Straylight in anterior segment disorders of the eye

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Chapter 13

COMPARISON OF FUNCTIONAL AND OPTICAL STRAYLIGHT MEASUREMENTS OF AN OPACIFIED INTRAOCULAR LENS

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ABSTRACT

Purpose
Clinical functional straylight measurements, defined psychophysically, are theoretically comparable to optically defined scatter, but no clinical proof of this relation has been published. This study reports on the unique opportunity to link straylight and scatter in a patient that had an opacified intraocular lens (IOL) explanted.

Design
Laboratory investigation and clinical testing.

Intervention
A 70-year old woman who had undergone Descemet stripping endothelial keratoplasty for Fuchs endothelial dystrophy presented with visual complaints due to an opacified IOL. Straylight measurements were performed with the C-Quant. After IOL explantation, in-vitro measurements of forward light-scattering by the IOL were performed with a validated optical set-up.

Main Outcome Measures
Comparison of functional straylight measurements with optical measurements of light-scatter.

Results
Before IOL explantation, straylight was log(\(s\)) = 2.22, which is twenty-fold increased compared with young, healthy eyes. One month postoperatively, straylight had improved to log(\(s\)) = 1.57, which is 4x lower than preoperatively and close to normal values for age-matched phakic eyes. Log(\(s\)) of the IOL was around 2.1, which corresponds well to the in-vivo straylight measurement.

Conclusions
This is a unique clinical comparison of the in-vivo functional straylight measurement by the C-Quant with an in-vitro optical measurement of light-scatter, showing that both measurements are comparable in absolute sense.
INTRODUCTION
Intraocular lens (IOL) opacification can decrease quality of vision by an effect on visual acuity and on intraocular light-scattering.1,2 Which effect predominates, depends on the size of the disturbances. Large disturbances, with sizes of 100 µm to several millimeters, typically corresponding to aberrations, disturb visual acuity.1 Small particles, with sizes comparable to the wavelength of visible light, cause increased intraocular forward light-scattering and straylight.1

Straylight is a functional term that denotes the visual effect of intraocular forward scattered light which is projected onto the patient’s retina. Straylight may disturb quality of vision even though visual acuity remains good and is the internationally known cause of disability glare.4 Clinically, this functional straylight measure can be assessed with the Oculus C-Quant (Oculus GmbH, Wetzlar, Germany), using the compensation comparison method.5 The measure for straylight is defined as part of the point-spread-function according proper definition.6 Although solid physical theory shows straylight according this definition to correspond precisely to light-scattering in the eye,7 and experimental proof was given using artificial light-scattering samples in front of the eye,6 one might wish for proof of this relation in the clinical situation. After all, straylight is defined and assessed functionally, as part of “subjective” vision, whereas scatter is defined and assessed optically. The present study reports on the unique opportunity to link straylight and scatter in a patient that had an opacified IOL explanted. With respect to usage of the word “subjective” above please note that usage of this word can give the false impression that such assessment is liable for influence by the subject. In the case of visual acuity this may be so, but this is not the case for straylight.6

The psychophysical measurement made in-vivo by the C-Quant is theoretically comparable to the in-vitro optical measurement, as described previously.7 However, clinical evidence for this assumption was lacking so far. Until now no optical instrument exists to assess correctly light-scatter in the eye,8,9 although promising studies are under way.10 In the present study we describe a patient who presented with major straylight problems and was measured in-vivo with the C-Quant. Her subjective complaints were caused by an opacified IOL and were of such disturbing nature, that explantation of the IOL eventually was necessary. This explanted IOL was measured in-vitro in a validated optical set-up11, offering the unique opportunity to correlate and compare the functional clinical measurement with optical measurements.

METHODS
The Institutional Review Board (IRB) approval of the IRB of the Academic Medical Center was obtained. The research adhered to the tenets of the Declaration of Helsinki and informed consent was obtained from the patient.
A patient with severe visual complaints due to an opacified IOL presented to the Department of Ophthalmology of a tertiary referral center, the Academic Medical Center in Amsterdam, the Netherlands. Functional straylight measurements with the Oculus C-Quant were performed before IOL explantation. After explantation, the isolated forward light-scattering caused by the lens was measured in-vitro with an optical set-up (Figure 13.1), which has been designed and validated to investigate forward light-scattering properties of the crystalline lens, spectacle lenses and IOLs.7,11 This measurement set-up has been described in detail before.7,11 In short, the explanted IOL is placed in a carefully cleaned holder filled with isotonic sodium chloride solution. A halogen light source illuminates the IOL. A Princeton Instruments NTE/CCD 512-TKB CCD camera is moved in a horizontal plane around the sample to collect the light scattered in forward direction by the IOL, which in-vivo would have fallen onto the retina. The scattered light is recorded at several predetermined angles (θ_p = -30°, -20°, -15°, -10°, -7°, -4°, +4°, +7°, +10°, +15°, +20° and +30°), but after correction for the refractive index of the interior of the eye, these angles correspond to visual angles of -22°, -15°, -11°, -7°, -4°, -1°, +1°, +4°, +7°, +10°, +15° and 22°. The straylight parameter s can be calculated by dividing the amount of light registered by the camera at each angle by the total amount of light going through the IOL, apart from a calibration constant.7 Usually, results are expressed as the logarithmic value of the straylight parameter s (log(s)). The total amount of intraocular straylight can be calculated by adding the amount of straylight caused by the IOL or crystalline lens plus that of other structures of the eye, such as the cornea, iris, fundus, and sclera. The opacified IOL can be held responsible for the major increase in straylight levels of the patient, when the addition of the straylight level of the pseudophakic eye with a clear IOL plus the amount of forward light-scatter caused by the isolated explanted opacified IOL adds up to the straylight level of the pseudophakic eye with the opacified IOL. To simplify this calculation, the straylight parameter s can be used instead of the logarithmic value log(s).

![Figure 13.1](image_url)  
**Figure 13.1** Simplified drawing of validated in-vitro set-up for optical measurements of forward light-scatter from intraocular lenses (IOL).
RESULTS
A 70-year-old woman presented with Fuchs endothelial dystrophy and bilateral pseudophakia (Rayner one piece acrylic IOL). On presentation, corrected distance visual acuity (CDVA) in her right eye was 20/50 and in her left eye 20/40. She complained of hazy and deteriorating vision, which caused problems with daily functioning. Fundus examination was normal and in both eyes there were no signs of ocular inflammation. Her past medical history included type II diabetes mellitus, hypertension, breast cancer and colon carcinoma. The patient underwent an uncomplicated Descemet stripping endothelial keratoplasty (DSEK) in her right eye. The DSEK technique is similar to that previously described in detail by Melles et al.\textsuperscript{12,13} Organ cultured posterior donor discs were manually pre-dissected by the cornea donor bank (Amnitrans Cornea Bank, Rotterdam, Netherlands) and stored in CorneaMax solution (Eurobio Lab., France) before transplantation.\textsuperscript{14} Fourteen days postoperatively air was injected into the anterior chamber as the posterior lamellar transplant had detached. This resulted in a successful reattachment of the graft. Otherwise the postoperative follow-up was uneventful. The patient was treated with topical corticosteroids, which were slowly tapered to once daily five months postoperatively. Two months after DSEK, visual acuity had improved to 20/40 and the patient was satisfied. However, visual complaints gradually recurred while subjective quality of vision worsened over the next months. Seven months postoperatively, CDVA of the right eye had diminished to 20/50. Figure 13.2 shows the result of the in-vivo straylight measurement of the right eye of this patient, as seen on the C-Quant operator screen after the measurement. The lower graph gives the patient’s responses in the initial (filled blue circles) and final (red Xs) phase of the measurement. The red curve is the psychometric function fitted to these responses, while the gray curves are the upper and lower limits of the age-related normal psychometric function. The straylight value is marked with a red dot in both the lower and the upper graph. In the upper graph, the solid black line shows the normal straylight values as a function of age for healthy eyes with the upper and lower 95% confidence limits (gray zones). The parameters “Esd” and “Q” are used to estimate the reliability of the measurement. Straylight of the right eye was $\log_{10}(s) = 2.22$, which is hugely increased compared with healthy eyes. The patient was visually handicapped by the diminished and hazy vision and increased disability glare. Slitlamp examination showed an attached posterior lamellar graft, a clear central cornea and a deep and quiet anterior chamber. Central corneal pachymetry was 680 µm and pupil diameter was 3.5 mm. A fine, pigmented deposit was visible on the anterior surface of the IOL, which covered the central part of the optic. (Right upper side of Figure 13.2; the deposit is indicated by an arrow)

One month later, subjective complaints, CDVA and straylight of the right eye remained the same and the deposit was unchanged, despite a course of intensive topical corticosteroids. Attempts

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to remove the deposit surgically with forceps or with a YAG capsulotomy were unsuccessful. The patient was so disturbed by the increased straylight and hazy vision of her right eye that she preferred to keep the eye closed continuously. Fifteen months after DSEK, she underwent an IOL exchange procedure. The IOL and capsule were removed surgically, an anterior vitrectomy was performed and an anterior chamber IOL (Artisan, OphtheC, the Netherlands) was inserted in the eye. Immediately after surgery, the patient noted an improved quality of vision. One week after IOL exchange, CDVA was 20/50 and straylight values of the right eye had decreased to $\log(s) = 1.81$, which is a significant decrease compared to preoperatively. One month postoperatively, the patient was very happy with the postoperative result. CDVA had improved to 20/40 and straylight was $\log(s) = 1.57$, which is 4x lower than preoperatively and close to normal values for phakic eyes of that age. The central cornea remained clear with a central corneal thickness of 691 µm. At the last follow-up visit eighteen months later, CDVA and straylight had remained at the same level.

Figure 13.3 shows the straylight values expressed as $\log(s)$ of the patient as measured with the Oculus C-Quant, and of the explanted IOL at different angles as measured with the optical set-up. Around the 0° scatter angle, the straylight parameter drops to lower values. Around 7°, which is the angle used for the clinical measurements made by the Oculus C-Quant, the straylight values of the explanted IOL are highest, with $\log(s)$ around 2.1, which corresponds well to the in-vivo measurements.
Comparison of functional and optical straylight measurements of an opacified intraocular lens

This study is the first clinical comparison of the in-vivo functional measurement made by the C-Quant with an in-vitro optical measurement of straylight. The psychophysical in-vivo measurement with the Oculus C-Quant was performed by a patient with major straylight complaints due to an opacified IOL. After IOL explantation, it was possible to isolate and quantify the amount of straylight caused by this IOL with the in-vitro optical set-up. Comparison of these measurements showed, that the amount of straylight caused by the explanted IOL was similar to the preoperative in-vivo straylight value, and that both measurements are indeed clinically comparable, as was hitherto only shown theoretically.²

Opacified IOLs after DSEK are a postoperative complication, of which the precise nature and cause are as yet unknown.¹² Several other forms of IOL opacification are described in literature, including diffuse opacification,¹³ “whitening”,¹⁶ calcification of hydrophilic acrylic IOLs¹⁷ and glistening,¹⁸ but none of these exactly matched our findings. Unfortunately, in our study the exact nature of the deposit covering the IOL optic is unknown, as laboratory investigation of the opacifying substance was not performed. When considering the influence on quality of vision of the different forms of opacification, glistenings do not seem to have much effect,¹⁸ especially on visual acuity and contrast sensitivity, whereas detailed straylight research is needed. However, diffuse opacification and whitening lead to clear glare complaints, objectifiable as straylight.

FIGURE 13.3 Straylight values of the explanted opacified IOL expressed as the logarithm of the straylight parameter s (log(s)) at different angles. Normal straylight values and the in-vivo straylight value of the patient are added in the graph for reference.

**DISCUSSION**

This study is the first clinical comparison of the in-vivo functional measurement made by the C-Quant with an in-vitro optical measurement of straylight. The psychophysical in-vivo measurement with the Oculus C-Quant was performed by a patient with major straylight complaints due to an opacified IOL. After IOL explantation, it was possible to isolate and quantify the amount of straylight caused by this IOL with the in-vitro optical set-up. Comparison of these measurements showed, that the amount of straylight caused by the explanted IOL was similar to the preoperative in-vivo straylight value, and that both measurements are indeed clinically comparable, as was hitherto only shown theoretically.²

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**Comparison of functional and optical straylight measurements of an opacified intraocular lens**

_**OD Mrs. W., 72 y, functional measurement (C-Quant) log(s) = 2.22**_

10x elevated straylight
3x elevated straylight (normal at age 77)

**Figure 13.3** Straylight values of the explanted opacified IOL expressed as the logarithm of the straylight parameter s (log(s)) at different angles. Normal straylight values and the in-vivo straylight value of the patient are added in the graph for reference.
increase, and sometimes necessitate IOL exchange, even though the effect on visual acuity is rather small.\textsuperscript{2,16}

As reported here and earlier,\textsuperscript{2} severe complaints of reduced visual function occur in patients with opacified IOLs, despite fairly good visual acuity.\textsuperscript{2} This can be understood by considering the two functional domains of the point-spread function, a small-angle and a large-angle domain.\textsuperscript{6,19} Visual acuity is affected by the small-angle domain, while straylight corresponds to the large-angle domain.\textsuperscript{6} Because both domains affect quality of vision independently, the measurement of visual acuity alone is insufficient to appropriately assess quality of vision, and straylight measurements have additional value.\textsuperscript{6} In our present study, the assessment of the large-angle domain as measured at 7° shows hugely increased straylight. A normal straylight value for a healthy, young eye is $\log(s) = 0.9$ ($s=8$). The explanted deposit-covered IOL showed strong scattering, close to the in-vivo straylight value of $\log(s)=2.22$ ($s=166$), corresponding to a twenty-fold increase of straylight compared with a healthy, young eye. Such a major increase in straylight will lead to severely reduced quality of vision. This study gave evidence that the opacified IOL was responsible for the hugely increased straylight. The patient’s pseudophakic eye with clear IOL had a straylight value of $\log(s)=1.57$ ($s=37$). Before IOL exchange the patient had an in-vivo straylight value of $\log(s)=2.22$ ($s=166$), so the increase in straylight parameter $s$ was 166-37=129, corresponding to $\log(s)=\log(129)=2.1$. This is exactly the amount of straylight which the explanted opacified IOL caused in the in-vitro set-up. In our patient, visual acuity was much less affected by IOL opacification than straylight. This corresponds to the finding illustrated in Figure 13.3, where around 0° the values decrease. Part of the light passes undisturbed through the uncovered part of the IOL, to form a proper retinal projection, albeit of decreased intensity, but sufficient for relatively good acuity. This can be compared with the situation with a small capsulorhexis, where also visual acuity can remain good up till very small capsulorhexis sizes, whereas straylight can be increased considerably.\textsuperscript{20} A more precise understanding of this dissociation between visual acuity and straylight can be derived from Figure 9 of reference 19.

When patients present with IOL opacification and subjective complaints of reduced visual quality, the decision whether to perform an IOL exchange should not be based on visual acuity alone.\textsuperscript{2} Visual acuity is a subjective investigation entirely dependent on patients’ responses. This makes it rather unreliable and less repeatable, as it can easily be influenced one way or the other by malingering or encouragement. Although the clinical examination of the amount of straylight does need patient responses, the design of the compensation comparison method is such that it cannot be biased by the patient, making it objective, free of learning effects, and repeatable.\textsuperscript{20-22} Moreover, this study has shown clinical evidence that the functional measurements made by the patient are equal to optical in-vitro measurements. Measuring straylight values is a useful
independent indicator of visual function, which correlates better than visual acuity to subjective complaints of these patients and the severity of IOL opacity as seen with the slitlamp. Because straylight and visual acuity are two separate aspects of visual function, straylight has additional value to visual acuity in the understanding of patients’ complaints and in the preoperative decision making process.
REFERENCES

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