Aim and scope of the thesis

Cataract is an opacification of the crystalline lens that progressively impairs vision. Cataract development can cause a perceived decrease of function of the affected eye. This perceived decrease of function is generally expressed as a loss of distance visual acuity (VA). Although early cataract most often does not cause VA symptoms,[1-3] patients may still report visual problems, which indicates that high contrast VA charts may not be a good representation of real-life situations,[4-6] To address this issue, the contrast sensitivity (CS) test has been adopted in the evaluation of cataractous patients.[1-4] CS measures the ability of the eye to detect small differences in luminance between a test object and its background. Although very important, VA and CS are limited to the central part (from 0.02 to 0.33°) of a functional point spread function (PSF).[7] But the outer part of the PSF (over approx. 1°) is also very important, and can be assessed by means of straylight measurements.[7] Development of (early) cataract is associated with increased straylight due to light scattering from lens opacification, and that may cause different visual symptoms, such as a loss of contrast, decreased color vision, and higher sensitivity to glare sources.[7-14] To restore good visual quality and to prevent loss of VA, a cataractous lens is removed, and replaced with an intraocular lens (IOL), in the course of cataract surgery. Although on average a substantial straylight decrease has been found following surgery, a recent clinical study has shown that in 15% of pseudophakic patients straylight remains at the preoperative level or increases after surgery.[15] A large population study on European drivers has reported that straylight of 10% of the pseudophakic patients was above the norm for phakic patients. Although in another 46% straylight was within the norm, a lower straylight level would be expected as the crystalline lens is an important source of straylight in the eye.[7, 10, 13] Based on the CIE standard, a value of 0.69 would be expected that is a straylight level of the young eye without contribution of the crystalline lens.[10, 13, 16] Clinical studies have shown, however, that even in the absence of postoperative complications the average straylight level ranges from 1.10 to 1.47 log(s).[15, 17-32] Therefore, the goal of this thesis was (1) to study *in vivo* the contribution to straylight of artificial eye lenses (with a focus on IOLs), (2) to determine the source of straylight elevation in pseudophakic eyes, and (3) to establish a new method for *in vitro* straylight assessment of IOLs.

To address the problem of increased straylight in pseudophakic patients, a literature review on straylight in pseudophakia was performed and is presented in **Chapter 3**. As it has also been realized that straylight–age dependence differs between phakic and pseudophakic patients, a new straylight norm for the pseudophakic patients was proposed. To minimize the potential for straylight increase following lens extraction, a model for predicting postoperative straylight improvement was created.

Several clinical studies have been conducted that investigate differences in straylight between different types of IOLs.[18-25, 29, 30, 32] Most often, monofocal and multifocal IOLs have been compared.[18-20, 25, 29] However, differences in multifocal designs and/or material properties must also be considered as potential reasons for straylight elevation. Straylight can be expected to be increased in patients with multifocal diffractive lenses, as only part of the light is focused while up to 18% is spread to higher-order foci, and might contribute to the straylight level.[33] In **Chapter 4**, postoperative straylight values were studied in 2 types of multifocal diffractive IOLs with different apodization patterns. To delineate other parameters (*e.g.* material properties) and to study the effect of different optical designs a literature review on multifocal IOLs was performed and is presented in **Chapter 5**.

Another reason for light scattering by IOLs may be "glistenings". Glistenings are fluid-filled microvacuoles of 1 to 20 μm size, which have most often been associated with hydrophobic acrylic material.[34-39] Postoperative glistenings formation in the IOL bulk is considered as an IOL-related complication, but it has not yet been well understood how they affect visual performance.[40-56] Although it is expected that the presence of glistenings must have adverse implications on visual quality, the scientific literature has shown rather inconsistent results. Most often, VA and CS have been used to assess glistenings effects.[40-56] However, as the difference in the refractive index of the fluid (glistenings) and of the surrounding medium (the IOL material) causes light scattering, one would expect to find these effects on straylight, instead of VA or CS. To better understand this problem, in **Chapter 6** straylight from glistenings is studied and discussed in relation to a general scattering theory.

In several studies IOL opacification following uneventful crystalline lens replacement has been reported.[57-63] The form of opacification depends on the type of material for IOLs.[57-63] Snowflake degeneration has been found in Poly(methyl methacrylate) (PMMA) lenses, in some patients ten (or more) years after implantation.[57] It has been suggested that a snowflake lesion may be triggered by UV light exposure, as it has frequently been found in the central and midperipheral areas of the lens.[57] Hydrophilic acrylic lenses have been associated with calcium and phosphate precipitations.[58, 60] However, studies have reported calcium deposits on hydrophilic lenses with hydrophobic coating,[62] and on PMMA lenses as well.[63] As opposed to snowflake degeneration, calcium-induced opacification appears relatively early postoperatively, in the second year following implantation.[57, 58, 60] It has been reported that calcification of hydrophilic lenses has a multifactorial etiology, and can be related to lens packaging, ophthalmic viscosurgical device or surgical technique.[58, 59] Calcification of silicone IOLs has been associated with asteroid hyalosis.[58, 61] Glistenings formation may occur in hydrophobic acrylic IOLs, as mentioned in the preceding paragraph.[39] The incidence rate of IOL degeneration/alteration and its effect on straylight were studied and are presented in **Chapter 7**. To this end, a random sample of 74 IOLs extracted from donor eyes were analyzed with a straylight meter, and with a slit lamp and light microscopy.

Straylight resulting from the use of contact lenses has been studied for soft as well as rigid gas permeable (RGP) materials.[64-70] A recent clinical study has shown that wearing RGP contact lenses is associated with increased straylight part of which persists after removal of the contact lenses.[70] That study also reported that soft contact lenses do not affect straylight.[70] Straylight of multifocal contact lenses has never been studied, but it might be that multi-zonal designs can increase straylight,[71] especially since it has been reported that multifocal contact lenses wearers are more prone to experience glare related symptoms (*e.g.* while driving at night).[72] To address this problem, straylight of 4 types of multifocal contact lenses was measured clinically with a commercial straylight meter. Results of this study are presented in **Chapter 8**.

To study light scattering from IOLs directly, *in vitro* methods are needed. Two such methods have been reported.[73, 74] These methods provide reliable and precise measurements, but require several specialized optical tools (*e.g.* an optical bench, a high-dynamic range camera). Therefore, they are not easily available for many researchers and clinicians. As discussed in the introduction, the C-Quant straylight meter is widely used in clinics. Although the C-Quant was designed to assess the functional *in vivo* straylight value,[75] it has been shown that this device can also be used for straylight measurements of, *e.g.* scattering filters.[76] Another potential application could be to evaluate (*in vitro*) straylight from IOLs. IOLs are, however, very different from standard scattering filters in terms of size and refractive power, as they are designed to have their refractive effect in the eye. Moreover, IOLs must be tested in solution. Therefore, an adaptation to the C-Quant was designed for straylight assessment of IOLs, and that is presented in **Chapter 9**. Since the straylight parameter refers to what is "seen" by the patient, the C-Quant adaptation is advantageous to clinical practice, as it allows a direct comparison between *in vivo* and *in vitro* straylight values.

In vitro straylight of IOLs has most often been assessed in case of the presence of large particles,[77-79] such as glistenings or surface deposits, but small ($< \lambda$) particles have also been found in implanted IOLs, *e.g.* nanoglistenings.[80-83] In **Chapter 10** a new method for detection and assessment of small particles is proposed and validated.

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