Straylight in anterior segment disorders of the eye

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GENERAL DISCUSSION AND SUMMARY

This thesis describes new insights in the role of clinical straylight measurements in patients with ocular anterior segment disorders. Ocular straylight involves the fraction of the incoming light that is scattered by the ocular media.\(^1,4\) It does not contribute to the normal retinal image formation, but generates a rather homogeneous haze over the entire retina instead.\(^1-3\) This leads to a decrease in quality of the retinal image and complaints of hazy vision, increased glare hindrance and loss of colour and contrast perception.\(^1-12\) Ocular straylight is a comparatively new factor to be taken into consideration in clinical practice. It has been studied for years in experimental and laboratory settings and recently a survey paper has appeared.\(^4\) The concept of straylight fills a gap in the evaluation of patients with visual complaints, as straylight measurements are able to translate subjective complaints into quantifiable and reproducible results which provide a valuable contribution to visual tests already in use. The aims of this thesis were to study 1) the influence of the healthy and diseased anterior ocular segment on the amount of straylight and 2) which contributions straylight measurements can make in the diagnostic and therapeutic process of several corneal and lenticular disorders, in relation to the commonly accepted and universally used visual function measures such as visual acuity and slitlamp evaluation. The studies in this thesis provide additional insights in the clinical relevance of straylight measurements in a multifold of diseases and disorders which can be encountered in the practice of an ocular anterior segment surgeon.

Chapter one introduces the subject of intraocular straylight. It describes the theoretical principles underlying straylight formation, how straylight can be measured and the potential place of straylight measurements in the clinical assessment of patients. It is a long-established practice that the assessment of visual function is dominated by visual acuity measurement, but these measurements are not able to correctly represent all aspects of quality of vision.\(^1,4,5,7,8,12-19\) Intraocular straylight and visual acuity are only weakly correlated\(^3,9,13,16,20-22\) and visual impairments caused by increased straylight differ markedly from those caused by decreased visual acuity.\(^5,7,21\) Although clinical overlap may exist, typical straylight complaints can develop separately from visual acuity-associated complaints.\(^3,13,21\) This can be understood by looking at the point spread function (PSF; see Figure 1.4), which consists of different domains, which each contribute in a distinct but complementary fashion to visual functioning.\(^1,13\) Visual acuity corresponds to the central, very steep peak of the PSF,\(^1,13,21\) while straylight relates to a different area and is defined as the outer part of the PSF from 1 to 90°.\(^1,3,4,6,10-12,21,23\)

Straylight can be measured clinically with the C-Quant (manufactured by Oculus Optikgeräte GmbH, Wetzlar-Dutenhofen, Germany), which is based on the psychophysical Compensation Comparison method.\(^1,8,11\) The resulting functional straylight parameter s (usually the logarithmic
value is used: $\log(s)$ expresses the amount of straylight as experienced by the patient. Straylight measurements with the C-Quant are suitable for routine clinical use in a busy practice, as they are quick and relatively easy to perform for the patient. Moreover, they are highly reproducible and resistant to fraud by both subject and operator.

Average straylight values for young, healthy, Caucasian eyes are around $\log(s)=0.9^{2,4,7,8}$ but the amount of intraocular straylight may greatly increase in the presence of ocular pathology. The anterior ocular segment has a particularly large influence on the amount of intraocular straylight, starting already with the young and healthy eye when the cornea and lens each contribute around 1/3 to intraocular straylight. Case descriptions in Chapter one illustrate how straylight can be considered as the missing part of the clinical evaluation of visual function and in which way straylight measurements can add to the clinical assessment of patients with decreased visual quality.

The considerable effect of the anterior ocular segment on the amount of intraocular straylight is outlined in more detail in Chapter two. In this chapter the impact of the healthy and diseased cornea and lens on intraocular straylight is elucidated and a short literature review is given for each of the chapters constituting this thesis, in which the circumstances are described which led to the separate studies underlying each chapter. Chapter 2 also delineates the organization of this thesis: the first part focuses on corneal light-scatter, while the second part is involved with several forms of lenticular light-scatter.

**Straylight and the cornea**

The first part of the thesis is dedicated to straylight measurement in corneal disorders. Corneal tissue has been shown to be particularly susceptible to changes that generate straylight. Although age does not lead to major changes in the amount of corneal light-scatter, small changes in corneal clarity at any level of the corneal anatomy may have a large influence on intraocular straylight. This inspired us to use straylight measurements to evaluate healthy corneas which were manipulated in some way, as described in Chapters 3 and 4, as well as diseased corneas, as depicted in Chapters 5 and 6.

**Chapter three** describes the visual effects of one of the most prevalent manipulations of the corneal environment, which is contact lens wear. This chapter reports the results of a study of corneal light-scatter in habitual contact lens wearers with healthy corneas, which aimed to clarify the light-scattering effect of contact lenses and associated corneal changes in rigid and soft contact lens wearers. Straylight levels were related to subjective complaints and contact lens and corneal characteristics. Straylight was measured during contact lens wear and after contact lens removal in 30 rigid contact lens wearers and 30 soft contact lens wearers. All participants were
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examined with the slitlamp to grade anterior segment changes using Efron grading scales and to score contact lens features. Subjective complaints related to straylight were assessed with a questionnaire, which assessed straylight hinderance in different circumstances (e.g. driving after dark).

This study showed that the amount of intraocular straylight experienced by soft contact lens wearers and normal subjects was comparable, both during contact lens wear and after contact lens removal. However, in rigid contact lens wearers straylight was strongly increased while contact lenses were worn. It decreased significantly after rigid contact lens removal, but remained elevated compared to values in normal eyes. The questionnaire confirmed these findings and showed more straylight complaints in rigid contact lens wearers than in soft contact lens wearers. We could not link straylight levels to slitlamp findings, as slitlamp evaluation did not show clinically significant corneal changes in the contact lens wearers. Although intraocular straylight in rigid contact lens wearers correlated with the amount of deposits found on the contact lens, it did not with other variables of the contact lens score.

Chapter four describes the consequences for intraocular straylight when complications occur after laser refractive surgery of healthy corneas. In three eyes which developed epithelial ingrowth after laser in situ keratomileusis, straylight was measured before and after the ingrowth was removed. When epithelial ingrowth did not reach the pupillary opening, no significant change in straylight level was observed after ingrowth removal. However, when the epithelial ingrowth reached the pupillary opening, the light-scattering effect was several factors larger than the influence on visual acuity. Ingrowth removal significantly lowered the amount of straylight: a 3.6-fold reduction in one eye and a 10-fold decrease in the other eye, while uncorrected distance visual acuity (UDVA) improved from 0.25 (20/80) in both eyes to 1.0 (20/20) and 0.8 (20/25), respectively.

The studies reported in Chapters 3 and 4 are important for elucidating the visual effects of manipulation of healthy corneas which are situated in normal ocular surroundings of mostly young individuals. The effect on straylight can be quite different from the effect on visual acuity. As young persons have high visual demands, straylight measurements may offer an explanation for subjective visual complaints which may be present despite excellent visual acuity. As contact lens wear and refractive surgery are both common among young, working adults with healthy eyes, increased awareness of this cause of possible visual problems in this population is very valuable.

In Chapters five and six, attention is given to the effect of corneal disease on straylight. Fuchs’ corneal endothelial dystrophy is characterized by accelerated loss of corneal endothelial cells,
leading to a diminished barrier and pump function and loss of corneal clarity by increased corneal hydration.\textsuperscript{25,26} The treatment of choice is Descemet stripping endothelial keratoplasty (DSEK), in which the diseased endothelium and Descemet membrane are surgically removed and replaced by a thin layer of donor stroma, Descemet membrane and endothelium.\textsuperscript{27-29} Chapter five reports our study of quality of vision in patients with Fuchs’ endothelial dystrophy and the improvement in visual quality after DSEK. The department of Ophthalmology of the Academic Medical Center (AMC) in Amsterdam, the Netherlands, collaborated with Mayo Clinic, Minnesota, Rochester, USA. At both sites phakic and pseudophakic patients with Fuchs’ endothelial dystrophy were enrolled. At the AMC 99 eyes were included in an observational case series (Amsterdam group), while at Mayo Clinic 48 eyes were entered in a prospective interventional case series (Mayo group). The Mayo group underwent DSEK, which was combined with cataract extraction in phakic patients, and was also examined at 1, 3, 6, and 12 months after DSEK. Eyes with Fuchs’ endothelial dystrophy had severely impaired quality of vision by reduced visual acuity (mean [SD], 0.42 [0.26] logMAR; Snellen equivalent 20/53) and a worsening in the amount of straylight (mean [SD], 1.54 [0.24] log(\textit{s})) compared with healthy eyes. Although the presence of corneal endothelial changes and stromal edema in eyes with Fuchs’ endothelial dystrophy deteriorates both aspects of quality of vision,\textsuperscript{25,26,28} visual acuity and straylight may be affected differently, as was shown in this study. Younger patients suffered more from elevated straylight levels than from decreased visual acuity, while for elderly patients the opposite was the case. This study showed that DSEK was successful in improving postoperative quality of vision significantly, as in the Mayo group both visual acuity and straylight levels improved at all postoperative examinations. LogMAR visual acuity improved from 0.43 preoperatively to 0.35 after 1 month, 0.27 after 3 months, 0.23 after 6 months to 0.17 after 12 months. For straylight these values were 1.55, 1.41, 1.36, 1.35 and 1.35, respectively (\textit{P} < .001 in all cases). Straylight improved more in younger than in older eyes after DSEK. Postoperative improvement in straylight was more predictable than that of visual acuity and was associated with a preoperative straylight level of more than 1.33 log(\textit{s}).

It can be quite difficult to decide when the time is right for surgical intervention in patients with different ocular anterior segment disorders who present with subjective visual complaints but relatively good visual acuity. The balance between operative risks and benefits is delicate and it is necessary to have a clear understanding of the postoperative gain which can be expected. This study made a useful contribution to preoperative clinical decision making in patients with Fuchs’ endothelial dystrophy, in showing that straylight measurements can be very helpful in accurately predicting in which patients postoperative improvement is likely to occur. Straylight measurements can be especially helpful in patients with subjective complaints and a preoperative visual acuity close to 20/20.
In Chapter six, attention is focused on the long-term follow-up after DSEK. Visual quality several years postoperatively is evaluated. In this study thirty-four eyes were examined, which all had undergone DSEK for Fuchs’ endothelial dystrophy 6 to 64 months previously (mean postoperative time was 1027 ± 453 days). Best-corrected visual acuity and straylight were analyzed and correlated with corneal parameters as corneal thickness and haze. The 39-item National Eye Institute Visual Function Questionnaire (NEI-VFQ-39) and a straylight questionnaire were used to evaluate how patients experienced their vision-related quality of life. In this group of patients with long-term postoperative follow-up after DSEK, mean best-corrected visual acuity was 0.33 ± 0.19 logMAR and straylight averaged 1.47 ± 0.19 log(\text{s}). Thus, both remained significantly reduced compared with age-related, healthy pseudophakic eyes. These values are also worse than in the patients which were evaluated up to one year post-operatively in Chapter 5. However, from these data it cannot be concluded that a worsening in quality of vision will occur with longer postoperative follow-up, as these groups cannot be compared. Many of the patients in the study of Chapter 6 were operated several years previously in the early days of DSEK. The surgical technique was still developing and the learning curve of the surgeon should be taken into account. Correlation of quality of vision with corneal parameters was weak, only best-corrected visual acuity correlated with corneal haze ($r = 0.50$), whereas straylight did not ($P = 0.12$), and both visual acuity and straylight did not correlate with corneal thickness. Slitlamp examination of corneas after DSEK surgery thus cannot offer an adequate explanation for decreased postoperative visual quality in these patients compared with normal pseudophakic eyes of the same age. Mean NEI-VFQ-39 score was 77/100, and mean score of the straylight questionnaire was 46/100, which indicated mild (NEI-VFQ-39) to moderate (straylight) subjective visual impairment.

DSEK surgery has become a standard procedure and a substantial part of our outpatient population consists of patients who have undergone this type of surgery. Many of these patients retain diminished visual quality, while the slitlamp examination shows a clear cornea with an attached donor disk. This study contributes to the understanding of these patients, and the finding that slitlamp examination cannot offer a sufficient explanation for decreased postoperative visual quality or persisting subjective complaints in these patients has considerable clinical relevance. The increased straylight levels are in agreement with the reduction in visual acuity and are most likely caused by persisting abnormalities in the operated cornea, which prevent visual quality to fully recover to normal levels. Several attempts have been made to localize in which corneal layer the disturbing corneal opacities are situated, which are responsible for the unsatisfying visual outcomes. It is interesting that the newest surgical technique in this field, the Descemet membrane endothelial keratopasty (DMEK), in which only endothelial cells on a Descemet membrane are transplanted, seems to promise a significant improvement in quality of vision postoperatively compared to DSEK. Patients who have undergone DMEK may achieve nearly
normal straylight (personal experience) and visual acuity levels after surgery. However, it is a technically very difficult surgery. In the AMC, several patients have undergone DMEK surgery since 2011.

**Straylight and the lens**

The lens is known to have a remarkably large influence on straylight, as is described in Chapter 2. With increasing age the lens becomes more and more opaque, eventually leading to cataract formation. Cataract is highly frequent among the population and has a direct effect on the amount of intraocular light-scatter, leading to hugely elevated straylight levels. Cataract surgery is regularly performed worldwide and an exact knowledge of the visual effects of crystalline lens opacities is necessary for accurate preoperative appraisal. Postoperative results depend for a considerable part on the influence of intraocular lenses (IOLs) and the remnants of the intraocular lens capsule on visual function. The second part of the thesis contributes to further elucidation of the influence of cataract, IOLs and lens capsules on quality of vision by studying straylight measurements in lenticular disorders. In chapter 7, results of cataract surgery are evaluated. The effects of the IOL and lens capsule on quality of vision are described in clinical studies in chapters 8 and 9, and in-vitro in chapters 10 and 11. Chapters 12 and 13 are dedicated to the disturbing visual consequences of IOL opacification.

As so many cataract surgeries are performed globally, it engages a large amount of money and other resources and accurate preoperative assessment is of paramount importance, as well as correct expectations of the postoperative results. This is especially true in current times, when an economic recession is present, medical expenses have to be cut back and insurance companies want a precise appraisal of preoperative indications and postoperative benefits. Moreover, with new possibilities in the form of multifocal, accommodating and toric IOLs, cataract surgery becomes more and more a form of refractive surgery. The expectations of patients surge accordingly, adding to the necessity of correct preoperative evaluation and estimation of postoperative improvement. In certain cases, e.g. in patients with good to excellent visual acuity but complaints of insufficient visual quality, visual acuity is known to be deficient in this respect, as is also the case for Fuchs’ endothelial dystrophy, as described previously in this thesis. The need was felt to have better predictors of postoperative success. The correlation between the amount of straylight and the extent of the cataract is better than that of other visual function measurements, such as visual acuity or contrast sensitivity, making straylight levels a better predictor of functional visual loss than visual acuity measurement. As cataract and straylight are so closely correlated, while straylight is only little correlated to visual acuity and is known to have functional importance, straylight measurements could have additive value in the preoperative decision making process concerning cataract surgery, and also in the
postoperative evaluation of visual functioning and postoperative results.\textsuperscript{3,4,6} This was investigated in a multicenter prospective interventional cohort study which is reported in Chapter seven. At two sites (Onze Lieve Vrouwe Hospital, Amsterdam, and Zonnestraal Eye Clinic, Hilversum, The Netherlands) 217 patients were included who visited the outpatient clinic for preoperative cataract assessment. Before and after cataract extraction, all patients underwent corrected distance visual acuity (CDVA) and straylight measurements and answered the NEI-VFQ-39 and a straylight questionnaire. Mean straylight of the preoperative population was $1.55 \pm 0.29 \log (s)$ and mean postoperative improvement was $0.31 \pm 0.32 \log (s)$ (range -0.50 to 1.27 log[s]). Mean preoperative CDVA was $0.28 \pm 0.21 \log \text{MAR}$, this improved postoperatively with a mean of $0.26 \pm 0.20 \log \text{MAR}$ (range -0.12 to 1.12 logMAR). This study confirmed that visual acuity and straylight showed little correlation ($R^2 = 0.08$), indicating that different aspects of visual quality are measured and that straylight values can have an additive value in preoperative decision making. Moreover, preoperative and postoperative questionnaires showed that straylight had almost equal influence as visual acuity on subjectively experienced quality of vision. It was possible to determine a preoperative break-even point (50% chance of postoperative improvement) for our population for CDVA and straylight, which was $0.06 \log \text{MAR}$ for CDVA and 1.29 log[s] for straylight. To account for the influence of both visual acuity and straylight, the values of both were added (on log scale) to calculate a value for total vision. This value offers a more complete and accurate predictor of postoperative improvement, as it takes both aspects of quality of vision in consideration, and it improved the postoperative predictability of the results.

This study contributes to improved preoperative considerations of cataract surgery. It supported the addition of straylight values to the preoperative decision-making process as these can make postoperative results more predictable.

After cataract extraction quality of vision can remain an issue. Postoperative straylight values are expected to return to the levels of young, healthy eyes or even better, as light passes through a clear IOL in the same, nearly undisturbed way as through the young transparent crystalline lens.\textsuperscript{4,7,22} However, the IOL is placed inside a capsular bag, which tends to become more or less opaque in the postoperative period. These opacities of the anterior or posterior part of the capsular bag will increase intracocular light-scatter and thus decrease visual quality.\textsuperscript{4} The effect of an opacified anterior capsulorhexis edge which overlies the periphery of the IOL optic is quantified in a model and documented in Chapter eight. Straylight was measured before and after pupil dilation in fifty-six pseudophakic eyes with an intact capsulorhexis. The difference in straylight values between natural and dilated pupils was correlated with the size of the capsulorhexis and the opacity of the anterior capsular rim. Mean straylight with a natural pupil was log($s$) = 1.25 (range, 0.68-2.13), which increased with 62% to 1.46 (range, 0.88-2.22) after pupil dilation ($P < .001$). It was possible
to quantify the effect of capsulorrhexis size and opacity on the increase in straylight in dim light conditions by the following formula: \( \Delta s = 19 \times \text{grading of anterior capsular rim} \times \text{fraction of pupil area covered by rhexis} \). A straylight level of \( \log(s) = 1.47 \) corresponds to a doubling of the amount of straylight compared with a normal value for a 65-year old eye and can be considered as a limit value for safe driving at night, as a further increase will cause problems due to disturbing disability glare. Taking this straylight level into account, from the formula it can be calculated that the capsulorrhexis should be sized larger than 4 mm to prevent such important difficulties with functional vision.

The visual effects of the anterior capsule which overlies the IOL are much less known and studied than those of posterior capsule opacification (PCO), probably because the visual consequences of an opacified anterior capsule are not measurable with visual acuity testing. Indeed, as the anterior capsular edges usually do not obscure the central part of the IOL, no immediate effect on visual acuity is expected. This may lead to a misjudgement of the influence of the anterior capsule on postoperative visual quality in some patients. This study showed that a small capsulorhexis may cause an opacified anterior capsular rim to be visible in the pupil area in scotopic conditions and that this rim could influence postoperative quality of vision. It also increased the knowledge of the disturbing factors which may influence postoperative quality of vision. By quantifying the visual effects of an opacified anterior rhexis edge, it was possible to determine optimal capsulorrhexis size and improve surgical technique.

Contrary to the visual effects of the anterior capsule, much is known of the visual influence of PCO. Several chapters of this thesis are dedicated to further elucidating and quantifying the effect of PCO on straylight both in-vivo and in-vitro.

Nd:YAG capsulotomy is the treatment of choice for PCO and usually works well in restoring visual acuity and improving straylight. However, when the capsulotomy size is too small and the edges partly obscure the pupil area, the effect on visual function will be comparable to that of a small sized capsulorhexis. In Chapter nine visual complaints (photophobia) resulting from an insufficiently sized posterior capsulotomy are described, which could be properly quantified with straylight measurements. While visual acuity remained normal, straylight was 5x increased. After widening the posterior capsulotomy symptoms resolved.

Chapters 8 and 9 confirm that straylight is very sensitive to the disturbing visual effects of capsular opacification. Straylight measurements are suitable to quantify and document visual symptoms caused by opacified lens capsules and may correspond better to subjective complaints than visual acuity measurement. When increased straylight is found in case of capsule opacities, even though visual acuity may remain normal, this could support an interventional decision.
To better understand and elucidate the effect of opacified lens capsules on light-scatter an in-vitro model was used. The results are reported in Chapters ten and eleven. Capsular bags were isolated from post-mortem donor eyes and installed in an optical set-up, validated to measure light-scatter in-vitro.\textsuperscript{3,22} In Chapter ten, the effect of the morphology of capsule opacification on the scattering of light is reported. Characteristics of the light scattered by opacified lens capsules were compared with those of scatter in the normal eye. The angular dependence of light scattered by capsule opacities was rather similar to that of scatter in the normal eye, regardless of severity and type of capsular opacity. The angular and wavelength dependence indicated that the light-scattering effect of opacified capsule is dominated by small particles, but the influence of larger elements with a refractile effect could also be shown. The two types of capsule opacification which were studied differed in their proportions of small, scattering particles and larger elements with refractile effects. Fibrotic capsule opacification consists mostly of small structures and consequently exerts a larger influence on straylight than on visual acuity. In pearl-type capsule opacification, the refractile component of the larger particles is most pronounced and therefore the effect on visual acuity may dominate over the scatter effects, depending on PCO coverage within the pupillary area (Chapter 11).

In Chapter eleven separate capsule areas with varying morphology and severity of capsule opacification were more extensively studied and the effect on light-scatter was quantified in terms of the straylight parameter \(s\). Depending on the condition and clarity of the lens capsule, the scattering effect could range from 10x below to 10x above the average value for a normal eye, which was compatible with the variety in straylight values found in in-vivo pseudophakic eyes. To shed some light on the particles responsible for the light-scattering, characteristics of the scattered light were also studied. The angular dependence of light scattered by clear lens capsules was weaker than in a healthy eye, whereas for opacified lens capsules a similar (fibrotic type) or stronger (regeneratory type) angular dependence was found. Wavelength dependence of the scattered light was comparable for all capsule types. Both forms of opacified posterior lens capsules (fibrotic and regeneratory types) which were studied showed increased angular and decreased wavelength dependence at the smallest visual angles. Although the wavelength dependence indicated that small elements are responsible for light-scattering by opacified lens capsules, refractile effects by larger particles become more significant at small visual angles as indicated by this combined stronger angular and weaker wavelength dependence.

The main advantage of these in-vitro studies is the possibility to isolate the light-scattering effects of the lens capsule from those of the other ocular media, which can never be accomplished in-vivo. In this way it is possible to document the visual influences of the different types of capsular opacities, which can help to better comprehend symptoms in patients with capsular phimosis.
(shrinkage of the anterior capsular rim) or PCO and support the decision whether to perform an Nd:YAG-capsulotomy.

Another example of how in-vitro studies can directly influence and assist clinical practice by increasing awareness and aiding clinical decisions is shown in the following chapters, in which the isolated light-scattering effects of opacified IOLs are studied.

Postoperative visual quality after cataract extraction depends not only on the clarity of the lens capsule, but also for a large part on the characteristics of the implanted IOL. Although IOL opacities in some cases may have only little effect on visual acuity, they may hugely increase the amount of intraocular straylight. This might thus be another group of patients who present with visual complaints, despite fairly good visual acuity. The opportunity to perform quick and reliable straylight measurements in a relatively easy manner is a major improvement in the clinical assessment of these patients and it facilitates interventional decisions concerning surgical lens exchange. IOL exchange remains a somewhat difficult procedure, of which the chance of complications exceeds that of simple cataract extraction. This makes it more difficult to decide when operative intervention is indicated in patients with quite good visual acuity, despite obvious drawbacks in visual functioning due to the opacified IOL. Patient 3 described in Chapter 1 offers a good example of a patient who was unmistakably hindered by the intraocular opacified IOL, but in whom visual acuity maintained at a reasonably good level. Straylight levels were markedly increased in this patient. In Chapters twelve and thirteen, the previously mentioned in-vitro set-up was used to study the forward light-scattering characteristics, which are the cause of straylight, of opacified explanted IOLs. In Chapter twelve, the light-scatter caused by two explanted opacified Aquasense IOLs was examined. The explanted IOLs showed large increases in forward light-scatter. Scatter could be increased as much as 100x compared with straylight values of young, healthy eyes with clear media. Scatter values were highest at large angles and declined steeply around the 0° angle, which correspond to an enormous effect on straylight but little on visual acuity, and explains why quality of vision is reduced while visual acuity remains good. As the in-vitro set-up gives results comparable to straylight values as measured in in-vivo situations, in Chapter thirteen the light-scatter brought about by the explanted IOL could be directly related to straylight measurements performed in-vivo before the IOL exchange. In this chapter a patient is described in whom the IOL opacified after Descemet stripping endothelial keratoplasty. Straylight measurements were performed with the C-Quant and log(s) equalled 2.22, which is a twenty-fold increase compared with young, normal eyes. As visual complaints were severe, an IOL exchange procedure was performed. After IOL explantation, in-vitro measurement of forward light-scattering by the opacified IOL was performed, offering the unique opportunity to compare the clinical functional straylight measurement, defined psychophysically, with optically defined
scatter. Around 7°, which is the angle used for straylight values with the C-Quant, the scatter value of the explanted opacified IOL was equivalent to a log(s) value around 2.1. This value corresponded well to the in-vivo straylight measurement and showed that both measurements are clinically comparable. One month after IOL explantation the straylight levels of the patient had decreased to log(s) = 1.57. This value is a clinically and statistically significant improvement; it is 4x lower than preoperatively and close to best normal values for age-matched phakic eyes.

All studies described in this thesis have demonstrated how straylight measurements can complement the existing diagnostic modalities in an anterior segment practice in a clinically useful way. Straylight measurements take only a short time to perform, are not cumbersome to undergo for patients, give highly reproducible results even when performed by untrained patients and were shown to be reliable and resistant to fraud.\textsuperscript{4,10,24} The studies which form this thesis have shown that straylight measurements can support the diagnostic process by being helpful in better understanding patient's complaints. Straylight measurements may even have a crucial role in the attempts to resolve these complaints in an extensive range of corneal, lenticular and capsular disorders. The place of straylight measurements in the clinical assortment of diagnostic tests has become more widely known in recent years. Patients with a wide variety of complaints and anterior segment problems are being referred to us specifically for straylight testing. Also, the use of the C-Quant straylight meter in other, national and international, ophthalmologic practices is increasing. Currently straylight has become a clinical factor which has to be taken into account; and the multitude of clinical experience, evidence and studies which have become available during the past years and are still mounting all clearly show how straylight can supplement our diagnostic arsenal and how much gain can be expected when straylight measurements are incorporated in clinical practice.\textsuperscript{4} This gain is multifold: in better understanding patients, but also in better documenting visual quality by having a quantifiable visual value to supplement visual acuity. This last can be of significance for research purposes, for preoperative choices, for postoperative evaluation of surgical results and for justifying surgical treatment to e.g. insurance companies or critical questions which are sometimes raised in society.

New developments in cataract surgery, such as the use of femtosecond laser to perform part of the surgery or the availability of premium IOls, lead to cataract surgery obtaining more and more elements of refractive surgery. Consequently, preoperative anticipations of patients are high, patients are willing and even expecting to undergo cataract surgery at an earlier stage and the preoperative decision process becomes more and more demanding, as cataract surgery is contemplated in patients with normal to excellent visual acuity of 20/20 or better.\textsuperscript{14} This thesis has demonstrated that in these patients straylight measurements are a useful addition to the preoperative decision making process. However, the role of straylight measurements is
not limited to these patients, but is gaining widespread acceptance as part of the preoperative indication process and can also be very helpful in, e.g. patients with posterior polar cataract or cortical cataract. With the increase in surgical and technical possibilities, not only for cataract but also for corneal disorders, an expansion of the role of straylight in the preoperative phase can be expected. Accurate preoperative counseling demands an exact assessment of the preoperative problem; this thesis proves that straylight measurement can be a useful addition to the therapeutic process by supporting interventional decisions for the anterior segment surgeon.
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REFERENCES


