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Retinal stray light originating from intraocular lenses and its effect on visual performance

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Chapter 9

GENERAL DISCUSSION

The objectives of this study were (1) to determine the impact of stray light on visual performance, (2) to evaluate a new technique that aims to quantify stray light, and (3) to determine the contributions of intraocular lenses to retinal stray light. Stray light levels induced by intraocular lenses are design and material dependent [1, chapter 7] and may increase in the presence of micro-vacuoles in the optic body of an intraocular lens [2, chapter 8]. Retinal stray light caused by micro-vacuoles in intraocular lenses may affect vision as illustrated by the intraocular lens explant case studies [3, 4, chapter 2]. This was also illustrated by the degraded visual performance of five healthy subjects when comparable low amounts of retinal stray light were induced [5, chapter 5]. It can be concluded that some intraocular lenses induce retinal stray light levels that may cause serious visual symptoms.

The visual impact of relatively low levels of stray light is hard to quantify in clinical practice, as it does not cause a significant decrease in visual acuity. Stray light is usually assessed using slit lamp exams, looking for potential sources of stray light, that is, cloudy optical media. Direct psychophysical measurement of stray light levels is possible by using the C-quant apparatus [6]. This instrument has the limitation that the glare source is at a fixed location of seven degrees on average. If stray light is uniformly distributed over the retina such as in cataract, then the location of the glare source is not important. For non-uniformly distributed stray light such as in the presence of glistenings, the distance between stimulus and the location of the glare source should match the retinal stray light profile in order to determine the visual impact. Other measures, such as the halo size induced by a light source may help clarify the impact of retinal stray light. Earlier, the halo size was reported to be correlated with the amount of forward light scatter [7]. The Rostock Glare Perimeter was developed [8, chapter 3] to quantify the halo size under simulated, but realistic, conditions. We found that the halo size increased with age [8, chapter 3] and that pseudo-phakic subjects had a larger halo size than healthy phakic subjects [9, chapter 4]. The method also showed that the halo size was reduced when binocular test conditions were used [8, chapter 3] and that patients with a monofocal IOL had a smaller halo size than patients with a multifocal IOL [9, chapter 4]. All these findings suggest that the Rostock Glare Perimeter method is a helpful device to quantify symptoms of retinal stray light. However, before regular clinical use of the Rostock Glare Perimeter is feasible, the psychophysical measurement procedure needs to be changed from a method of adjustment to a forced choice method. Also, it would be interesting to investigate if there are differences in retinal stray light effects using the Rostock Glare Perimeter among the various newly introduced multifocal lenses. Even if they are similar in distance power, optical design principle and material, they may differ largely in terms of induced stray light because of chosen reading power and specific implemented diffractive or refractive technology.

In addition, when using the Rostock Glare Perimeter one can change the background luminance glare source strength and target size to simulate different conditions. For instance, a luminance detection threshold test was developed making use of the same device [5, chapter 5]. The luminance threshold test is a detection task intended to capture the impact of stray light in low light environments, with low light levels both for glare source and stimuli. Degraded performance on this type of task could be a risk factor for, e.g., safe night driving. Relationships were found for increases in retinal stray light with visual performance measures: halo size, luminance detection threshold, and contrast sensitivity [5, chapter 5]. The luminance threshold test was the most sensitive visual performance test: it showed a 20 fold increase for a moderate cataract case. Hence, a luminance threshold test might be helpful in the case of an inconclusive slit lamp exam of the crystalline lens, to decide if cataract surgery should be offered to the patient or not. It may also be a diagnostic tool in cases where micro-vacuoles in intraocular lenses are suspected to be a source of visual complaints. Another visual test that can be used to study the impact of retinal stray light on visual performance is contrast sensitivity testing. The quick contrast sensitivity test [10] was able to detect differences in contrast sensitivity more easily than traditional contrast sensitivity tests because of a higher resolution in contrast levels and spatial frequency levels as well as shorter test duration.

In chapter 6 two complementary in-vitro quantitative methods [11, chapter 6] were developed that allowed us to show that stray light levels in intraocular lenses are design- and material dependent [1, 2, chapters 7 and 8]. Stray light induced by intraocular lenses may exceed stray light levels of a healthy 20 year old human crystalline lens and may even reach levels of a 70 year old human crystalline lens. Because of these adverse effects, the retinal stray light potential of intraocular lenses should be a product specification for lens manufacturers and the limit may be determined based on future studies addressing tolerance to retinal stray light. A first proposed limit for induced stray light is to be below the level of a healthy 20 year old crystalline lens [2, chapter 8]. In-vitro light scatter measurements in intraocular lenses are also useful because they allow for the assessment of stray light levels separately from sources of stray light that inevitably occur in-vivo such as that from the cornea, the vitreous body, and the retina. Furthermore, forward scatter and backward scatter of light can be determined in-vitro in one setup and both scatter directions can be compared. If there is a difference in forward and backward scatter levels, this may then serve as an explanation for differences found in clinical observations like in slit lamp exams which are dominated by backward scatter versus patients' perceptions which depend on forward scatter.

In one study, pseudo-phakic subjects were found to have an average stray light level comparable to that of a healthy 70 yr old eye [12] while based on the stray light levels of IOLs, a stray light level comparable to that of a young eye was expected. It would be worthwhile to study the origin of this unexpected result. Potential sources of the high

stray light levels could be the lens capsule and after-cataract (PCO) [13, 14, 15]. A study comparing the in-vitro and in-vivo stray light levels for one intraocular lens type may help to explain these results using the developed in-vivo and in-vitro technology described in this study.

To better understand the visual complaints of the two patients described in chapter 2 for which the intraocular lenses were exchanged, the developed knowledge was used to relate the effect of the measured stray light levels in the explanted lenses to the visual performance measures. The elevated stray light levels measured in-vitro corresponded to significant increases in halo size and luminance detection thresholds, and a significant decrease in contrast sensitivity [16]. Although these outcomes are retrospective in nature, it may help clinicians to understand visual complaints resulting from low amounts of retinal stray light.

Peripheral vision and motion detection capacities are used for navigation purposes and studies of the effect of stray light on the peripheral retina may show an effect on the execution of these tasks. This is even more relevant for patients with advanced age related macular degeneration because they rely on their peripheral vision. Continued improvement in technologies and knowledge of the effects of retinal stray light holds promise for the future. This leads to more advanced assessment of the quality of vision before and after refractive and cataract surgery, which may lead to improved diagnostic procedures, refractive correction procedures and optical designs of intraocular lenses.

In my opinion, improvements in diagnostic procedures should be addressed first in order to make advancements in the total field of refractive and cataract surgery. The availability of a single instrument that is able to measure the light intensity distribution over the entire functional retina resulting from a point source in object space, will enable an objective assessment of many important aspects of vision. The central part of this light intensity distribution (the point spread function) describes the eye's wavefront aberrations that determine visual acuity and contrast sensitivity, and its skirt describes the level of retinal stray light [chapter 6]. The intermediate part of the intensity profile is another interesting topic to investigate, i.e., the potential interaction between the wavefront aberrations and retinal stray light [17]. The availability of such a single diagnostic test may be an additional screening tool in addition to the traditional letter chart in cataract and refractive procedures, and visual complaints. In a wider context, such a comprehensive test may substantially contribute to healthy aging, and reduce the burden on the health care system when it can determine whether it is advisable to extend driver's licenses in the aging population or play a role in screening in professions where vision is relevant for safety.

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