluations. Further studies with confocal microscopy may be useful for identifying the factors that contribute to straylight changes after corneal refractive surgery.

References


