**Impact on optical image quality from glistenings in intraocular lenses – preliminary study**

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Received November 28, 2008; revised December 2, 2008; accepted December 4, 2008; published December 5, 2008

**Abstract** —The aim of the study was to determine how glistennigs phenomenon affects the quality of the retinal image. The phenomenon gistenigns a defect appearing in artificial intraocular lenses after a residence time of the lenses in the aqueous humor inside the eye. This defect occurs in all types of IOLs and is a phenomenon quite common. The study modeled three intraocular lenses, two made of acrylic and one made of PMMA. The lenses were located in the eye model prepared based on the work Atchinsona [1]. The study determined how strongly reduced image quality in the various models of lenses for specific size and density of the vacuole formed. The analysis can be concluded that the degree of deterioration in the image quality with the same parameters microvacuoles is different. The impact of glistennigs the fidelity depends on design parameters of the lens.

**INTRODUCTION** Prolonged exposure in the environment of aqueous humor results in aging process of an intraocular lens (IOL), which leads to progressive degradation of an IOL surface and other changes in material properties. It may further on result in lowering patient’s visual quality and his everyday comfort.

Due to increasing range of the problem, plenty of research are being conducted, describing and systematizing lesions in intraocular lenses after implantation [2-15].

However, majority of them concern IOL materials, while very few focus on impact of the lesions on visual quality. One of the most observed and discussed part of material degradation process is formation of microvacuoles filled with fluid, which tend to affect IOL optical properties and cause scattering of the light passing through the lens. This phenomenon is called glistenings [6-15].

In order to evaluate the impact of glistenings on retinal image quality, Atchison eye model [1] was implemented in popular software used for ray-tracing – Zemax. The crystalline lens was replaced with three commercially available IOLs made of different materials – acrylic and PMMA. Modulation transfer function (MTF) was used to compare the retinal image quality between a model including a homogenous lens and a lens with glistenings. In order to study the impact of scattering on image quality in optic of different refractive index, the analysis included different materials of IOLs.

**METHODS** Using Atchison eye model [1] as the basis, a pseudophakic eye model was constructed by replacing the crystalline lens with a 21.0 D intraocular lens. Abbe number of each optic in the model was calculated in order to receive optical image quality parameters in non-monochromatic light. Models of three IOL materials – two acrylic of different refractive index and one of PMMA, were analyzed in the study.Table 1 gives the parameters of IOLs used.

Table. 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Material | Manufacturer | Refractive index | Abbe number | Radius of curvature 1  [mm] | Thickness  [mm] | Radius of curvature 2  [mm] | A parameter |
| AR40N | Allergan | 1.470 | 71.0 | 12.71 | 1.008 | -12.71 | 118.4 |
| P359UV | Bausch&Lomb | 1.493 | 57.4 | 15.00 | 1.000 | -15.00 | 118.0 |
| Acrysoft MA60BM | Alcon | 1.552 | 46.4 | 32.00 | 0.800 | -15.00 | 118.9 |

Retina position in every model was optimized by Zemax tools to receive the best polychromatic optical quality for the paraxial rays.

For this analysis, we simulated scattering on microvacuoles in intraocular lenses. Glistenings were modelled as spherical inhomogeneities filled with aqueous humor randomly located in IOL material.

These inhomogeneities cause scattering of the light passing through the intraocular lens. Mie scattering was used in the study. This scattering was simulated in Zemax using a built-in source code. The variables changed during the study were the number of vacuoles per cm3 of the element, the diameter of a single microvacuole and other factors describing probability of scattering. In order to fully analyze the impact of pupil diameter and density of microvacuoles on image quality in pseudophakic eye model, three grades of glistenings introduced by Miyata [2] were considered.

Two parameters were calculated to analyze image quality – MTF50 [17] and MTFDrop [16]. Second one describes decrease in the image quality. The drop was calculated for 4.35 cycles/degree frequency. It was a value for which at least one model reached the first minimum. This choice prevented us from analyzing noises.

 (1)

Where MTFIOL(f) – MTF value of pseudophakic eye without scatter, while MTFscatter(f) – MTF value of pseudophakic eye with glistenings, f - reference spatial frequency value.

Parameter MTF50 limits the analysis to only one material, whilst MTFDrop allows to objectively compare the impact of refractive index on scattering.

**RESULTS** MTFDrop was calculated for three diffrernt pupil diameters: 3mm, 4.5mm, 6mm.

The biggest MTFDrop, irrespective of the lens material, was observed for the norrowest eye pupil.

Models with pupils 4.5 and 6 mm gives similar results. There is no significant difference (p>0,05), which could result in clear dependency between pupil diameter and MTFDrop. The biggest decrease in optical image quality for lenses AR40N (acrylic), P359UV (PMMA) and MA60BM (acrylic), was observed in photopic conditions (pupil diameter 3 mm) for vacuoles of 20 µm diameter and grade III in Miyata scale.

In scotopic, mesopic and photopic conditions (respectively 6, 4.5 and 3 mm) MTFDrop reached its highest value for P359UV lens (vacuole diameter φw=20 µm, glistenings of grade III in Miyata scale). Acrylic lens MA60BM gave the best optical image quality.

The following graphs show the dependence of the parameter change MTFDrop as a function of the diameter of a single mikrowakuoli for three degrees of density (I, II, III) in photopic conditions for entrance pupil diameter of 3mm. Lowering the quality of retinal imaging determined by MTFDrop is greater the larger the diameter and density microvacuoles. It can be noted that the degree of deterioration in the image quality with the same parameters micreovacuoles is different for different models of lenses.

Fig. 1. Decrease in the quality imaging of the retinal determined by MTFDrop a result of the creation miocrovacuoles inside the lens AR40N depending on the diameter microvacuoles Φw and the degree of density (I, II, III)

Fig. 2. Decrease in the quality imaging of the retinal determined by MTFDrop a result of the creation miocrovacuoles inside the lens MA60BM depending on the diameter microvacuoles Φw and the degree of density (I, II, III)

Fig. 1. Decrease in the quality imaging of the retinal determined by MTFDrop a result of the creation miocrovacuoles inside the lens P369UV depending on the diameter microvacuoles Φw and the degree of density (I, II, III)

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**DISCUSION** Preliminary analysis assumed that the lenses, in which the relative difference between the scatter and the media is more significant, should show more scattering effects []. In this case, the sequence of lenses, starting from the one which gives the worst image quality, should be: MA60BM, P359UV and AR40N. However, because of the fact that MA60BM lens has lower thickness (as a result of higher refractive index), it causes relatively low damage to the image quality. It might be explained by the dependency between the probability of scattering and the length of light propagation, which is described by the equation:

I(χ)=e-αχ  (1)

Where α is a coefficient in mm-1, whilst χ is the length of propagation [49]. Regarding the dependency above, the impact of refractive index of MA60BM lens is compensated by its axial thickness, which is 0.2 mm lower comparing to other lenses. Two other lenses, which thickness is similar (the difference is 0.008 mm) gives the expected results – MTFDrop of P359UV reaches higher values than AR40N (differences at p <0.05, Wilcoxon test). It is consistent with Mie scattering theory, because the lens of bigger difference between the material and scatters, shows bigger modulation transfer function drop.

The study considers only simplified model of intraocular lens with glistenings. In realistic element microvacuoles tend to occur in different sizes. Their location is also very irregular, depending on a structure of a polymer. Because of this diversity, experimental studies, which could precisely define the relation between optical image quality and glistenings, are impossible. However our technique is a place to start for further research, which may increase and improve the knowledge of described phenomenon. Owing to the technique it is possible to precisely measure the influence of density and diameter of microvacuoles and other design parameters of the lens. Further research could systematize the knowledge of glistenings and in the same time might be helpful for intraocular lens designers. Based on our study, it is believed that microvacuoles diameter, density of their location, eye pupil diameter, lens thickness and lens refractive index has an influence on lowering the image quality, which might be measured by MTFDrop. The results of our study confirmed the interpretation by DeHoog et al []. In order to minimalize scattering and its negative effects, thickness of the element needs to be as low as possible. A new method of modelling individual cases should be developed in further research. As a form of detailed analysis it should allow irregular vacuoles location and different diameter of microvacuoles in one lens.

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