·Clinical Research·

Comparison of pseudophakic retinal straylight in spherical/aspherical and hydrophobic/hydrophilic intraocular lens

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Abstract

• AIM: To study the potential reasons of increased straylight in pseudophakic eyes.

• METHODS: Cross-sectional study. Seventy patients diagnosed as bilateral age-related cataract and implanted with Tecnis ZA9003, Sensar AR40e, SA60AT, XLSTABI ZO or Akeros AO intraocular lens (IOL) were enrolled in this research. Straylight was measured by a C-Quant straylight meter three to four weeks postoperatively. Five different modalities of IOL, including spherical/aspherical optics and hydrophobic/hydrophilic material were tested in this study. Normal as well as dilated pupils were used. The main outcome variable for straylight measurement was the logarithmic straylight parameter, log(s).

• RESULTS: The straylight parameter increased significantly after pupil dilation (*P*<0.05). Straylight of aspherical IOL was significantly higher after pupil dilation (*P*<0.05) compared to spherical IOL. In normal pupil, straylight of hydrophobic IOL was significant higher when compared with hydrophilic IOL (*P*<0.05).

• CONCLUSION: Straylight and visual acuity stand for the different aspects of visual function. Several factors including pupil diameter, optic material, aspherical design of IOL influence intraocular light scattering in pseudophakic eyes. Further investigation was needed to study the impact of optic material and optic surface design on pseudophakic straylight.

• **KEYWORDS:** light scattering; retinal straylight; pseudophakia

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INTRODUCTION

Light scattering in eyes, which may decrease retinal image contrast [1], is attributable to imperfect eye optics in cornea, sclera, lens, vitreous humor, and retina. Structural change of crystalline lens in aged eyes is the major reason for the increase of light scattering [2], which explains why some elder cataract patients have visual complaints of glare or halos. Replacement of aged natural lens with intraocular lens (IOL) will decrease ocular straylight and improve visual quality[3].

Despite the significant decrease of ocular straylight after the implantation of IOLs [3], some pseudophakic patients still complain about glare and halo, which are more common in patients with multifocal IOLs [4,5], compared to patients with monofocal IOLs. Undesirable optical effects of IOLs, generally referred as glare or unwanted optical images, are often caused by the optic shapes and diameters, as well as IOL edge designs [6]. Therefore, it is of vital importance to evaluate the effects of IOLs on straylight after cataract surgery [7]. In this study, we utilized C-quant straylight meter (Oculus, German), which can precisely measure ocular straylight, to study the potential reasons of increased straylight in pseudophakic eyes.

SUBJECTS AND METHODS

From December 2010 to August 2011, 70 subjects (140 eyes) were recruited from Tianjin Eye Hospital cataract center. Patients were considered for participation if aged between 40 and 85y, diagnosed as bilateral age-related cataract with no other ocular diseases or optic neuropathy, and capable of communication and understanding. Patients in our study have accepted the cataract phacoemulsification and IOL implantation surgery and returned for examination three to four weeks postoperatively. No case of IOL tilting and decentration was found under slit-lamp observation by the time they were examined. All patients were provided with informed consent, the study was performed in accordance to the tenets of the Declaration of Helsinki. Anthropological information was listed as follows in details (Table 1).

Exclusion criteria included concurrent disease that might influence the optical or neural performance of the eye (*e.g.* uveitis), retinal or optic nerve pathology (*e.g.* macular

Table 1 Anthropological information of patients in our study

IOL	No.	Gender		Age (a)	UCVA	BCVA
		M	F			
General	70	34	36	68.42±8.35	0.70±0.20	0.89±0.08
AR40e	16	9	7	69.06±8.74	0.65±0.19	0.90±0.08
ZA9003	16	8	8	68.94±9.22	0.68±0.19	0.89±0.08
SA60AT	12	6	6	67.08±6.85	0.78±0.21	0.90±0.08
XLSTABI ZO	15	7	8	67.90±8.72	0.70±0.22	0.90±0.08
Akeros AO	11	4	7	68.91±7.92	0.73±0.19	0.88±0.08

BCVA: Best corrected visual acuity; UCVA: Uncorrected visual acuity.

Table 2 Technical data of IOLs

Parameters	AR40e	ZA9003	SA60AT	XLSTABI ZO	Akeros AO
Overall length (mm)	13	13	13	10.5	10.5
Overall design	Three-pieces	Three-pieces	One-piece	One-piece	One-piece
Optic diameter (mm)	6	6	6	6	6
Optic material	Hydrophobic acrylic	Hydrophobic acrylic	Hydrophobic acrylic	Hydrophilic acrylic 28%	Hydrophilic acrylic
Aspherical design	/	Modified anterior surface	/	Modified posterior surface	Modified anterior and posterior surface
Refractive index	1.47	1.47	1.55	1.46	1.458

degeneration, diabetic retinopathy, glaucoma), corneal or vitreousopacities and irregularities, abnormality of pupils, amblyopia, intraoperative complications, ocular trauma or past history of intraocular surgery other than cataract, and significant anterior chamber inflammation or corneal edema postoperatively. Patients who had a neodymium:YAG (Nd:YAG) laser capsulotomy to treat posterior capsule opacification (PCO) were excluded. Also excluded were patients with a spherical equivalent refractive error greater than ±2.00 D and/or astigmatism greater than 2.50 D after cataract extraction.

As listed in Table 2, we specifically analyzed two spherical designs: AR40e (Abbott Medical Optics, USA), SA60AT (Alcon, USA) and three aspheric designs: ZA9003 (Abbott Medical Optics, USA), XLSTABI ZO (Carl Zeiss Meditec, Germany) and Akeros AO (Bausch&Lomb, USA).

In our study, 32 eyes were implanted with AR40e, 32 eyes with ZA9003, 24 eyes with SA60AT, 30 eyes with XLSTABI ZO, and 22 eyes with Akeros AO. The IOL power was decided according to IOL master calculation.

All surgeries were performed by the same experienced surgeon (Chen J) in Tianjin Eye Hospital. Phacoemulsification was performed through a 3.0 mm clear corneal incision at the 12:00 o'clock position and IOL was implanted with a matched injector. All surgeries were uneventful.

The follow-up in this study was three to four weeks, which precludes analysis of long-term performance of these IOLs. The period is long enough to eliminate the influence of significant cornea edema and anterior chamber flare to straylight measurement but short enough to minimize the risk that later changes in the posterior capsule would influence the study results.

Every subject has accepted visual acuity measurement (including the uncorrected and best-corrected visual acuity), intraocular pressure measurement, slit-lamp examination, funduscopy examination, C-Quant 8000 straylight meter (Oculus Optikgeräte GmbH, Wetzlar, Germany) and KR-1W Wavefront analyzer examination (Topcon Europe Medical BV, Capelle a/d Ijssel, the Netherlands).

Visual Acuity Measurement Both uncorrected and best-corrected visual acuity (UCVA and BCVA) were recorded using the Snellen visual acuity chart in photopic condition (85 cd/m^2).

Pupil Diameter Measurement Pupil was dilated with one drop of tropicamide 0.5%, and pupil diameter was measured before and 30min after dilation by KR-1W wavefront analyzer in photopic condition (85 cd/m^2).

Straylight Measurement Straylight parameter was measured by C-Quant 8000 straylight meter (Oculus) in natural and dilated pupils three to four weeks postoperatively. The system and detailed procedures have been described previously [8]. Values were presented in log scale (straylight parameter) [log(s)]. Higher straylight values indicate higher sensitivity to glare and thus more compromised visual function. Only measurements with Esd ≤0.08 and Q value ≥0.5 were considered reliable and therefore included in this study. To ensure measurement quality, the test was repeated up to 3 times in case the computer software indicated low reliability.

Statistical Analysis Pearson correlation analysis was used to evaluate the relationship between straylight parameter and visual acuity (including UCVA and BCVA). Paired-samples t test was used to compare straylight parameter in normal and dilated pupil. Independent-samples t test was used to compare the value between spherical/aspherical IOL, and hydrophilic/hydrophobic IOL.

Table 3 Comparison of straylight in different IOLs between normal and dilated pupil

Pupil	Normal	Dilated	^{a}P
Total			
Straylight log(s)	1.29±0.20	1.54±0.23	<0.0005
Pupil diameter (mm)	3.74±0.61	6.62±0.59	<0.0005
AR40e			
Straylight log(s)	1.32±0.24	1.50±0.20	<0.0005
Pupil diameter (mm)	3.70±0.55	6.58±0.65	<0.0005
ZA9003			
Straylight log(s)	1.35±0.14	1.62±0.18	<0.0005
Pupil diameter (mm)	3.73±0.74	6.60±0.59	<0.0005
SA60AT			
Straylight log(s)	1.41±0.19	1.61±0.26	<0.0005
Pupil diameter (mm)	3.77±0.59	6.51±0.65	<0.0005
XLSTABI ZO			
Straylight log(s)	1.20±0.16	1.49±0.27	<0.0005
Pupil diameter (mm)	3.75±0.65	6.75±0.58	<0.0005
Akeros AO			
Straylight log(s)	1.17±0.16	1.49±0.19	<0.0005
Pupil diameter (mm)	3.74±0.45	6.67±0.49	<0.0005

$^{a}P<0.05$ was considered significant.

RESULTS

Comparison Between Normal Pupil and Dilated Pupil As shown in Table 3, the straylight parameter increased significantly with dilation ($P<0.0005$); the mean was 1.29±0.20 log (s) with natural pupils and 1.54±0.23 log (s) with dilated pupils.

Comparison Between Spherical and Aspherical Intraocular Lens According to Table 3, there was no significant difference of straylight parameter between spherical and aspherical IOL in normal pupil, but straylight of aspherical IOL was significantly higher than spherical IOL in dilated pupil ($P<0.05$).

Comparison Between Hydrophilic and Hydrophobic Intraocular Lens As shown in Table 3, straylight of normal pupil was significant higher in hydrophobic IOL compared to hydrophilic IOL ($P<0.05$).

DISCUSSION

This research was designed to study the straylight in pseudophakic eyes. Straylight was measured in 5 different modalities of IOL, including spherical/aspherical optics and hydrophobic/hydrophilic material. Clear differences in straylight levels are found between natural/dilated pupil, spheric/aspheric IOLs, and hydrophobic/hydrophilic IOLs.

Firstly, comparison of straylight between both eyes shows a high degree of correlation (Figure 1A, 1B). If one eye was considered as replica of the other, such comparison can be used to estimate accuracy of the measurements. The repeated measures standard deviation (rmsd) that follows from this comparison is 0.12 log units. That is not far from often found

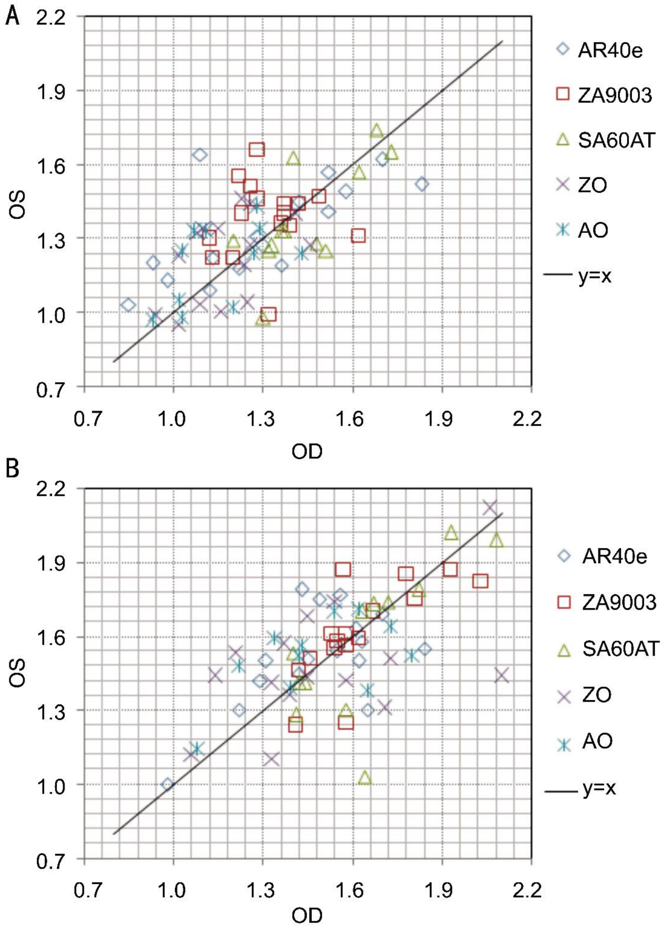

Figure 1 Plot of straylight in right eye versus left eye.

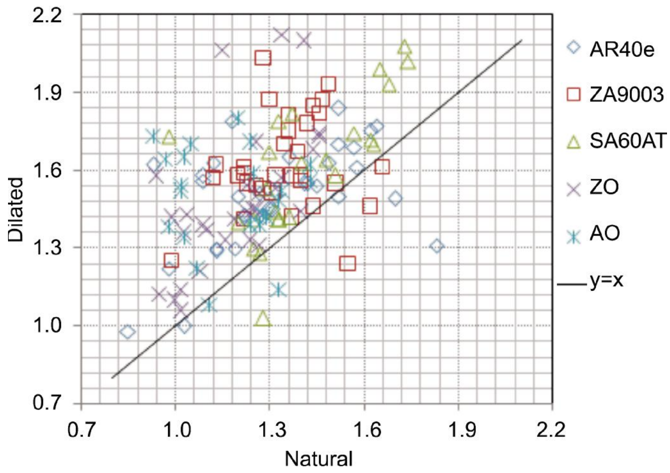

Figure 2 Plot of straylight in normal versus dilated pupils.

real rmsd of 0.08 log units. This result shows that our measurements have been accurate, and that the variation found in our study must be due to real factors (not measurement error). Assuming the 0.08 value to applied in our study, this result suggests that the straylight of pseudophakia varies somewhat between fellow eyes, but that the difference between fellow eyes is more limited as compared to the variation within the subgroups.

Secondly, straylight increased after pupil dilation in our study (Figure 2). The plot of straylight in dilated versus natural pupil shows in the vast majority of cases an increase, and a correlation between both values. This plot underlines the importance of considering night vision effects with IOLs. However, C-quant 8000 use straylight parameter, calculated as the ratio between scattered light and non-scattered light, to indicate the amount of straylight in one eye. Theoretically this value should remain the same before and after pupil dilation since both scattered and non-scattered light increase by the same scale in dilated eyes [9]. This inconsistence may be caused by exposure of optic edge, capsular opacification and cornea edema.

Previous study showed that the sharp-edged optical design was blamed as one of the main causes of glare disability[6,10]. The optic diameter of IOL in our study was 6 mm. After pupil dilation, exposure of optic edge especially the square edge[6] will enhance the light scattering.

There will always be subclinical cornea swelling [11] and endothelial cell loss [12] after phacoemulsification, which accounted for the increase of straylight in pseudophakic eyes. Therefore, the increase of straylight may be partly attributed to exposure of subclinical cornea swelling especially the edema around the corneal incision after pupil dilation.

Opacification on the anterior and posterior capsule is caused by migration of lens epithelium cells (LECs) and more capsular opacification will be exposed after pupil dilation[13,14]. The light distribution on the retina can be disturbed by the residual LECs, which leads to the increase of straylight and decrease of visual acuity and contrast sensitivity[15-17].

Thirdly, straylight was significantly higher in aspherical IOLs. There are several kinds of aspherical design of commercial marketed IOL, including the prolate anterior surface in Tecnis ZA9003 (AMO), prolate posterior surface in SN60WF (Alcon), Aspheric Balanced Curve (ABC) design in FY-60AD (HOYA), *etc.* Although some patients experience edge-related glare [6], it has been suggested clinically and shown theoretically in ray-tracing analysis that optic surface-related internal and external reflections could explain the glare and unwanted optical images reported by other patients[18].

Our data showed that straylight is significantly higher in aspherical IOL ZA9003, which is almost identical to AR40e (spherical) in lens design and optic material, except for the biconvex aspherical design with flatter anterior surface [19]. It is suggested that increased straylight or high glare disability might be caused by the prolate anterior surface of optic[20,21]. Previous research suggested that optic with a steeper anterior surface causes internally reflected light from the IOL to pass through a focus closer to IOL and to reduce the intensity on the retina as well as the potential for unwanted optical images [21,22]. Therefore the prolate anterior surface of IOL optic should account for the increased straylight or high glare disability. Further investigation is needed for final conclusion.

Lastly, our research revealed that straylight was significant higher in hydrophobic IOL. Data of normal pupil was used for analysis in order to eliminate the influence of capsule opacity [15], optic edge and IOL design to straylight measurement[6]. As shown in previous research, hydrophobic material of IOL optic lead to more inflammatory cells attachment and more rapid anterior capsule opacification[23,24]. Inflammatory cell adhesion and proliferation on the optic surface are influenced by the contact angle of the IOL biomaterials [25]. The more hydrophilic the IOL surface, the less adhesive and proliferative the cells [26]. To our knowledge, straylight as a function of inflammatory cells on the optic has not been reported in the literature; however, inflammatory cell adhesion may be a possible explanation for the difference of straylight between hydrophobic and hydrophilic IOLs.

Glistenings are refractile microvacuoles that result from water condensation within the matrix of IOL [27]. Previous findings point to the possibility that intraocular light scatter can be caused by a high density of glistenings, which in turn results in glare disability[28]. Behndig *et al* [29] also indicated that greater scatter was correlated with more glistenings, as quantified *via* Scheimpflug imaging. Glistenings can be observed in any type of IOL, but most of the currently available literature describes them in relation to hydrophobic acrylic IOLs [30]. Since there is a significant difference of refractive index in water droplets and the bulk polymer of IOL, the light is markedly refracted and scattered at the water-polymer interface [31]. It is therefore likely that glistenings in optic lead to the difference of intraocular straylight between hydrophobic and hydrophilic IOLs.

Refractive index (RI) of optics was another reason accounting for the higer straylight in hydrophobic IOLs. In our research straylight was significantly higher in SA60AT (RI=1.55) when compared with two kinds of hydrophilic IOLs (RI=1.46). According to Fresnel's reflectivity equations, reflectivity at the anterior optic surface increases as the difference of RI between IOL and aqueous humor increases, which will lead to the increase of light scattering consequently. Erie *et al* [21] suggested that increasing the RI of the IOL optic material has an additional but smaller effect on reflected light; the intensity of reflected light increases 5-fold when using a higher RI material (n=1.55) versus a lower RI material (n=1.43).

In summary, our study suggested that several factors influence straylight in pseudophakic eyes: pupil diameter, optic material, anterior surface curvature of IOL. Significant differences in straylight levels are found between natural/dilated pupil, spheric/aspheric IOLs, and hydrophobic/hydrophilic IOLs. Further investigation is needed to verify the influence of optic material and optic surface design to the pseudophakic straylight. Reasonable application of straylight measurement may allow surgeons to choose IOLs more appropriately for different surgical situations and individual patient characteristics.

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