Original Article

Effects on ocular aberration and contrast sensitivity after implantation of spherical and aspherical monofocal intraocular lens - A comparative study

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Purpose: Phacoemulsification with intraocular lens (IOL) implantation is the standard of care for cataractous eyes. Monofocal IOLs are spherical or aspheric. The aspheric design of IOLs reduces the spherical and higher-order aberrations and impacts contrast sensitivity post cataract surgery. There are some studies, but data in the Indian setting with the IOLs we used is lacking. We aimed to compare the effect of implantation of spheric and aspheric foldable intraocular lenses on postoperative quality of vision, spherical aberration, and contrast sensitivity. **Methods:** This prospective observational study was conducted at a tertiary care hospital with an ophthalmology specialty, data collection from January 2017 to May 2018 in 100 patients. Patients meeting the inclusion criteria were selected. Their preoperative and postoperative data were collected and divided into groups based on whether spherical or aspheric IOL was implanted after cataract surgery. Variables assessed were visual acuity on *days 7* and *30*, spherical aberrations, and contrast sensitivity was assessed at 1-month postoperative. **Results:** The mean age of the patients in this study was 64 ± 8 years with a majority of patients (60%) being females. There is no significant difference in postoperative visual acuity between the two groups. Internal SA was significantly lower (~50%) in eyes implanted with aspheric IOLs (P value = 0.004, 0.0001) compared with the spherical group. Contrast sensitivity of patients of the aspheric group was significantly better (P value <0.05). **Conclusion:** The optical design of the aspheric IOLs reduced spherical aberrations and increased contrast sensitivity.

Key words: Aspheric, contrast sensitivity, IOL, spherical, spherical aberrations

Access this article online
Website: www.ijo.in
DOI: 10.4103/ijo.IJO_19_22
Quick Response Code:

Cataract is the leading cause of avoidable blindness worldwide. It is estimated that 10.8 million people in the world are blind due to cataracts. Due to increased life expectancy, and at the current rates of surgery, this figure will increase to 32 million by 2020. In the year 2012–2013, approximately 6 million cataract surgeries were performed in India. With rising cataract surgery coverage, it is equally important that high-quality cataract surgery be maintained to achieve targets related to the vision 2020 initiatives. According to World Health Organization (WHO), around 15 million of the world's 45 million blind and half of the world's 1.5 million blind children live in the South-East Asia region. Three national surveys in India have extrapolated the survey result to project that number of people affected by cataract will reach 8.25 million by 2020.

Over time, the goal of cataract surgery has evolved from simple visual rehabilitation to optimum postoperative optical performance of the pseudophakic eye. Perfect vision now incorporates good contrast sensitivity, minimal wavefront errors, and other aberrations, and not just good visual acuity. Wavefront analysis is used to objectively calculate lower and higher-order aberrations and their effects on optical quality.

Spherical aberrations are the most significant monochromatic higher-order aberrations and have been shown to increase with age in the positive direction, consequently reducing the quality of vision.[1-3] In spherical aberrations, rays entering from the periphery of the lens are focused more tightly than the central rays thereby decreasing the contrast of the retinal image. With positive spherical aberrations, peripheral rays are focused in front of the paraxial rays; with negative spherical aberrations, the peripheral rays are focused beyond the paraxial rays.[4] The young lens compensates for the positive spherical aberrations of the cornea but, as the eye ages; the lens loses this property and instead contributes to positive spherical aberrations causing worsening of the optical performance.

Modern IOL designs seek to mimic normal physiological lens to achieve the objective of perfect vision. The initial IOL designs were spherical thus contributing to positive spherical aberrations in the elderly patient's optical system after cataract extraction.[5] The aspheric design of the IOL optic was thus designed to optically counterbalance the positive asphericity of the prolate cornea.[6]

Contrast sensitivity refers to a measure of how much contrast a person requires to see a target. Unlike acuity measurements, which measure the spatial-resolving ability of the visual system under conditions of very high contrast, contrast sensitivity is

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Received: 07-Jan-2022 Revision: 30-Mar-2022
Accepted: 22-Apr-2022 Published: 29-Jul-2022

Cite this article as: Deshpande R, Satijia A, Dole K, Mangiraj V, Deshpande M. Effects on ocular aberration and contrast sensitivity after implantation of spherical and aspherical monofocal intraocular lens - A comparative study. Indian J Ophthalmol 2022;70:2862-5.

a measure of the threshold contrast for seeing a target. It can detect differences in functional vision not explained by acuity alone and is highly correlated with visual performance.[7]

This study aims to assess visual outcomes of spherical and aspheric IOL in terms of quality of vision, spherical aberration, and contrast sensitivity.

Methods

This prospective observational comparative study was conducted at a tertiary eye care center during the period from January 2017 to May 2018. The study included patients with immature cataracts coming to the eye care center and meeting the inclusion and exclusion criteria. The study adhered to the tenets of the Declaration of Helsinki and was approved by institutional review board. The sample size was calculated using formula for comparing two means ($n = [\sigma_1^{2+} \sigma_2^2/k] [z_{1-\sigma/2} + z_{1-\beta/2}]/\Delta^{2)}$ and was determined to be 50 for each group. Purposive sampling was done and the patients were divided equally into two groups ($n = 50$), namely, spherical and aspheric based on their choice of the intraocular lens.

Inclusion criteria

- All patients with unilateral age-related cataracts are willing to undergo cataract surgery.
- Patients with expected postoperative BCVA 20/40 or better.
- Patients with an axial length between 22 mm and 26 mm.
- Patients with the absence of any other ocular pathology besides refractive errors.

Exclusion criteria

- Patients with coexisting ocular pathologies like corneal opacities, pterygium, dry eye syndrome, and glaucoma, retinal pathologies, which would affect vision or aberrations.
- Patients with IOL tilt or decentration
- Patients with surgical complications.
- Patients not willing to participate in the study.

Patients meeting the inclusion criteria and giving written informed consent to be a part of the study were recruited. They were divided into two groups based on their choice of intraocular lenses [Fig. 1]. Demographic data like age and gender were recorded. Preoperative LogMAR visual acuity, optical biometry using Lenstar LS 9000, Wavefront aberrometry using Visionix VX120, and contrast sensitivity using the Pelli–Robson Chart were collected by a single optometrist. The patients underwent phacoemulsification surgery with intraocular lens implantation by a standard technique by a single surgeon. Postoperative data were collected at *weeks 1 and 5* and then at the 3rd month. Contrast sensitivity testing was evaluated using the Pelli–Robinson chart at 1 m at room lighting.

The IOLs that were used in this study included a hydrophilic spherical lens (Ocuflex IOL from IoCare© group), a hydrophilic aspheric lens (Rayone IOL, Rayner©), a hydrophobic spherical IOL (Aurovue, Aurolab©), and a hydrophobic aspheric lens (Acrysof IQ, Alcon© group). The optic size of all IOLs used in the study was 6 mm.

Statistical analysis

The data were entered in Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) Version 20.0. Association between the two qualitative data was done using Chi-square test. Comparison of the mean between the two groups was done using unpaired *t*-test. *P* value < 0.05 was considered statistically significant.

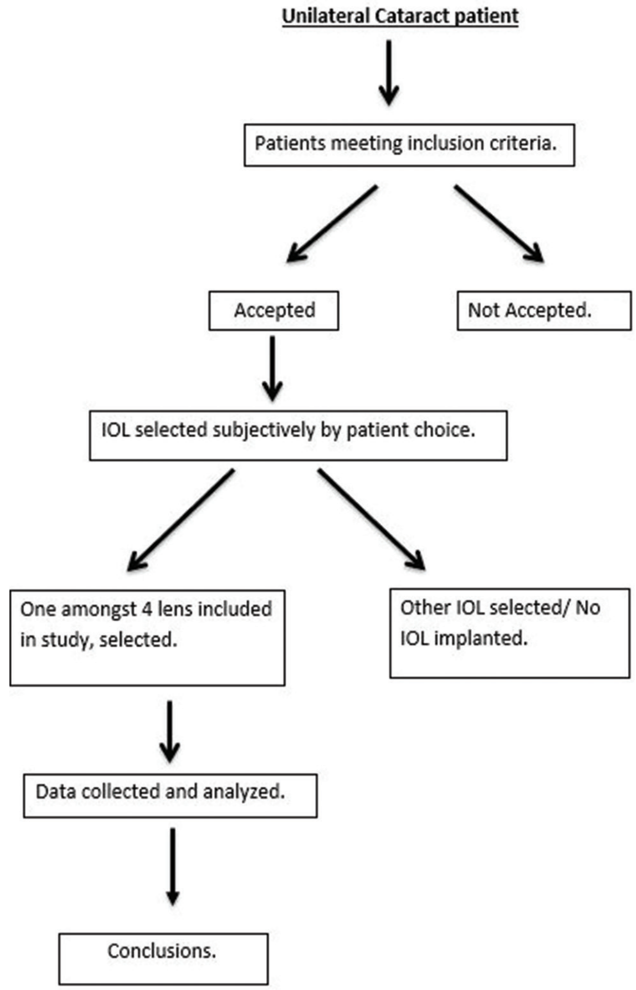

Figure 1: Scheme of the study

Results

A total of 100 eyes of 100 patients were included in this prospective observational study. The mean age of patients opting for a spherical IOL was 64.48 ± 7.58 while that of patients opting for the aspheric IOL was 64.22 ± 8.52. Age did not affect the choice of IOL in this study. A total of 68% of patients that chose spherical IOL implantation after cataract surgery were females while 32% were males. In the aspheric IOL group, 52% of patients were females and 48% were males. There were 60 females and 40 males included in our study and it was found that gender played no role in the choice of IOL when these two groups are considered. The mean preoperative UCVA was 0.95 (±0.48) for the spherical IOL group while it was 0.82 (±36) and was statistically not significant ($P = 0.119$), the mean pre-op BCVA was 0.42 (±0.15) while it was 0.37 (±0.14) in the aspheric group, but this difference was not statistically significant ($P = 0.07$). There was found to be no significant difference in the UCVA and BCVA on postoperative *day 7* [Table 1] between the two groups implying that UCVA and BCVA are not a function of this IOL design. The mean LogMAR UCVA and BCVA on *day 30* post-op between the two IOL groups was similar [Table 2]. It signifies that the visual acuity is unaffected by the IOL designs. Postoperative BCNVA at *day 30* was N6 for >95% of patients in both spherical as well as the aspheric group (*P* value >0.05). Both groups were also comparable for preoperative internal spherical aberration and the power of IOL implanted [Table 3].

Unpaired *t*-test was used to compare the mean spherical aberration within IOL, between the groups. The spherical aberrations in either the spherical or aspheric IOL group were not significantly different [Table 4] whether the IOL is hydrophilic or hydrophobic as long as the basic design was the same (aspheric or spherical). The internal spherical aberrations postoperatively were significantly higher in the spherical IOL group as compared with the aspheric IOL group (*P* value < 0.05) [Table 5]. This signifies that the asphericity helps in the reduction of SA in the eye. The postoperative Contrast Sensitivity (CS) was 1.46 ± 0.22 in the spherical group and 1.54 ± 0.185 in the aspheric group. The difference in postoperative CS between the two IOL groups was statistically significant (*P* value < 0.05) [Table 6].

Discussion

Cataract is the leading cause of avoidable blindness worldwide. It is estimated that 10.8 million people in the world are blind due to cataracts. Over time, the goal of cataract surgery has evolved from simple visual rehabilitation to optimum postoperative optical performance of the pseudophakic eye. The perfect vision now incorporates good contrast sensitivity, minimal wavefront errors, and other aberrations, and not just good visual acuity. The initial IOL designs were spherical thus contributing to positive spherical aberrations in the elderly patient's optical system after cataract extraction. The aspheric design of the IOL optic that was eventually designed to optically counter-balance the positive asphericity of the prolate cornea has led to better vision postoperatively. This study sought to find if there was any difference in postoperative quality of vision, internal spherical aberration, and contrast sensitivity in those patients who were implanted with spherical versus those implanted with aspheric lenses. The preoperative UCDVA and BCDVA were comparable between the two groups. Our patients had similar levels of nuclear sclerosis and posterior subcapsular cataract, which was reflected by comparable preoperative BCDVA between the patients. The postoperative BCDVA was better with the aspheric IOLs but the difference was not statistically significant. These results were similar to most other studies.[3,5,8-12] Studies conducted by Bellucci *et al*. and Mester *et al*.,[13,14] had contrasting results where aspheric IOL produced significantly better postoperative BCVA.

We found no difference in best-distance-corrected near visual acuity between the two groups with 96% of each group of patients improving to a best-corrected near visual acuity of N6 and the remaining improving to N8. This is in contrast to the study of Holladay *et al*.[15] and Rocha *et al*.[16] and who found worse distance-corrected near acuity in eyes with an aspheric IOL. They attributed the poorer near vision to the loss in the depth of focus due to the asphericity, resulting in better distance acuity but mildly poorer near vision. The design of the aspheric IOL results in a reduction of Higher Order Aberrations (HOA), mainly SA postoperatively. This was confirmed by our study wherein the patients implanted with aspheric IOLs had significantly lower spherical aberrations (50% lower) compared with those implanted with the spherical IOLs. Similar studies had results that matched ours with respect to spherical aberrations with a significant advantage in favor of the aspheric IOLs.[17-21] Contrast sensitivity or low-contrast visual acuity testing also plays a role in determining the quality of vision. In the present study, contrast sensitivity postoperatively was 1.46 ± 0.2 SD in the spherical IOL group and 1.54 ± 0.18 in the aspheric group, measured using the Pelli–Robson chart. Our study demonstrated a significant benefit in contrast sensitivity after the use of aspheric IOL compared with the spherical group. The reduced spherical aberrations could be the cause of the improved CS in aspheric group, which corresponds with the results of some other studies.[9-11,13,22] Nanavaty *et al*.[1] found that under mesopic conditions, eyes with the aspheric IOLs had increased contrast sensitivity without a significant correlation between the degrees of spherical aberration corrected by the IOLs, but photopic CSF between the two groups is comparable. Johansson *et al*.[23] found similar high and low contrast visual acuities as well as photopic and mesopic contrast sensitivities in their study. The above variations in photopic contrast

Table 1: Postoperative BCVA on *day 7*

Group	*n*	Mean	SD	*P*
Post-op BCVA on *day 7*				
Spherical	50	0.20	0.11	0.92
Aspheric	50	0.20	0.09	

Table 2: Postoperative BCVA on *day 30*

Group	*n*	Mean	SD	*P*
Post-op BCVA on *day 30*				
Spherical	50	0.15	0.05	0.580
Aspheric	50	0.14	0.05	

Table 3: Preoperative internal spherical aberration

Group	*n*	Mean	SD	*P*
Pre-op Internal SA				
Spherical	50	0.07	0.08	0.345
Aspheric	50	0.12	0.42	

Table 4: Spherical aberrations within IOL

Aberration	Spherical		Aspheric	
	Hydrophilic	Hydrophobic	Hydrophilic	Hydrophobic
SA				
Mean±SD	0.018±0.016	0.014±0.013	0.02±0.04	0.01±0.02
P	0.47		0.28	

Table 5: Postoperative internal SA

Group	*n*	Mean	SD	*P*
Post-op Internal SA				
Spherical	50	0.02	0.015	0.0001
Aspheric	50	0.01	0.01	

Table 6: Comparison of pre- and postoperative contrast sensitivity between the groups

Group	*n*	Mean	SD	*P*
CS Pre-Op				
Spherical	50	1.203	0.219	0.532
Aspheric	50	1.227	0.159	
CS Post-Op				
Spherical	50	1.466	0.221	0.05
Aspheric	50	1.545	0.185	

sensitivity could be due to differences in the testing methods and the spherical and aspheric IOLs used in various studies. Among the limitations of the study is that the effect of pupil size, which plays an important role in controlling spherical aberration, has not been accounted for in this study.

Conclusion

In conclusion, it may be inferred from this study that, the visual acuity, after implantation of aspheric IOLs, is slightly better than that after spherical IOLs but this difference is not statistically significant. Aspheric IOLs reduce postoperative internal spherical aberrations to almost 50% when compared with spherical IOLs and result in 5%–10% better contrast sensitivity postoperatively.

Since aspheric IOLs are more expensive as compared with spherical IOLs, it is recommended that patients should be counseled taking into account the cost-benefit ratio of implanting aspherical vis-à-vis a spherical IOL. Patients who require good contrast and better quality of vision by virtue of their jobs like airplane pilots, nighttime drivers, people who require reading in dim light, and people living in Nordic countries, which have prolonged twilight hours, might significantly benefit from aspheric IOL designs. Whereas, elderly patients with lesser visually demanding lifestyles can be given the option of spherical IOL over an aspheric counterpart. Spherical IOLs have a better depth of focus due to the spherical aberrations; hence, further studies of binocular implantation of spherical multifocal IOLs compared with aspheric for better uncorrected near visual acuity can be done. For the conclusive subjective beneficial effect of aspheric IOL, studies can be done on the abovementioned population group.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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