Objective: To evaluate the quality of vision (visual acuity and straylight) in patients with Fuchs dystrophy and the improvement in visual quality after Descemet stripping endothelial keratoplasty (DSEK).

Methods: There was an observational case series (Amsterdam group) and a prospective interventional case series (Mayo group). Corrected distance visual acuity (CDVA), straylight, and corneal thickness were measured in patients with phakic and pseudophakic eyes with Fuchs dystrophy recruited at the Academic Medical Center, Amsterdam, the Netherlands (99 eyes), and at Mayo Clinic, Rochester, Minnesota (48 eyes). The Mayo group was also examined at 1, 3, 6, and 12 months after DSEK; all these eyes were rendered pseudophakic during DSEK.

Results: Eyes with Fuchs dystrophy had decreased CDVA (mean [SD], 0.42 [0.26] logMAR; Snellen equivalent 20/53) and increased straylight (mean [SD], 1.54 [0.24] logarithm of the straylight parameter) compared with normal eyes. Younger patients were affected more by increased straylight than by decreased CDVA. Corrected distance visual acuity ($r=0.26; P=.003; n=135$) and straylight ($r=0.26; P=.003; n=133$) were correlated with corneal thickness. Corrected distance visual acuity and straylight improved at all postoperative examinations ($P<.001$), and improvement in straylight from before DSEK to 12 months after DSEK correlated with recipient age ($r=-0.43; P=.01; n=33$). Improvement in straylight was more predictable than that of CDVA and was associated with preoperative straylight more than 1.33 logarithm of the straylight parameter.

Conclusions: Quality of vision is severely impaired in patients with Fuchs dystrophy and improves significantly after DSEK. Straylight improves more in younger than in older eyes after DSEK. Preoperative straylight can be a useful clinical metric to predict postoperative improvement, especially in cases where preoperative visual acuity is close to 20/20.

host cornea. In a previous study, we found that straylight trended toward improvement after DSEK but we were unable to verify this statistically because of a small sample size. As a result, we were unable to determine the clinical utility of measuring straylight in patients with Fuchs dystrophy and, specifically, if straylight could be an indicator of whether surgical intervention would be beneficial.

In this study, we determined the effect of Fuchs endothelial dystrophy on quality of vision, as assessed by visual acuity and straylight. We combined 2 groups of subjects with Fuchs dystrophy from 2 institutions to increase the number of subjects over a broad age range; both groups had standardized visual acuity and straylight measurements. In addition, we determined the improvement in quality of vision after DSEK in one of these groups, which was larger and had longer postoperative follow-up than previously reported, with the goal of assessing whether straylight could be a useful metric in the clinical evaluation of patients with Fuchs dystrophy.

### METHODS

#### SUBJECTS

All subjects were patients who had corneal guttatae with or without corneal edema, consistent with a diagnosis of Fuchs endothelial dystrophy. Two groups of patients were recruited at 2 sites. The first group had Fuchs dystrophy and was recruited at the Academic Medical Center, Amsterdam, the Netherlands; this group will be called the "Amsterdam group." A second group of patients, who had Fuchs dystrophy requiring DSEK, was recruited from the Cornea Service at Mayo Clinic, Rochester, Minnesota; this group will be called the "Mayo group." Patients were excluded from either group if they had other eminent ocular pathology, including decreased vision from any cause other than cataract. The study complied with the tenets of the Declaration of Helsinki, and all subjects gave informed consent to participate. Institutional review board approval was obtained at both sites.

#### DSEK PROCEDURE

Patients in the Mayo group were in a prospective study and were examined before and after DSEK. The surgical procedure has been described previously. Preoperatively, all eyes were either pseudophakic or had lenticular changes justifying cataract extraction, and postoperatively all eyes were pseudophakic. Postoperative follow-up was at least 6 months, and only 37 eyes were examined at 12 months because 1 patient had died, 2 patients had withdrawn from the study, 1 graft had failed after 6 months, and 6 eyes had not yet reached the 12-month examination.

#### OUTCOME MEASURES

The severity of Fuchs dystrophy was assessed by measuring central corneal thickness with an ultrasonic pachymeter (DGH-1000; DGH technologies Inc, Frazer, Pennsylvania). High-contrast corrected distance visual acuity (CDVA) was measured in both groups by using the Early Treatment Diabetic Retinopathy Study protocol and was reported as logMAR.

Functional forward light scatter was measured in both groups by using the Oculus C-Quant straylight meter (Oculus GmbH, Wetzlar, Germany, or Oculus, Lynwood, Washington) and was reported as the logarithm of the straylight parameter [log(s)]. This measurement is based on the psycho-physical “compensation comparison” technique and has been described in detail elsewhere. Briefly, the test consists of a computer-controlled 2-alternative forced-choice protocol. Straylight is a psychophysical measurement that is proportional to forward light scatter; a higher value indicates more straylight (more sensitivity to glare). The test is repeatable, and the instrument supplies a reliability index, called the “estimated standard deviation,” for each measurement. The standard deviation of repeated log(s) measurements has been approximately 0.07 log unit when using the instrument’s reliability test. Straylight of phakic eyes with Fuchs endothelial dystrophy was compared with that of age-matched normal subjects. Normal data for straylight values as a function of age for healthy eyes were generated by measuring 3182 eyes without comorbidity of a population of European drivers. Straylight of pseudophakic eyes with Fuchs endothelial dystrophy was compared with that of normal pseudophakic eyes, because the influence of the aging crystalline lens was absent in these eyes. A recent study of 56 normal pseudophakic eyes that had undergone uncomplicated cataract surgery showed that the age-related regression for straylight in pseudophakic eyes was log(s) = 0.003 × Age + 1.13, with subject age measured in years.

### STATISTICAL ANALYSIS

All statistical analyses were performed in Excel (Microsoft Corp, Redmond, Washington) or SPSS version 16.0.2 (SPSS Inc, Chicago, Illinois). Correlations were examined by using the bivariate Pearson method or when data were not normally distributed, the Spearman coefficient. A P value of less than .05 was considered statistically significant, and unless otherwise stated, all tests were 2-tailed. Straylight in patients was compared with straylight in age-adjusted normal subjects by using an unpaired t test.

#### SUBJECTS

Ninety-nine eyes of 66 patients with Fuchs endothelial dystrophy were included in the Amsterdam group; some fellow eyes were not included because they had had a previous penetrating keratoplasty or DSEK. Sixty-three eyes of 44 patients had mild to moderate cataract and 36 eyes of 30 patients were pseudophakic. Mean (SD) age in the Amsterdam group was 67 (11) years (range, 44-84 years) in the patients with phakic eyes and 72 (12) years (range, 40-92 years) in the patients with pseudophakic eyes (Table 1). Forty-eight eyes of 41 patients with Fuchs endothelial dystrophy were enrolled in the Mayo group and all underwent DSEK. Nine eyes were pseudophakic preoperatively, and 39 eyes had a cataract that justified extraction and was extracted at the same time as the DSEK procedure. Postoperatively, all eyes had posterior chamber lenses without posterior capsule opacification. Mean (SD) age at the time of surgery was 67 (10) years (range, 41-87 years) (Table 1).

#### VISUAL ACUITY

Corrected distance visual acuity was similar between the Amsterdam and preoperative Mayo groups (Table 1). In Fuchs dystrophy, CDVA was correlated with age, with better CDVA being associated with younger patients (Am-
Table 1. Visual Quality and Corneal Thickness in Phakic and Pseudophakic Eyes With Fuchs Endothelial Dystrophy in the Amsterdam and Mayo Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Eyes</th>
<th>Age, y, Mean (SD) [Range]</th>
<th>CDVA, logMAR, Mean (SD) [Snellen Equivalent]</th>
<th>Straylight, Log(s)</th>
<th>Central Corneal Thickness, µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phakic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All eyes</td>
<td>102</td>
<td>66 (9) [41-84]</td>
<td>0.39 (0.23) [20/49]</td>
<td>1.55 (0.26)</td>
<td>677 (62)</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>63</td>
<td>67 (11) [44-84]</td>
<td>0.39 (0.25) [20/49]</td>
<td>1.53 (0.25)</td>
<td>696 (65)</td>
</tr>
<tr>
<td>Mayo</td>
<td>39</td>
<td>64 (8) [41-83]</td>
<td>0.40 (0.21) [20/50]</td>
<td>1.57 (0.26)</td>
<td>655 (51)</td>
</tr>
<tr>
<td>Pseudophakic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All eyes</td>
<td>45</td>
<td>73 (12) [40-92]</td>
<td>0.48 (0.26) [20/60]</td>
<td>1.51 (0.18)</td>
<td>653 (64)</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>36</td>
<td>72 (12) [40-92]</td>
<td>0.45 (0.28) [20/56]</td>
<td>1.53 (0.19)</td>
<td>650 (67)</td>
</tr>
<tr>
<td>Mayo</td>
<td>9</td>
<td>78 (8) [58-87]</td>
<td>0.56 (0.14) [20/73]</td>
<td>1.42 (0.17)</td>
<td>660 (51)</td>
</tr>
</tbody>
</table>

Abbreviations: CDVA, corrected distance visual acuity; log(s), logarithm of the straylight parameter.

a Sample size = 35 because straylight measurements were unreliable in 4 eyes.
b Sample size = 8 because straylight measurements were unreliable in 1 eye.

Table 2. Visual Quality Before and After DSEK for Fuchs Endothelial Dystrophy

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Eyes</th>
<th>Age, y, Mean (SD) [Range]</th>
<th>CDVA, logMAR, Mean (SD) [Snellen Equivalent]</th>
<th>Straylight, Log(s)</th>
<th>Central Corneal Thickness, µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before DSEK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amsterdam</td>
<td>63</td>
<td>67 (11) [44-84]</td>
<td>0.40 (0.21) [20/49]</td>
<td>0.35 (0.21) [20/45]</td>
<td>0.27 (0.20) [20/37]</td>
</tr>
<tr>
<td>Mayo</td>
<td>39</td>
<td>64 (8) [41-83]</td>
<td>0.40 (0.21) [20/50]</td>
<td>0.27 (0.20) [20/37]</td>
<td>0.23 (0.17) [20/34]</td>
</tr>
<tr>
<td>All eyes</td>
<td>102</td>
<td>66 (9) [41-84]</td>
<td>0.39 (0.23) [20/49]</td>
<td>0.35 (0.21) [20/45]</td>
<td>0.27 (0.20) [20/37]</td>
</tr>
<tr>
<td>After DSEK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amsterdam</td>
<td>63</td>
<td>67 (11) [44-84]</td>
<td>0.39 (0.25) [20/49]</td>
<td>0.27 (0.20) [20/37]</td>
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<td>73 (12) [40-92]</td>
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<tr>
<td>After DSEK</td>
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<td>Amsterdam</td>
<td>63</td>
<td>67 (11) [44-84]</td>
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<td>0.27 (0.20) [20/37]</td>
<td>0.23 (0.17) [20/34]</td>
</tr>
</tbody>
</table>

Abbreviations: CDVA, corrected distance visual acuity; DSEK, Descemet stripping endothelial keratoplasty; log(s), logarithm of the straylight parameter.

a P < .001.
b For straylight, unless otherwise indicated, data were unreliable in some eyes, reducing the number of eyes available for analysis.

Corneas were thicker in the Mayo group than in the Amsterdam group: 642 (8) µm (range, 572-779 µm) in the preoperative Mayo group, 662 (11) µm (range, 549-837 µm) in the Amsterdam group, and 655 (5) µm (range, 532-779 µm) in the preoperative Mayo group. Although corneas appeared slightly thicker in the Mayo group, this difference was not statistically significant. Preoperative central corneal thickness (r = 0.26; P = .003; n = 133) and CDVA (r = 0.26; P = .003; n = 133) were correlated with central corneal thickness (Figure 6).

**CORNEAL PACHYMETRY**

The distribution of central corneal thickness was remarkably similar between the Amsterdam and Mayo groups. Mean (SD) corneal thickness was 683 (105) µm (range, 549-837 µm) in the Amsterdam group and 662 (46) µm (range, 572-779 µm) in the Mayo group. Although corneas appeared slightly thicker in younger patients, the difference was not statistically significant. Preoperative central corneal thickness (r = 0.26; P = .003; n = 133) and CDVA (r = 0.26; P = .003; n = 133) were correlated with central corneal thickness (Figure 6).

**COMMENT**

In this study, we found that quality of vision was decreased in subjects with Fuchs endothelial dystrophy, with...
older subjects being affected by decreased visual acuity more than younger subjects, and younger subjects being affected by increased straylight compared with older subjects. After DSEK, mean visual acuity and straylight improved, but the improvement in straylight was greater in younger subjects than in older subjects. This study is important because it corroborates anecdotal clinical experiences that some younger patients with Fuchs dystrophy can have symptoms of increased straylight despite having good visual acuity and that endothelial keratoplasty can be a reasonable treatment to improve straylight.

Quality of vision (CDVA and straylight) of the subjects with Fuchs endothelial dystrophy was similar between the Amsterdam and Mayo groups (Table 1).

Younger subjects with Fuchs dystrophy with decreased quality of vision often maintained good CDVA but had increased straylight compared with age-matched normal subjects. Although increased straylight has typically been associated with scattered light induced by lenticular changes and cataract, these changes are typically not advanced in younger subjects. In Fuchs dystrophy, because the anterior and posterior cornea are a significant source of scattered light, increased straylight in the younger subjects probably resulted from the abnormal cornea, explaining why these subjects might be bothered by symptoms of poor contrast and glare. In contrast, our results indicated that quality of vision in the older subjects with Fuchs dystrophy was impaired by decreased visual acuity because straylight was similar to that of age-matched normal subjects. However, because many of the older subjects in this study had cataracts sufficient to degrade visual acuity because straylight was similar to that of age-matched normal subjects. Nevertheless, that straylight in the pseudophakic eyes with Fuchs dystrophy in our study was higher than that of otherwise normal pseudophakic eyes (Figure 3) is further evidence that increased straylight can at least partly be attributed to the cornea in Fuchs dystrophy.
Straylight and CDVA significantly improved after DSEK, and the improvement was greater in patients with poorer preoperative straylight and visual acuity. Visual recovery after DSEK is limited in part by the surgical lamellar interface and chronic host corneal changes associated with long-standing endothelial dysfunction. Of interest, the improvement in straylight from before DSEK to 12 months after DSEK was greater with younger recipient age (Figure 4), further indicating the importance of straylight. The regression line (\(y = 0.93x - 1.24\), where \(y\) is the postoperative improvement and \(x\) is preoperative straylight) highlights that eyes with preoperative straylight higher than 1.33 log(s) (1.24/0.93) can be expected to improve after Descemet stripping endothelial keratoplasty. Zero improvement is denoted by the dotted line.

Straylight Improvement, log(s)

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The distribution of corneal thickness was similar between the Amsterdam and Mayo groups. Although there were significant correlations between central corneal thickness and CDVA in both groups, the predictive value \(r^2 = 0.07\) was low, indicating that quality of vision cannot be judged from central corneal thickness. Seitzman et al. also found that decreased CDVA was associated with increased corneal thickness in patients with Fuchs dystrophy, with particular deterioration of CDVA when corneal thickness exceeded 640 µm.

In summary, the subjects with Fuchs endothelial dystrophy in the Amsterdam and Mayo groups experienced remarkably similar quality of vision. Corrected distance visual acuity, straylight, and central corneal thickness were all comparable between these 2 groups. Consequently, the conclusions drawn for the postoperative Mayo subjects may also be valid for the Amsterdam subjects. Straylight symptoms dominate visual impairment in younger patients with Fuchs dystrophy, even in the presence of acceptable visual acuity. Because straylight and CDVA are 2 separate aspects of visual function, straylight is a useful independent measurement of visual function and easily measured in the clinic.

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Correspondence: Ivanka J. E. van der Meulen, MD, Department of Ophthalmology, A2 Room 123.1, Academic Medical Center, Meibergdreef 9, 1100 DD Amsterdam, the Netherlands (i.j.vandermeulen@amc.uva.nl).

Author Contributions: Drs van der Meulen, Patel, McLaren, and van den Berg had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Financial Disclosure: Dr Lapid-Gortzak has been a consultant for Alcon and received speaker’s fees from Al-
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