·Clinical Research·

Contrast visual acuity after multifocal intraocular lens implantation: aspheric versus spherical design

Jun-Hua Li[1], Yi-Fan Feng[2], Yun-E Zhao[1], Yin-Ying Zhao[1], Lei Lin[1]

[1]School of Ophthalmology and Optometry, the Eye Hospital of Wenzhou Medical University, Zhejiang Eye Hospital, Wenzhou 325000, Zhejiang Province, China
[2]Department of Ophthalmology, Zhongshan Hospital, Fudan University, Shanghai 200023, China
Correspondence to: Yun-E Zhao. School of Ophthalmology and Optometry, the Eye Hospital of Wenzhou Medical University, Zhejiang Eye Hospital, Wenzhou 325000, Zhejiang Province, China. zye@mail.eye.ac.cn
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Abstract

• AIM: To evaluate contrast visual acuity (CVA) after implantation of an aspheric apodized diffractive intraocular lens (IOL) or a spherical apodized diffractive IOL in cataract surgery.

• METHODS: This prospective randomized controlled study with a 12-month follow-up compared the results of cataract surgery with implantation of an aspheric AcrySof ReSTOR SN6AD3 IOL (30 eyes) and a spherical AcrySof ReSTOR SN60D3 IOL (30 eyes). CVA with best distance correction was measured at 4 contrast levels (100%, 25%, 10% and 5%) under 3 levels of chart luminance [250, 85 and 25 candelas per square meter (cd/m²)] using a multi-functional visual acuity tester (MFVA-100).

• RESULTS: At 12 months after surgery, there were no statistically significant differences in 100% CVA and 25% CVA under 250cd/m² ($P_{100\%}$=0.875 and $P_{25\%}$=0.057) and 85cd/m² ($P_{100\%}$=0.198 and $P_{25\%}$=0.193) between the aspheric group and the spherical group. However, the 10% CVA and 5% CVA were significant better in aspheric group than spherical group under 250cd/m² ($P_{10\%}$=0.042 and $P_{5\%}$=0.007) and 85cd/m² ($P_{10\%}$=0.002 and $P_{5\%}$=0.039). Under the luminance level of 25cd/m², no significant differences was found in the 100% CVA between the 2 group ($P_{100\%}$=0.245), while aspheric group had better visual acuity in the remaining 3 contracts($P_{25\%}$=0.023, $P_{10\%}$=0.026 and $P_{5\%}$=0.002, respectively).

• CONCULSION: The aspheric AcrySof ReSTOR SN6AD3 IOL provided patients with better low-contrast visual acuity than the spherical AcrySof ReSTOR SN60D3 IOL.

• **KEYWORDS:** cataract surgery; intraocular lens; contrast sensitivity; visual acuity
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INTRODUCTION

Nowadays, phacoemulsification is the standard technique for cataract surgery. Although many factors affect visual outcomes, mounting studies reported that the visual performance of patients who have undergone phacoemulsification depends on the type of intraocular lens (IOL) that has been implanted. Implantation of a monofocal IOL usually provides excellent visual function, but for many patients its limited depth of focus does not allow clear vision at both distance and near. Multifocal IOL, in which multiple focal lengths are present within the optical zone, has been designed with the intention of providing satisfactory distance and near vision without the need for spectacles[1,2].

Visual evaluation of the spherical multifocal IOL, AcrySof ReSTOR SN60D3 (Alcon, Inc.), has been previously performed in detail. Several large studies have indicated that the quality of vision with this IOL is good [3-5]. Recently, the aspheric multifocal IOL, AcrySof ReSTOR SN6AD3 (both Alcon, Inc.), which with a near addition (add) of +4.00 diopters (D) (equivalent to approximately 3.20D at the spectacle plane), was developed to improve intermediate vision, reduce unwanted visual phenomena, increase the range of focus, and improve image quality [6]. A previous study reported that patients with the aspheric multifocal SN60D3 IOL had significantly better near vision than patients with the multifocal spherical SN6AD3 IOL, but the night-vision symptoms and contrast sensitivity were similar[7].

Contrast sensitivity is a valuable test after cataract surgery and has been suggested as an indicator of surgical quality[8]. Many studies have demonstrated that impaired contrast sensitivity may exist in the presence of normal visual acuity [9,10]. The purpose of the current study was to compare the contrast visual acuity (CVA) in patients who had cataract extraction and AcrySof ReSTOR SN6AD3 IOL (aspheric model) implantation and patients with AcrySof ReSTOR SN60D3 IOL (spherical model).

SUBJECTS AND METHODS

Subjects This prospective randomized controlled study comprised patients having phacoemulsification and posterior chamber IOL implantation for senile cataract at the Affiliated Eye Hospital of Wenzhou Medical University from January to December 2010. The study was approved by the institutional ethics committee and followed the tenets of the Declaration of Helsinki. The procedures were fully explained to each patient, and each provided written informed consent.

All patients were randomly assigned the day before surgery to one of the two groups: those who were to undergo implantation of the aspheric IOLs and those who were to receive spherical IOLs. The clinical research coordinator generated a code using a computer, and kept concealed the assignment schedule until all data were collected. Inclusion criteria in both groups were age 50 to 80 years, cataract in both eyes classified by the Lens Opacities Classification System III, corneal astigmatism less than 1.5D, potential acuity meter reading better than 0.2logMAR units, and axial length between 23.0mm and 24.0mm. Exclusion criteria were anterior segment pathology such as chronic uveitis, zonular dialysis, pseudoexfoliation syndrome, and glaucoma; posterior pathology such as diabetic retinopathy; and macular pathology. Patients with previous anterior and posterior segment surgery and intraoperative or postoperative complications were also excluded.

Methods

Preoperative examination A complete preoperative ophthalmic examination, including slit lamp and dilated fundus evaluation, was performed. Axial length (AL) was measured by partial coherence interferometry (IOLMaster, Carl Zeiss Meditec); if this was not possible due to the density of the cataract, AL was measured by ultrasonography.

Surgical technique All surgeries were performed by the same experienced surgeon (Zhao YE.) using topical anesthesia and a 2.8mm clear corneal incision. Phacoemulsification was performed with the Infiniti Vision System (Alcon). Phacoemulsification was followed by irrigation and aspiration of the cortex, posterior capsule polishing and IOL implantation in the capsular bag. After IOL insertion, the viscoelastic material was thoroughly evacuated.

Postoperative follow –up All postoperative examinations were performed at 12 months by the same ophthalmic technician. The technician was unaware of the objective of the study and masked to the IOL implanted.

Main outcome measures Dynamic measurement of CVA with best distance correction was achieved using a multi-functional VA tester (MFVA-100, BriteEye Medical Tech Co. Ltd, Shenzhen, China), which can continuously measure distant VA (5.5m) over a desired period (5min in this study) [11]. A staircase psychophysical procedure was employed with a minimum step of 0.05logMAR. The optotype was a tumbling E, presented on a calibrated LCD computer monitor and its open direction was randomly selected from four directions (left, right, up and down) by the computer. The subject's task was to report the open direction to the examiner and the response was entered into the computer by the examiner. The size of the tumbling E was determined according to the subject's response to the previous stimuli, with one up or down for one correct or wrong response. A step of 0.1logMAR was applied if two correct or wrong responses occurred consecutively. If the difference between a just-presented size and baseline visual acuity (0.3logMAR in this study) was greater than 0.1logMAR, the next size returned to baseline visual acuity, when two correct responses occurred in a row. Four contrast percentages of visual targets (100%, 25%, 10% and 5%) were measured under 3 levels of chart luminance (250, 85 and 25 candelas per square meter (cd/m^2); *i.e.* the luminance recommended in the manufacturer's guidelines). As noted previously, visual performance was expected to be dependent on pupil size. Pupil diameters in distance vision were therefore measured in each patient under the illumination of 85cd/m^2 by means of the iTrace aberrometer (Tracey Technologies, Houston, Tx, USA).

Table 1 Patient demographics

Characteristic	Aspheric group (n=30 eyes)	Spherical group (n=30 eyes)	P
Mean age (a)±SD	65.97±7.53	63.93±8.34	0.33
Sex (M/F)	16/7	15/7	0.85
Axial length (mm)±SD	23.66±0.68	24.16±1.94	0.19
Implanted IOL power (D)±SD	20.50±2.27	19.47±2.09	0.07
BCVA[1] (logMAR)±SD	0.61±0.42	0.65±0.55	0.71
Mean SE[2] (D)±SD	-0.36±0.40	-0.33±0.36	0.99
Mean pupil diameter (mm)±SD Photopic (85cd/m^2)	3.53±0.61	3.77±0.83	0.38

[1]Best corrected visual acuity; [2]Manifest spherical equivalent.

Statistical Analysis Data analysis was performed using SPSS for Windows software (version 19.0, SPSS, Inc.). Statistical comparisons of the 2 study groups were calculated using the Student's t test for numerical data and the Chi-square test for categorical data. Differences were considered statistically significant when the P value was less than 0.05.

RESULTS

Sixty eyes of 47 patients were enrolled in the study. The mean age of the 31 men and 14 women was 64.95 ±7.94 years (range 51 to 77 years). Thirty eyes (23 patients) were received the aspheric IOL and thirty eyes (22 patients) were received the spherical IOL. Table 1 shows the patients' demographics by IOL group. There were no statistically significant differences between the aspheric group and spherical group in age, ratio of men to women, axial length, best corrected visual acuity (BCVA), implanted IOL power, manifest spherical equivalent (SE) and postoperative pupil diameter. All surgeries were uneventful and all IOLs implanted in the capsular bag. At 12 months after surgery, no patient occurred posterior capsule opacification.

The means and standard deviations of visual acuity under the various contrast percentages and illumination conditions are given in Table 2. Figures 1 and 2 show there were no statistically significant differences in 100% CVA and 25% CVA under 250cd/m^2 ($P_{100\%}$=0.875 and $P_{25\%}$=0.057) and 85cd/m^2 ($P_{100\%}$=0.198 and $P_{25\%}$=0.193) between the aspheric group and the spherical group. However, the 10% CVA and 5% CVA were significant better in aspheric group than spherical group under 250cd/m^2 ($P_{10\%}$=0.042 and $P_{5\%}$=0.007) and 85cd/m^2 ($P_{10\%}$ =0.002 and $P_{5\%}$ =0.039). Under the luminance level of 25cd/m^2, no significant differences was

Table 2 Postoperative contrast visual acuity

Contrast percentage	Aspheric group (n=30 eyes)	Spherical group (n=30 eyes)	P
250cd/m^2			
100%	-0.012±0.094	-0.016±0.097	0.875
25%	0.198±0.113	0.247±0.176	0.198
10%	0.397±0.138	0.490±0.202	0.042
5%	0.609±0.176	0.781±0.286	0.007
85cd/m^2			
100%	0.007±0.075	0.050±0.099	0.057
25%	0.233±0.091	0.273±0.141	0.193
10%	0.439±0.115	0.521±0.178	0.039
5%	0.656±0.136	0.843±0.283	0.002
25cd/m^2			
100%	0.077±0.085	0.106±0.107	0.245
25%	0.286±0.102	0.353±0.120	0.023
10%	0.455±0.120	0.533±0.142	0.026
5%	0.596±0.119	0.730±0.188	0.002

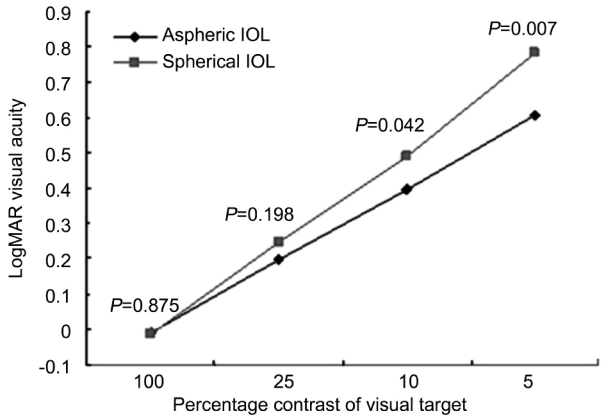

Figure 1 Between-group comparison of mean contrast visual acuity under the luminance level of 250cd/m^2 at 12 months postoperatively.

found in the 100% CVA between the 2 group ($P_{100\%}$=0.245), while aspheric group had better visual acuity in the remainder 3 contracts ($P_{25\%}$ =0.023, $P_{10\%}$ =0.026 and $P_{5\%}$ =0.002, respectively; Figure 3).

The mean pupil diameter was 3.43±0.61mm in the aspheric group and 3.77±0.83mm in the spherical group, respectively. Table 3 shows no statistically significant correlation was found between the CVA and pupil diameter in both groups.

DISCUSSION

The Acrysof Restor IOL (Alcon Laboratories, Inc.) was designed to achieve distance, intermediate, and near visual acuity without compromising visual performance[12]. After the introduction of the 3-piece model (MA60D3), the first 1-piece spherical version (SA60D3), and the model with blue light-filtering chromophore (Acrysof Natural Restor SN60D3), an aspheric design was incorporated into the optic of the IOL (model SN6AD3)[13-16]. In the current study, we compared the contrast visual acuity of implantation of the spherical AcrySof ReSTOR SN60D3 IOL and the aspheric AcrySof ReSTOR SN6AD3 IOL. Our results found that patients with the aspheric multifocal IOL had significantly better 10% and

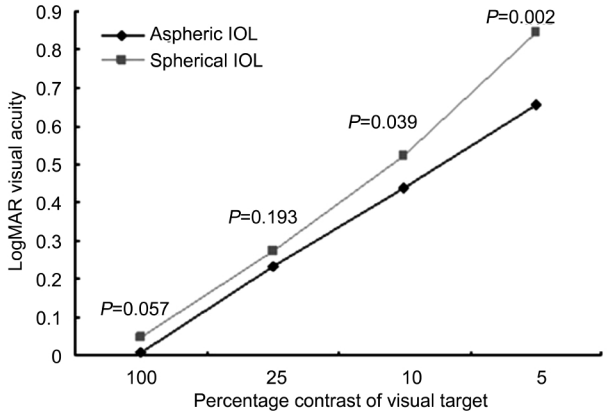

Figure 2 Between-group comparison of mean contrast visual acuity under the luminance level of 85cd/m^2 at 12 months postoperatively.

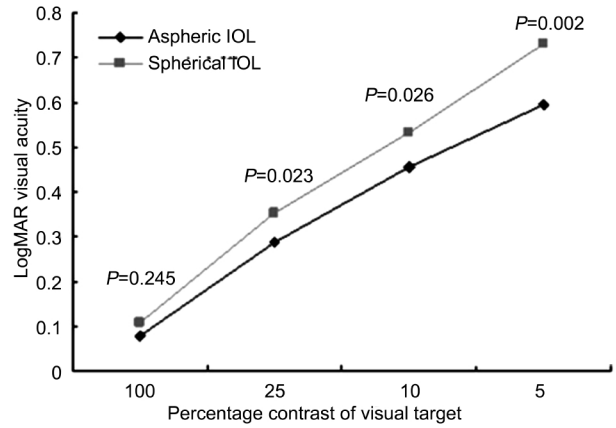

Figure 3 Between-group comparison of mean contrast visual acuity under the luminance level of 25cd/m^2 at 12 months postoperatively.

Table 3 Simple correlation coefficients between contrast visual acuity and pupil diameter under 85cd/m^2

Contrast percentage (%)	Aspheric group		Spherical group	
	r	P	r	P
100	0.055	0.774	0.036	0.850
25	0.217	0.248	0.080	0.673
10	-0.004	0.985	0.238	0.205
5	0.078	0.681	0.120	0.527

5% CVA under the luminance of 250, 85 and 25cd/m^2 than patients with the spherical multifocal IOL.

It is well recognized that conventional intraocular lenses (IOLs) degrade image quality by increasing higher-order aberrations (HOAs), such as spherical aberration, and several studies show that decreasing spherical aberration with aspheric IOLs improves retinal image quality and mesopic contrast sensitivity at low spatial frequencies [16-21]. A clinical study comparing monofocal IOLs found a significant difference in the reduction of 4th-order and primary spherical aberrations in eyes with aspheric IOLs than in eyes with spherical IOLs, especially when the pupil was at least 5.0mm[19]. In the studies comparing multifocal IOLs, Hida *et al* [20] reported that Tecnis ZM900 aspheric IOL provided

good quality of vision with high contrast condition in low luminosity with reduction in spherical aberration when compared to AcrySof ReStor SN60D3 spheric IOL; Fuentes-Mendoza *et al* [21] found The aspheric AcrySof ReSTOR IOL induces less spheric aberration and better contrast sensitivity than spheric AcrySof ReSTOR. These results were similar to our current study. However, de Vries *et al* [7] found no significant differences in contrast sensitivity between the aspheric and spherical AcrySof ReSTOR IOL. A possible explanation for this finding could be that aspheric IOLs do not solve the problem of chromatic aberration, which is mainly dependent on the material of the IOL rather than its shape.

Contrast sensitivity can be tested using chart, light box, view-in tester, and computer/video systems. The most common printed plates include the Arden, Vistech, Regan, Cambridge, and the Pelli-Robson grating charts [8]. In the current study, we used the MFVA-100 for contrast sensitivity testing because of the whole test process was controlled by computer, which avoiding the impacts of tester and providing us with more objective and reliable results. In addition, the "E" chart is familiar to patients and its ease of presentation. Moreover, several studies suggested that patients with larger pupils might benefit more from aspheric IOLs than patients with smaller pupils. In our studies, the mean pupil diameter after surgery was 3.43 ±0.61mm in the aspheric group and 3.77 ±0.83mm in the spherical group, there was no significantly different between the 2 groups and no correlation was found between the CVA and pupil diameter in each group. However, we did not measured the HOAs in each patient after cataract surgery in this study, which may provide us an important information when we comparing the two IOLs.

To summarize, the present study found that the aspheric AcrySof ReSTOR SN6AD3 IOL provided patients with better low-contrast visual acuity than the spherical AcrySof ReSTOR SN60D3 IOL. Despite the theoretic advantages of aspheric IOLs, with their efficacy in correcting spherical aberration and providing better psychophysical results (*e.g.* contrast sensitivity), further studies are needed to investigate whether the subjective quality of vision is enhanced by implantation of an aspheric IOL.

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