Straylight in anterior segment disorders of the eye
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Chapter 3
STRAYLIGHT MEASUREMENTS IN CONTACT LENS WEAR

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ABSTRACT

Purpose
1) to quantify the effect of contact lens wear on straylight in rigid and soft contact lens wearers and 2) to relate findings to morphological changes and subjective complaints.

Methods
Straylight was measured using the Oculus C-Quant during contact lens wear and after contact lens removal in 30 rigid contact lens wearers and 30 soft contact lens wearers. Semi-quantitative (0-4) slitlamp grading of anterior segment changes using Efron grading scales and contact lens characteristics were performed. Subjects answered a straylight questionnaire.

Results
Soft contact lens wearers had a mean straylight of \( \log(s) = 0.934 \) during contact lens wear and after contact lens removal (comparable to \( \log(s) = 0.938 \) of age-matched normal eyes). Rigid contact lens wearers had a mean straylight during contact lens wear of \( \log(s) = 1.167 \). After contact lens removal, \( \log(s) \) significantly decreased to 0.997 \( (P < 0.01) \). Straylight values with rigid contact lenses were strongly increased \( (P < 0.001) \) compared with age-matched normal eyes; after contact lens removal, these values decreased but remained elevated. Straylight in rigid contact lens wearers correlated with the amount of deposits on the contact lens \( (P < 0.01) \) but not with other variables of the contact lens score. The questionnaire showed more straylight complaints in rigid contact lens wearers than in soft contact lens wearers \( (P < 0.01) \).

Conclusion
Rigid contact lens wear leads to increased straylight during contact lens wear and after contact lens removal. This may be because of subclinical effects of contact lens wear on the cornea and is not seen in soft contact lens wearers.
INTRODUCTION

Glare disability can be a problem among contact lens wearers. Straylight is the known source of disability glare and is assumed to be caused by the cornea for 1/3, by the lens for 1/3 and by sclera and retina for 1/3 in young healthy eyes. Contact lenses may influence this process by mechanical effects on corneal structures and disturbance of normal corneal physiology, which can lead to (sub)clinical corneal edema in early stages of contact lens wear and after lens adaptation. The resulting loss of corneal transparency may cause increased corneal light-scattering and thus straylight, being the functional result of light-scattering in the optical media. An effect of the contact lens itself on the amount of straylight could also be present because rigid lens material, size, or fit might affect intraocular light-scatter in rigid contact lens wearers. The present article focuses on the occurrence of contact lens-related straylight problems in present-day habitual contact lens wearers.

Although previous studies show a potential influence of contact lens wear on quality of vision, variable and sometimes confusing or contradictory results are presented. In a study on five hydrogel lens wearers using a two-channel tachistoscope with separate point glare source, significant contact lens-induced increase in glare-related visual disability was found in all cases. However, a subsequent study using the same apparatus on 15 subjects confused the authors by demonstrating an increase, no difference, or a decrease in disability glare during hydrogel contact lens wear. Lohmann et al measured forward scattered light with a computerized technique, which generated a series of concentric annuli on a video graphics display, based on the direct compensation method of van den Berg. Ten hydrophilic lens wearers and five rigid lens wearers were included. Forward light-scatter was increased considerably in hydrophilic contact lens wearers but remained close to normal values for rigid lens wearers. Several wearers of soft contact lenses had decreased low-contrast visual acuity and contrast sensitivity as well. Other studies have used the direct compensation method without modifications to measure the amount of straylight. In hydrophilic lens wearers, slightly increased light-scatter scores were found after contact lens removal. Rigid contact lens wearers showed increased light-scatter scores during contact lens wear, which normalized after contact lens removal. A study by Nio presented data on 8 subjects with low myopia wearing soft contact lenses and 7 subjects with high myopia wearing rigid contact lenses. Both groups had increased straylight values during contact lens wear. These relatively old studies were handicapped by smaller numbers of subjects, the use of older contact lens types and older versions of glare testers or straylight meter. Previous types of glare testers often provided unreliable results with poor repeatability or inadequate discriminative ability to detect small but significant changes in light-scattering, as can be expected with contact lens wearers. Subject bias and learning effects could not be excluded.
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Contact lenses are frequently used to correct refractive disorders; their effect on quality of vision is therefore an important health care issue and needs to be documented in a reliable way. Also in refractive surgery, preoperative quality of vision denominators are important in evaluating treatment effect. Because many candidates for refractive surgery are contact lens wearers, this study bears relevance to the above issue. The recently developed Oculus C-Quant is an accurate and clinically useful instrument, which is able to objectively measure the amount of intraocular scattered light. This approach gives highly repeatable results for untrained subjects over a wide range of straylight values. Previous studies have shown that there is no learning process involved in repeated measurements. The purpose of this study was to clarify and quantify effects of contact lenses on quality of vision by 1) including a larger sample than has been included thus far of rigid and soft contact lens wearers without other ocular pathology, 2) measuring straylight without bias using the C-Quant, 3) investigating the relation between straylight and anterior eye segment changes by documenting tissue responses to contact lens wear with the Efron grading scales, and 4) documenting subjective complaints of contact lens wearers using a straylight questionnaire.

MATERIALS AND METHODS

Thirty volunteers wearing rigid gas permeable contact lenses and thirty volunteers wearing soft contact lenses were included in the study. Because all rigid contact lenses prescribed today are gas permeable, these contact lenses will be referred to as rigid contact lenses throughout this article. Contact lens material and size represented a (random) selection of contact lenses used by people living and working around Amsterdam. Ninety percent of soft contact lens wearers used monthly disposable soft contact lenses. All soft contact lenses had diameters between 14.0 and 14.5 mm. Water content in the soft contact lens group ranged from low to high water content, with oxygen permeability (Dk) varying between 5-10 and 30. Mean age of rigid contact lenses was 1.4 years (standard deviation 0.9 years, range 0.6 to 3.4 years) at the time of measurement. Several other aspects of these rigid contact lenses were taken into consideration separately in the contact lens score, which is explained below. Mean diameter of the rigid contact lenses was between 9.0 and 10.0 mm.

All subjects had visual acuity of at least 6/7.5 and no ocular or systemic pathology. Both eyes of all patients were included. All subjects were established contact lens wearers of at least six months and most of them habitual wearers. The study was performed according to the Declaration of Helsinki and gained approval from the Medical Ethical Committee of the Academic Medical Center in Amsterdam, the Netherlands. After purpose and nature of the study were explained, a signed consent form was obtained from each participant.

All subjects answered a questionnaire concerning subjective complaints of dry eyes and contact lens type, age, and handling characteristics. The questionnaire included five questions.
Straylight measurements in contact lens wear specifically regarding straylight complaints during contact lens use, which was created based on clinical practice. (Table 3.1) While subjects were wearing their contact lenses, visual acuity and straylight measurements were performed for each eye separately. A semi-quantitative (0-4) slitlamp grading of contact lens movement, diameter, wetting, deposits, damage, central fluorescein image (rigid lenses), peripheral clearance (rigid lenses), and keratometer image (soft lenses) was recorded by the contact lens practitioner. Immediately after contact lens removal, straylight measurements were repeated and corneal pachymetry was registered. Best-corrected visual acuity with glasses was determined. Behind the slitlamp, grading of contact lens-related complications of the anterior segment of the eye was performed using the Efron grading scale.13,14

Table 3.1 Straylight questionnaire.

<table>
<thead>
<tr>
<th>Straylight questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have difficulty seeing what is ahead of you when you drive into a tunnel during</td>
</tr>
<tr>
<td>the daytime?</td>
</tr>
<tr>
<td>Do you have difficulty seeing what is ahead of you when an oncoming car has bright</td>
</tr>
<tr>
<td>headlights on at night?</td>
</tr>
<tr>
<td>Do you have difficulty seeing what is ahead of you when a low sun is shining in your</td>
</tr>
<tr>
<td>eyes during the daytime?</td>
</tr>
<tr>
<td>Did you stop driving a car because of the above-mentioned problems?</td>
</tr>
<tr>
<td>Do you have trouble recognizing faces against the light?</td>
</tr>
</tbody>
</table>

Subjects answered these questions with a grading of 0 to 5, where 0 indicated most complaints and 5 no complaints at all.

In fifteen soft contact lens wearers, the measurements were repeated 1 hour after contact lens removal. Fourteen of these subjects had repeated measurements 2 hours later and 3 subjects 24 hours after contact lens removal. Twelve rigid contact lens wearers were rechecked after 1 hour, 9 of them after 3 hours, and 2 after 24 hours. Deposits on the contact lens or contact lens size were expected to influence the amount of straylight, especially in rigid contact lens wearers. In three rigid contact lens wearers, straylight measurements were performed 1) with the subject’s own rigid contact lenses, followed by 2) with brand new rigid lenses with the same diameter, and 3) with brand new rigid lenses with a large diameter (12.0 mm).

Visual acuity was determined with the Early Treatment of Diabetic Retinopathy Study chart (which measures logarithm of minimum angle of resolution acuity), according to the modified Early Treatment of Diabetic Retinopathy Study protocol.15 Corneal pachymetry was measured using a scanning slit topography by a noncontact pachymeter (Orbscan II; Bausch & Lomb), which automatically detected the thinnest value. Earlier studies have shown the reliability and usefulness of this system in corneal research and clinical settings.16 Functional forward light-scatter was objectified using the Oculus C-Quant, developed by van den Berg17,18 and according to previously reported techniques.11 The measurement is based on the psychophysical
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“compensation comparison” technique. In short, the compensation comparison method works as follows: the subject looks at a central test field subdivided in two halves, one with and one without counterphase compensation light. A flickering ring surrounds this test field. Intraocular light-scattering causes part of the flickering light from this ring to reach the center of the retinal projection of this ring. The subject perceives this as (faint) flickering in the central test field. The added counterphase compensation light can silence this flickering and causes a difference in modulation between the two halves of the central test field. The subject’s task is a forced choice comparison to identify which half shows the strongest flicker. A psychometrical response curve is computed from the subject’s responses. Values are expressed as the logarithmic value of the straylight parameter, log(s). Higher log(s) values indicate more straylight and more sensitivity to glare. In the healthy aging eye, straylight values increase with age mostly because of lenticular changes. Under 40 years of age, a normal value for log(s) is 0.9.19 This value increases to log(s) = 1.2 at age 65, which corresponds to a doubling in the amount of straylight.19 For the correct interpretation of straylight values, the age effect has to be taken into consideration. The same instrument was used for all straylight measurements under the same ambient conditions. The technique gives a reliability control by means of the expected standard deviation or ESD. Only reliable measurements defined as ESD <0.1 log units were included, resulting in actual repeated measures standard deviations of around 0.07 log units. Each eye was measured twice, and results were averaged. To check whether a learning effect occurs with repeated straylight measurements, results of second measurements were compared with those of first measurements. Straylight values of contact lens wearers were compared with a control group of healthy eyes measured with the same instrument. The increase of straylight values with age in this group was comparable to previously published results after correction of the age effects (mean log(s) = 0.938).19 Results on the contact lens wearers will also be presented after correction of the age effects. The Efron grading scale is designed to provide a simple and convenient means to record the severity of anterior segment complications of contact lens use behind the slitlamp.13 Common complications are depicted by artist-rendered full colour images, in five stages of increasing severity – from grade 0 (normal) to grade 4 (severe). The contact lens complications shown in the Efron grading scale are: conjunctival redness, limbal redness, corneal neovascularisation, epithelial microcysts, corneal edema, corneal staining, conjunctival staining, papillary conjunctivitis, blepharitis, meibomian gland dysfunction, superior limbic keratoconjunctivitis, corneal infiltrates, corneal ulceration, endothelial polymegathism, endothelial blebs, and corneal distortion. The clinical use and validation of this grading scale has been described in detail previously.13,14 In this study, straylight was compared with the separate scores of the corneal complications. These were expected to have the largest influence on straylight changes. We also compared straylight with the total score of all graded complications of the Efron grading scale.
We used custom software (SPSS version 12.0) to process raw data. To determine whether there was a significant difference in straylight between the two groups with and without wearing their contact lenses, we used a paired t-test. Correlations were calculated with the bivariate Pearson method.

RESULTS

Mean age of soft contact lens wearers was 31.7 years (range 21 – 57 years) and of rigid contact lens wearers 37.7 years (range 18 – 60 years). Straylight increases with age mainly because of physiological aging of the human lens. For our statistical data analysis, we used the straylight measurements corrected for the age effect.

Soft contact lens wearers had a mean straylight of log(s) = 0.934 while wearing their contact lenses. (Figure 3.1) The change in log(s) after contact lens removal was virtually zero, so no significant change in straylight occurred immediately after contact lens removal or during any of the periods in which testing took place (1, 3, and 24 hours after contact lens removal) (Table 3.2). Straylight values with and without contact lenses were largely within 95% confidence limits of age-matched normal eyes. Mean corneal pachymetry after contact lens removal was 546 µm (range 484 – 622 µm), mean contact lens score was 0.30 (range 0 – 1.14) and mean Efron grading was 0.28 (range 0.02 – 0.75). All values were normal, and no correlation with the amount of straylight was found.

FIGURE 3.1 Straylight values of soft contact lens wearers while wearing (■) the contact lenses and after removal (x). Age-normal straylight values and 95% confidence interval are shown.
In the rigid contact lens group, mean straylight while wearing contact lenses was $\log(s) = 1.167$ (Figure 3.2; Table 3.2). After removal of contact lenses, $\log(s)$ became 0.997, which was a significant decrease ($P<0.01$). Later measurements (1, 3, and 24 hours after contact lens removal) showed no significant subsequent changes in straylight. Straylight values with rigid contact lenses were strongly increased ($P<0.001$) compared with age-matched normal eyes; after contact lens removal these values decreased but remained elevated compared with age-matched normal eyes (Table 3.2). Mean corneal pachymetry after contact lens removal was 531 µm (range 429 – 617 µm), and mean Efron grading was 0.31 (range 0.02 – 0.73). These values were normal, and no correlation with straylight was found. Mean contact lens score was 0.60 (range 0 – 1.75). Straylight values of rigid contact lens wearers did show a correlation with part of the contact lens score ($P<0.01$) but not with other variables of the contact lens score (Figure 3.3). Figure 3.3 shows the correlation of straylight values with amount of deposits on the contact lens in rigid and soft contact lens wearers. In Figure 3.3, one participant can be found with a deposit score of zero but nevertheless a very high straylight value. This was the only subject in the population with an extreme score on one of the other parts of the contact lens score (a very poor contact lens fit), which explained the elevated straylight value. Both large diameter (12.0mm) rigid contact lenses and new rigid contact lenses (without deposits) did not result in a decrease in straylight value, compared with normal diameter (9.3-9.6 mm) rigid contact lenses (1-sided paired $t$-test $P>0.2$; $n = 6$).

Mean scores on the Efron grading scales were very low in both groups (Table 3.3). Special attention was given to the scores of corneal complications because these were supposed to influence straylight the most.

### Table 3.2 Straylight values in subjects while wearing hydrophilic or rigid contact lenses and after removal.

<table>
<thead>
<tr>
<th>Average straylight (SD)</th>
<th>During contact lens wear</th>
<th>After contact lens removal</th>
<th>$t$-test during contact lens wear (n = 30)</th>
<th>$t$-test after contact lens removal (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft contact lens</td>
<td>0.934 (0.107)</td>
<td>0.934 (0.096)</td>
<td>$P = 0.41$</td>
<td>$P = 0.41$</td>
</tr>
<tr>
<td>Rigid contact lens</td>
<td>1.167 (0.237)</td>
<td>0.997 (0.126)</td>
<td>$P &lt; 0.001$</td>
<td>$P = 0.013$</td>
</tr>
</tbody>
</table>

The one sided $t$-test compares mean straylight values of both eyes of 30 contact lens wearers during contact lens wear or after contact lens removal with the age-matched normal value (without contact lenses), $\log(s) = 0.938$. Mean straylight value of both eyes of a contact lens wearer was determined as follows: during contact lens wear: ($\log(s)$ with contact lens in left eye + $\log(s)$ with contact lens in right eye)/2) and after contact lens removal: ($\log(s)$ without contact lens in left eye + $\log(s)$ without contact lens in right eye)/2). SD = standard deviation.
Straylight measurements in contact lens wear

**FIGURE 3.2** Straylight values of rigid contact lens wearers while wearing (■) the contact lenses and after removal (×). Age-normal straylight values and 95% confidence interval are shown.

**FIGURE 3.3** Correlation between straylight values of rigid contact lens wearers (upper line, ■) and soft contact lens wearers (lower line, ×) and amount of deposits on the contact lens.
Virtually, no differences existed on average between first and second straylight measurements, so a learning effect could be excluded (average differences: -0.009 during contact lens wear, -0.016 after contact lens removal, -0.014 control subjects) (Figure 3.4). From the same data, repeated measures standard deviations were determined. For hydrophilic contact lens wearers, repeated measures standard deviation was 0.068 both during contact lens wear and after removal. For rigid contact lens wearers, repeated measures standard deviation was 0.095 while wearing their contact lenses and 0.057 after contact lens removal.

### Table 3.3 Scores on the Efron grading scales for various contact lens-related anterior segment complications of all included contact lens wearers.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corneal stromal edema</td>
<td>0.26</td>
<td>0 - 2.5</td>
</tr>
<tr>
<td>Corneal staining</td>
<td>0.63</td>
<td>0 - 3</td>
</tr>
<tr>
<td>Epithelial microcysts</td>
<td>0.03</td>
<td>0 - 1.3</td>
</tr>
<tr>
<td>Superior limbic keratoconjunctivitis</td>
<td>0.15</td>
<td>0 – 1.6</td>
</tr>
<tr>
<td>Corneal infiltrates</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total score</td>
<td>0.30</td>
<td>0.02 – 0.75</td>
</tr>
</tbody>
</table>

FIGURE 3.4 No significant differences exist between 1st and 2nd measurements of straylight with the Oculus C-Quant.
When the outcomes of the questionnaires were compared between rigid lens wearers and soft contact lens wearers, subjective straylight complaints as documented by the questionnaire were significantly higher in the rigid contact lens wearers than in the soft contact lens wearers ($P < 0.01$). Participants with subjective dry eyes also had significantly higher straylight values ($P = 0.014$). When the results of all straylight values of all contact lens wearers were compared with all outcomes of the questionnaire of all contact lens wearers, straylight values showed a weak but non-significant correlation with the straylight questionnaire. During contact lens wear, $r = 0.17$ ($P = 0.10; n = 60$). After removal of contact lenses, correlation was understandably even less, $r = 0.04$ ($P = 0.40; n = 60$).

**DISCUSSION**

Contact lens wear may lead to chronic hypoxia, tear film instability, allergy, toxicity, inflammation, infection and desiccation. Some of these ocular surface effects can be expected to influence quality of vision. Straylight is caused for approximately 1/3 by the cornea in young, healthy eyes and is more sensitive to small corneal changes than visual acuity. A clinical application of straylight measurement is to diagnose patients with complaints, even when visual acuity is completely normal. This makes this technique suitable to evaluate visual functioning in contact lens wearers. Considering the high prevalence of contact lens wear worldwide, the effect of contact lenses on quality of vision needs to be known. It is also essential to be able to compare contact lens effects with the performance of other currently available forms of refractive corrections.

Straylight measurement is an accurate, sensitive and clinically useful tool to document the effects on visual functioning of slight corneal changes because of long-term contact lens wear. As shown in Figure 3.4, a learning effect can be excluded with the new technology because the first and second straylight measurements are on average very close. An interesting side observation can be noted. The repeated measures standard deviation (0.095) among rigid contact lens wearers during contact lens wear is clearly higher compared with the other values, showing normal good reproducibility (0.057 and 0.068). Speculatively, this might be explained by movements of rigid contact lenses, during wear. These movements might cause different parts of the contact lens to influence quality of vision during repeated measurements, that is, variations in the amount of deposits of the contact lens, which become visible at the location of the pupillary opening through movements of the contact lens.

In our study, soft contact lenses did not influence straylight values at all and showed in this respect better optical performance than rigid contact lenses. Both during contact lens wear and after contact lens removal, straylight values were comparable to those found in age-matched
individuals. This matches the findings of Applegate and Jones, who, on average, reported no significant hydrogel contact lens-induced disability glare effects.\(^4\) However, Applegate and Jones suggested that approximately 40% of the population of hydrogel contact lens wearers do experience a significant increase in disability glare and that different contact lens materials, cleaning procedures, and wearing conditions can influence induced glare effects.\(^4\) In other studies, increased straylight values have been found among subjects with soft hydrogel contact lenses.\(^2,10\) Spectacles, rigid contact lenses, Intacs, Artisan claw lens implantation, laser in situ keratomileusis, and photorefractive keratectomy were reported to perform superiorly, compared with soft contact lenses regarding low-contrast visual acuity and forward light-scatter.\(^2,10\) However, there may be limiting and possibly confounding factors in these studies, such as small numbers of participants, older contact lens types, and perhaps learning effects made possible by older technology.

In our study, rigid contact lens wearers had significantly increased straylight values on average while wearing their contact lenses but the variation was large. After contact lens removal, straylight values drastically decreased in this population but remained slightly elevated as opposed to normal eyes for 24 hours after contact lens removal. Elliott also found more contact lens-induced straylight by rigid contact lenses than by soft hydrogel contact lenses.\(^1\) However, in this study, no difference with normal straylight values after contact lens removal was found.\(^1\) In our study, participants wearing rigid contact lenses obtained a significantly higher score than soft contact lens wearers on a questionnaire, which scored subjective straylight discomfort. Nonetheless, when testing the relationship between the questionnaire outcome and straylight values in all contact lens wearers during contact lens wear, the correlation was low \(r = 0.17; P = 0.10\), and it was even less after contact lens removal \(r = 0.04; P = 0.17\), as can be expected. A speculative explanation for this weakness of correlation could be that contact lens wearers are in general in control over the visual effects of their contact lenses. It may be assumed to be a conscious choice to accept visual effects of (dirty) contact lenses because advantages of contact lens wear outweigh possible inconveniences.

The increased straylight that was found in rigid contact lens wearers and the strong decrease after contact lens removal seems to be related to deposits on rigid contact lenses. In rigid contact lens wearers, poor cleaning regimens and aged lenses often result in deposits on the lens, in particular proteins.\(^2\) Elliott could not find any influence of lens deposits on light-scatter scores, in contrast to what was expected and our results.\(^2,10\) Lohman et al\(^2\) did find an influence of lens deposits, resulting in loss of low-contrast visual acuity. Nevertheless, it was concluded that on hard lenses extensive deposits were needed to be of sufficient magnitude to create considerable increases in scatter.\(^2\) This could also be concluded from our experiments with replacements of patients'
own contact lenses with brand new contact lenses, which did not lead to a significant reduction in straylight. The lack of effect could be because of an insufficient amount of deposits on the patients’ own rigid contact lenses. Increased straylight might also be attributed to direct effects of the contact lens itself. Elliott et al. suggests that increased light-scatter in rigid lens wearers may be because of rigid lens material, possible edge effects because of the small lens diameter and an increase in lens/tear surface boundaries when wearing rigid lenses. In our study, we were able to show that changes in the diameter of the rigid contact lens did not lead to a significant decrease in the amount of straylight.

The slightly increased straylight values that continued to exist even 24 hours after rigid contact lens removal could not be linked to visible changes in the anterior segment. Efron grading showed only minor anterior segment changes and hardly any contact lens-related complications (Table 3.3). These grading scales are a validated instrument to document clinically relevant contact lens-related ocular changes. Our findings suggest that straylight measurements could be an indicator of subclinical changes in the anterior segment because of contact lens wear. It has been suggested that straylight primarily reflects changes in the corneal epithelium caused by the contact lens. Corneal epithelial edema is supposed to cause a large increase in forward light-scatter and is considered to be visually disabling. Because epithelial changes tend to produce more forward light-scatter than back-scattered light, such changes may not be visible at the slitlamp; in consequence, the straylight meter may be more sensitive to epithelial changes than the slitlamp. More powerful anterior segment imaging techniques, such as the anterior segment optical coherence tomography (OCT) or corneal confocal microscopy, might be necessary to detect such changes. These effects may occur to a lesser extent with stromal edema. The straylight meter shows increased forward light-scatter purely because of stromal swelling to occur only if stromal thickness is substantially increased. Significant light-scatter change from stromal edema was reported to arise when the edema reaches about 10% or more.

Our study shows that it is difficult to document clinically visible changes in the cornea because of contact lens wear, even when using a validated grading scale designed to detect these complications. Anterior segment alterations probably only become visible relatively late, which makes it hard to relate these changes to differences in straylight values or subjective complaints of decreased quality of vision. This was also found in a previous study by Elliott et al., in which none of the hydrogel lens wearers showed any signs of corneal edema as assessed by slitlamp examination. After contact lens removal, however, several hydrophilic contact lens wearers had elevated straylight scores, possibly because of subclinical corneal edema. In a study by Lohman et al., virtually no backward scatter was measured in soft contact lens wearers but several subjects had considerable problems with forward light-scatter. In contact lens wearers, small changes in
hydration levels or tear film quality seemed to result in major changes in low-contrast visual acuity. Many different approaches have been used in previous studies to estimate loss of corneal transparency, for example, slitlamp photography, high-frequency ultrasound, Scheimpflug photography, confocal microscopy, and OCT. However, none of these are commonly used clinically and none seem very useful in explaining or documenting the underlying corneal processes, which cause increased straylight. Further research is necessary to understand the effects of contact lens wear on the cornea and the influences of these anterior segment changes on straylight and quality of vision.

CONCLUSIONS

Today, various options exist for correction of refractive anomalies, each with its own profile in visual acuity, straylight, wavefront aberration, and contrast sensitivity. Because contact lenses are widely used, often in young healthy eyes, it is imperative to know the effects of contact lenses on quality of vision. Straylight measurements are an objective way to document quality of vision and more sensitive to early changes in corneal microstructure than visual acuity or slitlamp examination. Our study showed that present-day soft hydrogel contact lenses do not increase straylight values and have a better optical performance than rigid contact lenses. Rigid lens wearers have on average significantly increased straylight values while wearing their contact lenses, partly related to lens deposits. After contact lens removal, straylight does not return to base level. This may be because of subclinical corneal changes because slitlamp examination hardly showed anterior segment alterations in these long-term contact lens wearers. Although rigid contact lens wearers have more subjective straylight complaints, acceptance of visual effects of contact lenses seems high.
REFERENCES

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