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Visual function and higher order aberration after implantation of aspheric and spherical multifocal intraocular lenses: a meta-analysis

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Received: 2012-06-08 Accepted: 2013-08-09

Abstract

• AIM: To assess the visual outcomes of aspheric multifocal intraocular lenses (IOLs) compared with spherical multifocal IOL after cataract surgery.

• METHODS: Potential prospective controlled trials that comparing aspheric multifocal IOL implantation with spherical multifocal IOL group were extracted from the computer database. The statistical analysis was carried out using Stata 10 software. Standardized mean differences with 95% confidence intervals (CIs) were calculated for continuous variables. The pooled estimates were computed in the use of a random-effects model.

• RESULTS: A systematic review identified five prospective nonrandomized controlled trials, including 178 aspheric multifocal IOL and 164 spherical multifocal IOL. There was no significant difference in uncorrected distance visual acuity (95%CI, −0.248 to 0.152; *P*=0.641) and uncorrected near visual acuity (95% CI, −0.210 to 0.428; *P*=0.504) between aspheric multifocal IOL and spherical multifocal IOL. Statistically significant differences were detected less spherical aberration in aspheric multifocal IOL (95% CI, −1.111 to −0.472; *P*< 0.001) when compared to spherical multifocal IOL. Spherical multifocal IOL showed a greater higher order aberration compared to the aspheric multifocal IOL (95% CI, −1.024 to −0.293; *P*<0.001). Sensitivity analysis suggested that the results were relatively reliable.

• CONCLUSION: The overall findings indicated that aspheric multifocal IOL and spherical multifocal IOL provided similar visual acuity at near and distance. Patients implanted with aspheric multifocal IOL had less spherical aberration and higher order aberration than patients with spherical multifocal IOL. Further well-organized, prospective controlled trials involving larger patient numbers are needed.

• **KEYWORDS:** aspheric multifocal intraocular lens; uncorrected near visual acuity; uncorrected distance visual acuity; spherical multifocal intraocular lens; higher order aberration; meta-analysis

DOI:10.3980/j.issn.2222-3959.2013.05.27

Liu JP, Zhang F, Zhao JY, Ma LW, Zhang JS. Visual function and higher order aberration after implantation of aspheric and spherical multifocal intraocular lenses: a meta-analysis. *Int J Ophthalmol* 2013; 6(5):690-695

INTRODUCTION

Currently, with advances in cataract surgery, the main surgical procedures are phacoemulsification and intraocular lens (IOL) implantation [1]. With the improvement of life quality, cataract surgery has developed from a procedure for the safe removal of the cataract to one aimed at refining to achieve the best possible postoperative refractive result [2]. The implantation of optimized IOL models aimed at restoring not only visual function at distance but also in near conditions is an important advance in cataract surgery [3]. Traditional monofocal IOLs designed with a single fixed focal length can provide excellent distance vision, the monofocal IOL's limited depth of focus means that they cannot provide clear vision at both distance and near[4,5]. Patients with traditional monofocal IOLs usually require glasses for near vision-task, such as computer work or reading [6].

An alternative treatment is implantation of multifocal IOLs, which increases the depth of field and improves intermediate and near vision after cataract or clear lens extraction and gives a more acceptable range of near through distance vision as well as increased spectacle independence [7]. The success of cataract and refractive lens exchange surgeries to provide pseudoaccommodation is determined by the improvement in visual acuity at distance, near, and intermediate distances [8]. Several studies reported that the multifocal IOL simultaneously creates images on the retina that are conjugate with 2 or more depth planes, when the eye views a distant object, a sharp retinal image is provided by the parts of the lens within the papillary area that have the distance correction and a somewhat blurred image by the other parts of the lens as these images are superimposed on the retina [9,10]. The unwanted effects, such as increased wavefront errors, contrast sensitivity, glare disability, and halos, have been reported with some multifocal IOL models[11]. With modern techniques, manufacturers are not only concerned with the far and near foci, but they also aim to optimize the image quality with more complex IOL surfaces.

Ideally, multifocal IOLs would provide excellent distance and near visual acuity without compromising characteristics of visual function. Previous studies have demonstrated that wavefront aberration is the potent indicator of functional vision [12]. Optical aberrations for a specific wavelength of visible light as it travels through an optical system are generally classified into several categories: spherical refractive error (defocus), cylindrical refractive error, spherical aberration, coma, and other higher order aberrations. Spherical aberration to be one of the most significant higher order aberrations that reduce retinal image quality [13]. Considering that the amount of intraocular light scattering and higher-order aberrations, due to refractive or diffractive optics, may lead to a poor retinal image quality, and such new IOL designs with aspheric profiles were developed with the goal of reducing unwanted visual phenomena associated with multifocal IOL performance, thus increasing the range of focus and improving image quality[14].

The aim of this meta-analysis is to compare the clinical performance in patients who had cataract surgery with implantation of aspheric multifocal IOL and spherical multifocal IOL.

MATERIALS AND METHODS

Study Strategy An extensive literature review was searched through PubMed/Medline, Web of science, Cochrane Library and Chinese Science and Technology Periodicals Databases (most recently updated in 2013 January), using the search terms "cataract surgery", "aspheric multifocal IOL", "spherical multifocal IOL", "comparison", and "higher order aberration". To increase the chance to find all relevant publications describing the visual performance of aspheric multifocal IOL, there were no limitations in the initial search in terms of language. Abstracts were read and full tests were retrieved if they seemed to meet the objective of this review. Related references and articles were checked and analyzed in depth. Considering all the study design, this meta-analysis was undertaken according to a predetermined protocol described below [15]. The study and data accumulation were carried out with approval from the Institutional Review Board of The Fourth Affiliated Hospital of China Medical University and the study complies with the tenets of the Declaration of Helsinki.

Trials Selection The following inclusion criteria were used to identify published studies for this meta-analysis: 1) Study design: clinical controlled studies (randomized or nonrandomized) addressing the visual performance of aspheric multifocal IOL; 2) Population and intervention: patients who were diagnosed as age-related cataract underwent cataract surgery with aspheric multifocal IOL and spherical multifocal IOL implants; 3) Outcome measurement: outcome variables of the report are needed to meet the orientation of this review. We also excluded studies with double implanting in the same eye, double reporting, *in vitro* studies, no bilateral implantation, unrelated outcome measurement, use of refractive surgery, delivering no baseline data and no aggregated results.

Data Extraction All available data from the selected articles were extracted by two independent reviewers cautiously. The following categories of information were extracted: each study's identity, publication year, study design, study location, outcome measures, IOL name and IOL type, number of patients at baseline and at final follow up, follow-up duration. Whenever any disagreements occurred, they were resolved through discussion by a third reviewer till a consensus was made.

Statistical Analysis The statistical analysis was carried out through Stata software version 10 (Stata corp's College station, TX, USA). Forest plots were used to present the results, and the results were expressed as standardized mean differences (SMD) and 95% confidence intervals (CI). The center of each square indicated the SMD and the size of the square was proportional to percent weight each study contributed to the pooled estimates. The horizonal line bisecting each square represented the 95% CI for the SMD. Heterogeneity among studies was tested using the Chi-squared statistic. If the significant evidence of statistical heterogeneity or clinical diversity was not found (P>0.10), fixed efforts mode were used [16]. However, for the result showing significant heterogeneity (P<0.10), we used random effort models to account for inter-study heterogeneity, and test for statistically significant difference between the estimates with respect to each IOL group. No protocol of this review has been registered and published.

Funnel plot was used to observe included studies' publication bias, asymmetry plots implied possible existence of publication bias [15]. The asymmetry degree was measured by Egger' test, a P value < 0.05 was considered as an evidence of publication bias. To explore the steadiness of our result, sensitivity analysis investigating the influence of each individual study on the overall meta-analysis summary

Table 1 Characteristics of the meta-analysis for visual outcomes of aspheric and spherical multifocal intraocular lens

Author(a)	Design	MIOL	Study location	Trt	MIOL type	Follow-up (weeks)	Patients (*n*)	Quality scores
Santhiago *et al*[18]	P	Tecnis ZM900	Brazil	N	Aspheric diffractive	12	20	4
		ReSTOR SN60D3			Spherical diffractive	12	20	
de Vries *et al*[19]	P	ReSTOR SN6AD3	Netherlands	N	Aspheric diffractive	24	47	3
		ReSTOR SN60D3			Spherical diffractive	24	45	
Hida *et al*[20]	P	Tecnis ZM900	Brasil	N	Aspheric diffractive	24	46	2
		ReSTOR SN60D3			Spherical diffractive	24	32	
Santhiago *et al*[21]	P	Tecnis ZM900	Brazil	N	Aspheric diffractive	24	20	4
		ReSTOR SN60D3			Spherical diffractive	24	20	
		ReZoom			Spherical refractive	24	20	
Song *et al*[22]	P	IQ ReSTOR +4.0D	China	N	Aspheric diffractive	12	25	3
		IQ ReSTOR +3.0D			Aspheric diffractive	12	20	
		ReSTOR +4.0D			Spherical diffractive	12	27	

P: Prospective; Trt: Treatment affected at random; N: No; IOL: intraocular lens; *n*: Number; MIOL: Multifocal intraocular lens.

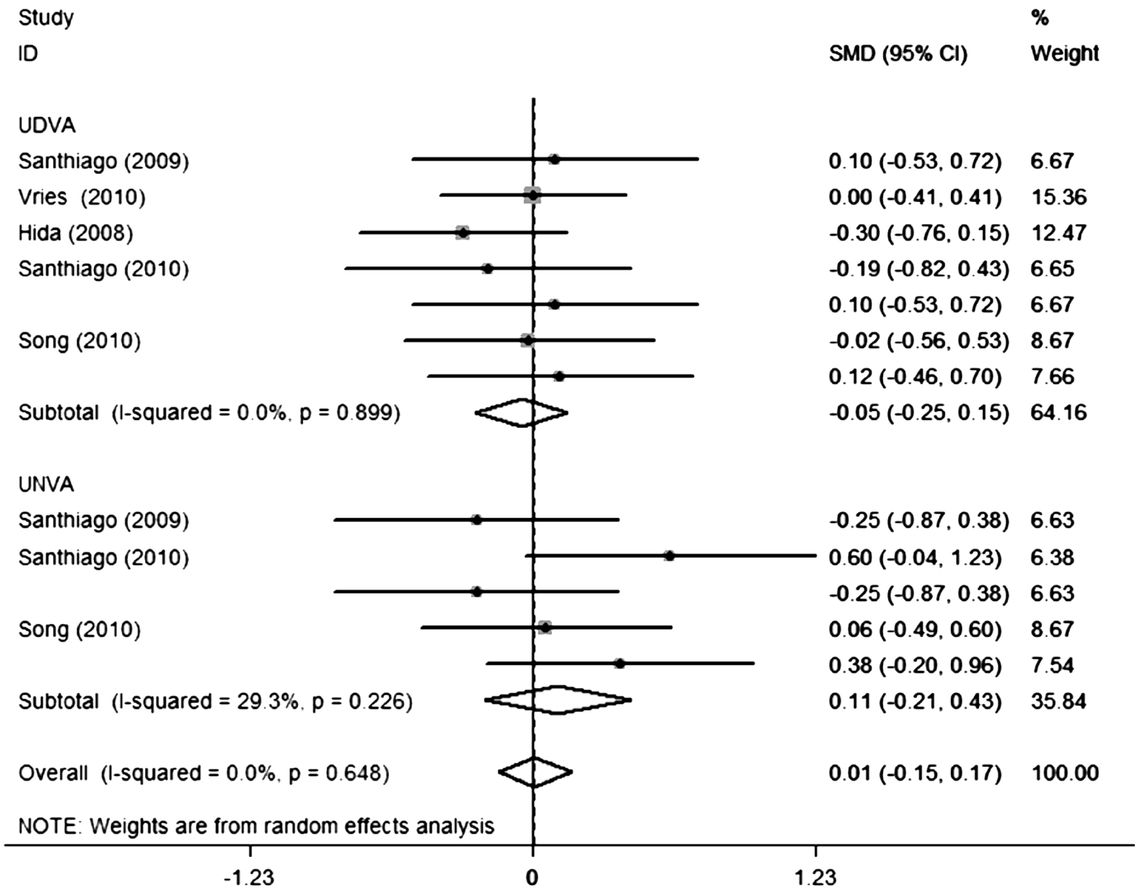

Figure 1 Random effects pooled estimates of postoperative uncorrected distance visual acuity (UDVA) and uncorrected near visual acuity (UNVA).

estimates was carried out to identify potential outliners[15,17]. All statistical tests were two-sided.

RESULTS

Selection of the Studies Initial electronic searches retrieved sixty-seven articles after discarding some citations by individual searches and reviewing all titles and abstracts, sixty-two studies were eliminated after full text review according to the inclusion and exclusion criteria specified earlier. Hence a number of five prospective comparative clinical study were identified [18-22]. The uncorrected distance and near visual acuity, higher order aberration analysis as outcomes. The characteristics of five studies are summarized in Table 1. Methodological quality of included trials was assessed using the Jadad [23]. A checklist was applied to appraise studies' quality. The checklist system, which evaluates studies based on appropriate randomization, proper blinding, and an adequate description of withdrawals and drop-outs.

Visual Acuity Figure 1 shows pooled estimates of random effects, with 95%CI, for uncorrected distance and near visual acuity (LogMAR scale), it was not significant(SMD=-0.048, 95%CI, -0.248 to 0.152, P=0.641;SMD=0.109, 95%CI,

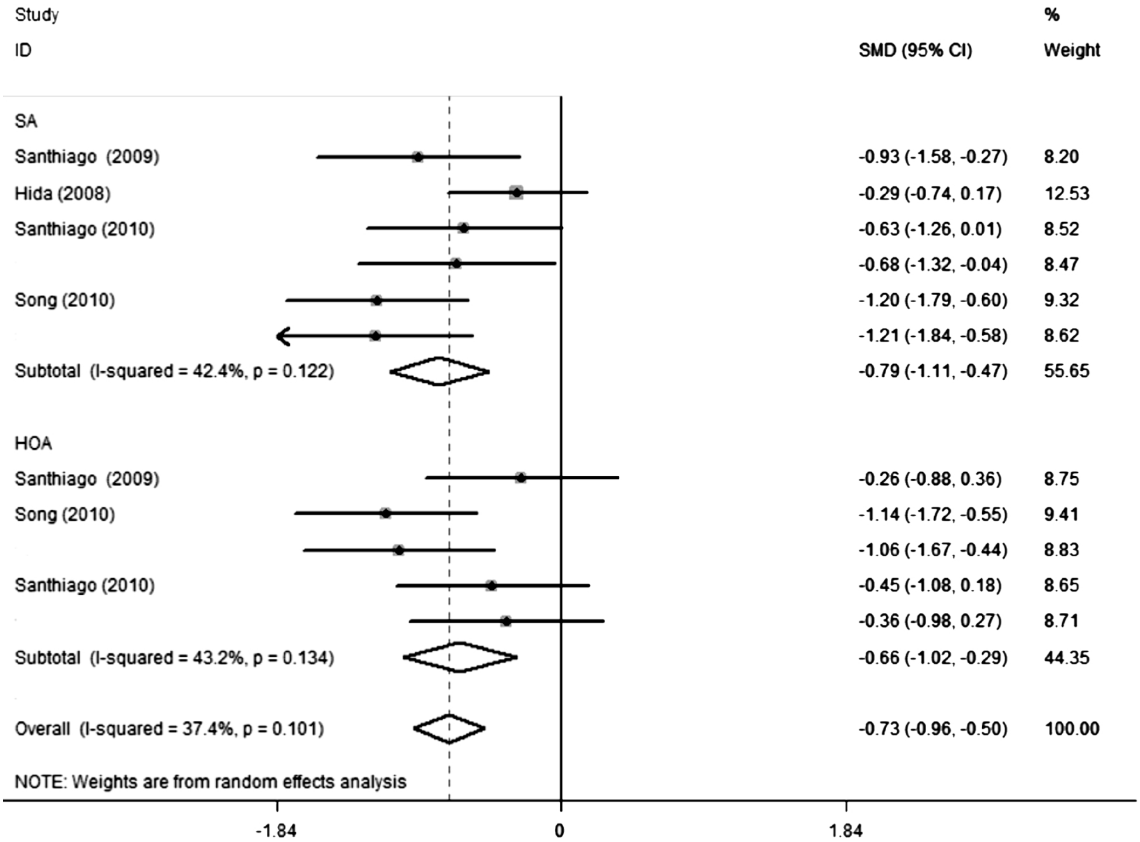

Figure 2 Forest plot and pooled results of spherical aberration (SA) and higher order aberration (HOA) between aspheric multifocal IOL and spherical multifocal IOL.

-0.210 to 0.428, P=0.504, respectively) after aspheric multifocal IOL and spherical multifocal IOL implants.

Higher Order Aberration Figure 2 shows that eyes implanted with aspheric multifocal IOL had a less spherical aberration than spherical multifocal IOL (SMD=-0.791, 95% CI, -1.111 to -0.472; P<0.001). Compared with spherical multifocal IOL, the higher order aberration was significantly less (SMD=-0.658, 95%CI, -1.024 to -0.293, P<0.001).

Sensitivity Analysis We checked the inclusion criteria of this meta-analysis by a sensitivity analysis. Pooled estimates for all IOL groups were insensitive to the removal of individual studies and the corresponding pooled SMDs were not substantially altered (data not shown) that indicating that our results were stable and reliable.

Publication Bias Funnel plot was performed to assess the publication bias of literatures (Figure 3). The symmetrical funnel plots provide no evidence for publication bias in the five publications (t=0.09, P=0.934).

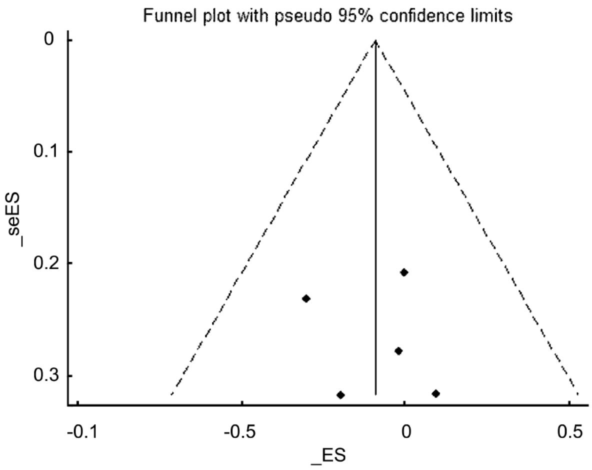

Figure 3 Funnel plot for the results of aspheric multifocal IOL versus spherical multifocal IOL.

DISCUSSION

In the current study, we compared visual outcomes after aspheric multifocal IOL and spherical multifocal IOL implants. To our knowledge, this is the first meta-analysis of comparing the aspheric multifocal IOL with the spherical multifocal IOL. By combining the results of these trials through a meta-analysis, our study has a greater statistical power than the powers of the studies as individuals [24]. We did not compare the different types of aspheric multifocal IOLs, because this was not our objective and the experimental design was not appropriate for us to do so.

In this meta-analysis, it should be noted that all the trials did not randomize treatment, which could be considered as a weaker level of evidence than is often included in a meta-analysis. Therefore, these meta-analysis results did not provide the preferred and highest level of evidence, which they were not based on randomized controlled trials.

However, no randomized controlled trials that evaluating the visual outcomes after implantation of aspheric multifocal IOL versus spherical multifocal IOL were found.

Traditional monofocal IOLs as replacements for human crystalline lenses is the fixed focus of the IOLs [25]. Although patients may see well at a distance following cataract surgery, reading spectacles are generally required for near vision [26]. Many different multifocal IOL designs have been introduced aiming to provide useful vision for different distances, increasing the depth of field and improving optical quality for both distance and near vision [27]. All multifocal IOL designs divide the incoming light into 2 or more foci. The effect of the light in the out-of-focus image reduces the contrast of the in-focus image, thus reducing image contrast and unwanted visual phenomena, including glare and halos[28]. Snellen visual acuity insufficiently describes the quality of eye optics before and after surgery [29].The deficiencies in the optical quality of vision may be effectively evaluated using a contrast sensitivity test and wavefront analysis [30]. IOL designs, including aspheric modified prolate surfaces, aim to reduce the total amount of spherical aberration and improve contrast sensitivity in the eye, thereby improving visual quality[31].

Since the incoming light through a multifocal IOL generates out-of-focus images that overlap the distant focus image, the image sharpness is generally compromised. Aspheric multifocal IOLs have been shown to result in better image quality than spherical multifocal IOLs in clinic and laboratory studies [32,33]. Multifocal IOLs with an aspheric optics may perform better than previous-generation multifocal IOLs [34]. However, in our study, uncorrected distance and near visual acuities were similar in the aspheric multifocal group and the spherical multifocal group. In addition, there were significantly better spherical aberration and higher order aberration with aspheric multifocal IOL.

This meta-analysis showed no publication bias by Egger's test. However, this meta-analysis has its own limitations. For example, the examination of visual performance between aspheric multifocal IOL and spherical multifocal IOL was based on pooled data from trails of different duration, and the diversity of follow-up time ranged from 2 to 6 months. Furthermore, numbers of studies included are not quite adequate to reveal the true difference between aspheric multifocal IOL and spherical multifocal IOL. Another specific limitation of this meta-analysis is the distribution of patients between the clinical trials of the different IOL implants. Although this meta-analysis has several limitations as described above, it is noteworthy that this study indicates that aspheric multifocal IOL can provide better visual performance. Also, our research lays powerful evidence for future large scale patients-based prospective controlled trials.

In conclusion, the aspheric multifocal IOL, when implanted bilaterally during cataract surgery, provided patients with higher levels of spherical aberration and higher order aberration than the spherical multifocal IOL. However, aspheric multifocal IOL and spherical multifocal IOL had similar levels of uncorrected distance and near visual acuities. Further well-designed studies with a larger sample size are required.

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