Original Article/นิพนธ์ต้นฉบับ

Comparison of Contrast Sensitivity, Higher-Order Aberrations and Subjective Visual Function after Different Aspheric Intraocular Lenses Implantation

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาเปรียบเทียบผลของการใส่เลนส์เทียม aspheric 2 ชนิดที่มีต่อความคมชัดในการมองเห็น และการเบี่ยงเบนของแสง รวมทั้งคุณภาพการมองเห็นและคุณภาพชีวิตของผู้ป่วย

วัสดุและวิธีการ: การศึกษาในผู้ป่วยต้อกระจกจำนวน 45 ราย ทั้งหมด 45 ตา ผู้ป่วยได้รับการสลายต้อกระจกแผลเล็กด้วยคลื่นเสียงความถี่สูงร่วมกับการใส่เลนส์เทียม aspheric โดยสุ่มตัวอย่างเป็นสองกลุ่ม กลุ่มแรกใช้เลนส์เทียม Tecnis ZA9003 จำนวน 23 ตา กลุ่มที่สองใช้เลนส์เทียม AcrysofIQ จำนวน 22 ตา ผู้ป่วยจะได้รับการตรวจตาโดยละเอียดร่วมกับการตรวจค่าความคมชัดของการมองเห็น และการวัดการเบี่ยงเบนของแสงโดยใช้เครื่อง Aberrometer ผู้ป่วยทุกรายจะได้รับการสัมภาษณ์โดยใช้แบบสอบถามคุณภาพการมองเห็นและคุณภาพชีวิต (Visual function questionnaire) โดยจะทำการตรวจก่อนผ่าตัดและหลังผ่าตัดเป็นเวลาอย่างน้อย 3 เดือน

ผลการศึกษา: หลังการผ่าตัด 3 เดือน ผู้ป่วยทุกรายมีระดับสายตา (LogMar UCVA) มีค่า 0.30 (20/40) หรือดีกว่า และระดับสายตา LogMar BCVA มีค่า 0.18 (20/30) หรือดีกว่า โดยไม่พบความแตกต่างของระดับสายตาระหว่างผู้ป่วยสองกลุ่ม เลนส์เทียมทั้งสองชนิดให้ผลเพิ่มระดับความคมชัดของการมองเห็นทั้งในที่สว่างและที่มืดได้ไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ผลการวัดการเบี่ยงเบนของแสงพบว่าเลนส์ทั้งสองชนิดสามารถลดค่าการเบี่ยงเบนของแสงชนิด spherical aberration และ higher-order aberration ได้ไม่แตกต่างกันทางสถิติ โดยค่า spherical aberration หลังการผ่าตัดใส่เลนส์ Tecnis และ AcrysofIQ มีค่า 0.02 $\pm$ 0.04 μm และ 0.03 $\pm$ 0.02 μm ตามลำดับ และค่า higher-order aberration หลังการผ่าตัดใส่เลนส์ Tecnis และ AcrysofIQ มีค่า 0.19 $\pm$ 0.10 μm และ 0.23 $\pm$ 0.11 μm ตามลำดับ การเปรียบเทียบผลคะแนนจากแบบสอบถามระดับคุณภาพการมองเห็นและคุณภาพชีวิตพบว่าไม่แตกต่างกันทางสถิติ อย่างไรก็ตาม คะแนนคุณภาพการมองเห็นในกลุ่มที่ได้รับการใส่เลนส์ Tecnis มีการเปลี่ยนแปลงเพิ่มขึ้นจากก่อนและหลังผ่าตัดมากกว่าในกลุ่มที่ใส่เลนส์ AcysofIQ

สรุป: เลนส์เทียม aspheric ทั้งสองชนิดสามารถทำให้ประสิทธิภาพความคมชัดในการมองเห็น และการเบี่ยงเบนของแสงดีขึ้นไม่แตกต่างกัน รวมทั้งคุณภาพการมองเห็นและคุณภาพชีวิตของผู้ป่วยดีขึ้นไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ

จักษุเวชสาร 2554; กรกฎาคม-ธันวาคม 25(2): 69-76.

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Original Article/นิพนธ์ต้นฉบับ

Comparison of Contrast Sensitivity, Higher-Order Aberrations and Subjective Visual Function after Different Aspheric Intraocular Lenses Implantation

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Abstract

Objective: To compare contrast sensitivity, higher-order aberrations (HOAs), and patient satisfaction after two aspheric intraocular lenses (IOLs) implantation.

Materials and Methods: This randomized prospective study included 45 eyes of 45 cataract patients who underwent phacoemulsification and aspheric IOLs implantation. Patients were randomized to receive one of two aspheric IOL types: Tecnis ZA9003 (Advanced Medical Optics; n=23) or Acrysof IQ SN60WF (Alcon Laboratories; n=22). Preoperative and 3-month postoperative evaluations included uncorrected and best-corrected distance visual acuity (LogMar UCVA and BCVA), photopic and mesopic contrast sensitivity testing (Optec®6500), wavefront analysis (LADARWave aberrometer (Alcon Laboratories, Fort Worth, Texas, USA), and Visual Function (VF-14) questionnaire.

Results: Three-month postoperative LogMar UCVA and BCVA in all eyes were 0.30 (20/40) or better and 0.18 (20/30) or better, respectively; with no statistically significant difference between the groups ($p > 0.05$). Both aspheric IOLs yielded similarly better contrast sensitivity at all spatial frequencies under photopic and mesopic conditions ($p > 0.05$). Comparisons of ocular aberrations for a 4-mm pupil showed no statistically significant difference in mean postoperative spherical aberration (SA) and HOA (SA of Tecnis 0.02 ± 0.04 μm vs. SA of AcrysofIQ 0.03 ± 0.02 μm; $p=0.46$ and HOA of Tecnis 0.19 ± 0.10 μm vs. HOA of AcrysofIQ 0.23 ± 0.11 μm; $p=0.17$). In comparison of subjective visual function, patients reported comparable high postoperative VF-14 scores (Mean 94.4 ± 6.0 vs. 96.2 ± 4.4; $p=0.27$), although mean increase in VF scores was higher in the Tecnis group than in the AcrysofIQ group ($p=0.005$).

Conclusion: Both aspheric acrylic IOLs improved contrast sensitivity, subjective visual function, and provided significant reduction in spherical aberration and higher-order aberration similarly. **Thai J Ophthalmol 2011; July-December 25(2): 69-76.**

Keywords: Aspheric intraocular lens, Contrast sensitivity, Higher-order aberration, Spherical aberration, Wavefront analysis

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The evolution of phacoemulsification technology and new-generation intraocular lenses (IOLs) has led cataract surgery in the current era not only to restore the patients' visual acuity, but also to obtain the most favorable quality of vision. Aspheric IOLs have been shown to improve functional vision in a number of previous studies[1-6]. The IOLs have originally been designed to decrease or neutralize positive ocular spherical aberration in aging eyes, thus providing enhanced contrast sensitivity and better image quality in pseudophakic patients compared with those implanted with conventional spherical IOLs. The gaining popularity of aspheric IOL use is rapid and widespread among cataract surgeons. At the time of the present study, comparative studies of visual outcomes in different optic designs have not been reported. The authors aimed to compare the contrast sensitivity, higher-order aberrations and patients' satisfaction of the two widely used aspheric IOLs in Thailand.

Materials and Methods

This prospective randomized study was conducted at the Department of Ophthalmology, Priest Hospital, Bangkok and the RSU Eye Medical Center, Faculty of Optometry, Rangsit University, Pathumthani, Thailand from June 2007 to May 2009. Two currently available aspheric IOLs of different designs, Tecnis ZA9003 (Advanced Medical Optics, Santa Ana, California, USA) and AcrysofIQ SN60WF (Alcon Laboratories, Fort Worth, Texas, USA) were investigated. Table 1 shows the characteristics of the two IOLs. Patients with bilateral cataract undergoing phacoemulsification with intraocular lens implantation were included. The exclusion criteria were

1) eyes with extreme refractive errors i.e. corneal astigmatism of 1.5 diopters and over, high myopia or hyperopia of 6 diopters and over;

2) eyes with pathology that can affect the vision, the acquisition of wavefront analysis and contrast sensitivity tests;

3) eyes with previous intraocular surgery.

Table 1 Characteristics of two aspheric intraocular lenses in the study

	Tecnis ZA9003	**AcrysofIQ SN60WF**
IOL type	3-piece	1-piece
Overall length (mm)	13	13
Optic diameter (mm)	6	6
Optic material	UV-blocking hydrophobic acrylic	Acrylate methacrylate copolymer with UV and proprietary blue light-filtering chromophore
Angle (degrees)	5	0
Haptic material	60% Blue-core Polymethylmethacrylate (PMMA) Monofilament	Acrylate methacrylate copolymer with UV and proprietary blue light-filtering chromophore
Refractive index	1.47	1.55
Optic shape	Biconvex, anterior aspheric	Biconvex, posterior aspheric
Estimated A-constant	119.1	118.7
Z [4,0]*	-0.27 μm	-0.20 μm

* for 6 mm pupil diameter

Patients were randomized to receive Tecnis ZA9003 (AMO) or AcrysofIQ SN60WF (Alcon). The IOL calculation was done using the SRK/T formula. Axial length was measured with the IOL Master (Carl Zeiss Meditec, Inc, Dublin, California, USA). The post-operative target refraction was plano. Uneventful pha-coemulsification and aspheric IOL implantation were performed by experienced surgeons in the same manner. Each patient provided informed consent.

Questionnaires and ocular exams were done preoperatively and 3 months postoperatively. Ocular examinations included uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), manifest and subjective refraction, Goldmann applanation tonometry, slit lamp biomicroscopy, and dilated fundus exam. Contrast sensitivity function test was performed at photopic (85 cd/m^2) and mesopic (5 cd/m^2) conditions using Optec® 6500 (Stereo Optical Co, Inc, Chicago, Illinois, USA). Wavefront analysis was done at 4 mm pupil diameter with LADARWave aberrometer (Alcon Laboratories, Fort Worth, Texas, USA). The visual function (VF-14) questionnaire, originally developed to measure functional impairment caused by cataract, was used to evaluate subjective visual function[7] and modified to Thai patients in rural areas[8]. The questionnaire contained questions about a variety of vision-dependent activities performed in everyday life i.e. distance and near activities, activities that required color vision, daytime and night vision. The scores were assigned from 0 to 100. If the patients reported inability to do all activities because of their vision, the score was 0, if they could do all applicable items, the score was 100. Statistical analysis was done using mean, percentage, and standard deviation for descriptive data. The Student's t-test was used for comparison of quantitative variables. A P value <0.05 was considered statistically significant.

Results

Forty-five eyes of 45 cataract patients were included in the study. Preoperative demographic and clinical data are provided in Table 2. All patients were men with the mean age of 66.6 years. (SD 5.7, range 51-81 years). Overall mean preoperative LogMar UCVA and BCVA were 0.81 (SD 0.23) (equivalent to 20/126) and 0.49 (SD 0.19) (equivalent to 20/61), respectively. Overall mean preoperative spherical equivalence (SE) was -1.82 (SD 2.28). Overall mean preoperative pupil size was 4.76 mm (SD 0.11). There were no statistically significant differences between the 2 different IOL groups in age, preoperative BCVA, preoperative SE, and preoperative pupil size. Pre-operative contrast sensitivity testing and wavefront analysis also showed similar photopic and mesopic contrast sensitivity and wavefront maps between the two groups (Table 3).

At 3 month postoperative, all eyes in both groups had mean UCVA of 0.30 (equivalence to 20/40) or better, and mean BCVA of 0.18 (equivalence to 20/30) or better. There was no statistical difference in postoperative BCVA between groups. (P=0.46). Overall mean postoperative pupil size was 4.54 mm (SD 0.74), which was not significantly different from preoperative pupil size (p=0.17). There were no significant differences in mean pupil size between the Tecnis and the AcrysofIQ groups both pre-operatively and postoperatively. (p >0.05)

Postoperative contrast sensitivity testing showed no significant difference between the groups under photopic and mesopic conditions. Figures 1, 2, and 3 demonstrate postoperative contrast sensitivity in log units at all spatial frequencies under photopic, mesopic and mesopic with glare conditions. There was no statistically significant difference in the mean contrast sensitivity between the Tecnis and AcrysofIQ groups.

Table 2 Mean preoperative patient demographics

	Total (n = 45 eyes)	Tecnis ZA9003 (n = 23 eyes)	Acrysof IQ (n= 22 eyes)	p-value
Age - years (SD) Range	66.6 (5.7) 51-81	65.3 (5.6)	68.0 (5.6)	0.11
Gender : Male-n (%)	45	23 (100%)	21 (100%)	
UCVA - LogMar (SD)	0.81 (0.23)	0.85 (0.23)	0.77 (0.23)	0.22
BCVA - LogMar (SD)	0.49 (0.19)	0.51 (0.18)	0.47 (0.20)	0.58
Spherical equivalence Diopters (SD)	-1.82 (2.28)	-1.94 (2.44)	-1.69 (2.15)	0.71
Pupil diameter - mm (SD)	4.76 (1.11)	4.50 (0.89)	4.89 (0.97)	0.17

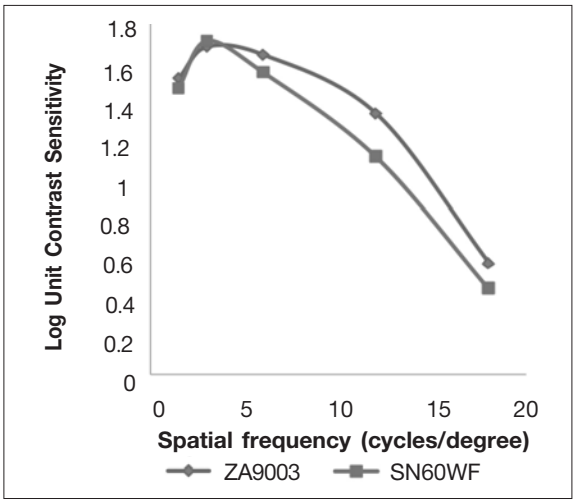
Table 3 Preoperative and postoperative spherical aberration and higher order aberration for both intraocular lens groups

Aberrations - mean (μm ± SD)		All	Tecnis ZA 9003	AcrysofIQ SN60WF	p-value
Spherical aberration	Preoperative	0.16 ± 0.09	0.15 ± 0.09	0.16 ± 0.09	0.81
	Postoperative	0.04 ± 0.03	0.03 ± 0.02	0.04 ± 0.04	0.12
Higher-order aberration	Postoperative	0.29 ± 0.16	0.24 ± 0.15	0.34 ± 0.17	0.15
	Preoperative	0.52 ± 0.19	0.46 ± 0.23	0.60 ± 0.16	0.14
Coma	Preoperative	0.29 ± 0.18	0.26 ± 0.18	0.33 ± 0.18	0.22
	Postoperative	0.17 ± 0.10	0.15 ± 0.98	0.19 ± 0.11	0.29
Total aberration	Preoperative	2.62 ± 1.56	2.26 ± 1.39	3.02. ± 1.68	0.16
	Postoperative	0.83 ± 0.42	0.84 ± 0.50	0.82 ± 0.30	0.87

* 4 mm pupil diameter analyzed

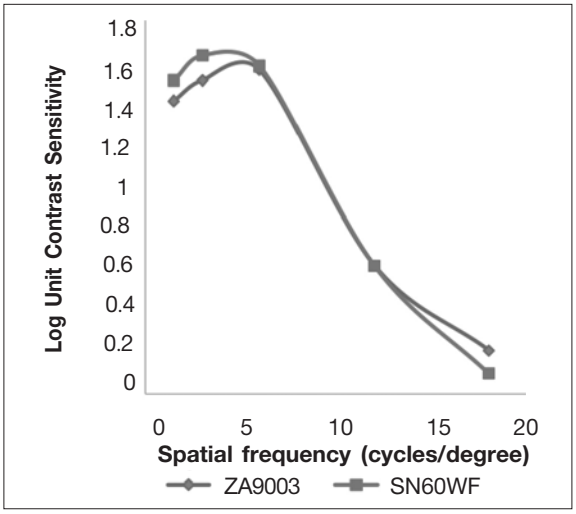
Comparisons of ocular aberrations for a 4-mm pupil diameter revealed no statistically significant different mean postoperative spherical aberration between the two groups (p=0.12); 0.03 μm (SD 0.03) in the Tecnis group and 0.04 μm (SD 0.04) in the AcrysofIQ group. Mean postoperative higher-order aberrations (HOAs) were also similar between two groups; 0.24 μm (SD 0.15) for the Tecnis group and 0.34 μm (SD 0.17) for the AcrysofIQ (p=0.15) group; Table 3.

When considering subjective visual function, the patients reported comparable high postoperative VF-14 scores with the mean scores of 94.4 ± 6 and 96.2 ± 4.4 in the Tecnis and AcrysofIQ groups, respectively (p=0.27). However, the mean increase in VF scores was significantly higher in the Tecnis group than that in the AcrysofIQ group (p=0.005).



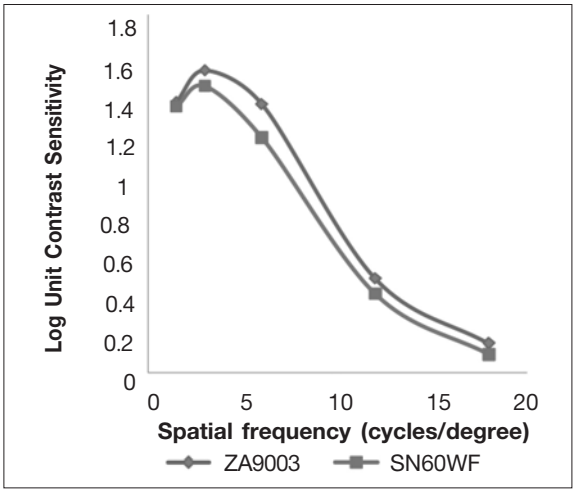
Spatial frequency	Tecnis	AcrysofIQ	p-value
1.5	1.51 (0.23)	1.46 (0.19)	0.388
3	1.67 (0.24)	1.70 (0.16)	0.710
6	1.63 (0.19)	1.54 (0.52)	0.127
12	1.33 (0.23)	1.11 (0.57)	0.085
18	0.57 (0.54)	0.44 (0.53)	0.443

Figure 1. *Postoperative contrast sensitivity under photopic condition without glare for 2 intraocular lens groups (รูปสีท้ายเล่ม)*



Spatial frequency	Tecnis	AcrysofIQ	p-value
1.5	1.41 (0.48)	1.51 (0.24)	0.382
3	1.51 (0.49)	1.63 (0.17)	0.261
6	1.56 (0.62)	1.58 (0.60)	0.712
12	0.62 (0.62)	0.62 (0.59)	0.984
18	0.21 (0.33)	0.10 (0.18)	0.572

Figure 2. *Postoperative contrast sensitivity under mesopic condition without glare for 2 intraocular lens groups (รูปสีท้ายเล่ม)*



Spatial frequency	Tecnis	AcrysofIQ	p-value
1.5	1.21 (0.48)	1.19 (0.24)	0.889
3	1.35 (0.49)	1.28 (0.17)	0.673
6	1.20 (0.62)	1.05 (0.60)	0.485
12	0.42 (0.62)	0.35 (0.59)	0.647
18	0.13 (0.33)	0.08 (0.18)	0.728

Figure 3. *Postoperative contrast sensitivity under mesopic condition with glare for 2 intraocular lens groups (รูปสีท้ายเล่ม)*

Discussion

Based on the knowledge of wavefront analysis of the optical system, ocular aberrations other than astigmatism and defocus have a critical impact on visual function. Aspheric IOLs have demonstrated improvement in contrast sensitivity and visual performance when compared to spherical lens, which theoretically introduce more positive spherical aberration as the lens power increases. This has been confirmed in several prior studies comparing conventional spherical lens vs. aspheric lens results[2-5,9]. Our investigations found significant enhancement of contrast sensitivity at all spatial frequencies under photopic and mesopic conditions in pseudophakic patients implanted with two different aspheric IOLs.

Two aspheric IOL designs studied were Tecnis ZA9003 (AMO) and AcrysofIQ SN60WF (Alcon). The Tecnis ZA9003 is a hydrophobic acrylic three-piece lens with an anterior aspheric surface. The AcrysofIQ is a single-piece lens made of hydrophobic acrylic with a posterior aspheric design. It also incorporates blue light-filtering chromophores believed to prevent retinal pigment epithelial cell damage and age-related macular degeneration[10]. The reported advantage of blue light-filtering IOLs has been conflicting. Previous studies have suggested no effects of yellow IOLs on contrast sensitivity[11,12]. Nevertheless, recent reports found decreased contrast sensitivity especially at scotopic conditions[13,14]. In the present study, the difference in contrast sensitivity improvement between UV-absorbing IOL and additional blue-light absorbing IOL could not be confirmed.

Considering correcting spherical aberration, if one aims to reach the target total root-mean-square (RMS) of 0 μm or optimal spherical aberration, an aspheric IOL can be customized in each individual eye to neutralize preoperative corneal spherical aberration. Although the present study designed to randomly select the IOLs without customization to corneal wavefront maps, the results showed post-operative spherical aberration clustered between 0 to 0.1 μm and patients reported relatively high visual function scores in both IOL groups. Despite the benefit of asphericity on visual function, using aspheric IOL universally is not recommended. Limited advantages of aspheric IOLs with smaller pupils have been reported[9]. Moreover, an earlier report has proposed that decentration and tilting of IOL with negative spherical aberration can decrease IOL performance and even induce higher-order aberrations i.e coma[15]. This is of concern in patients with uncertain capsular stability such as cataract with exfoliation syndrome. In the present study, the authors detected a decline in coma, spherical aberration, and higher-order aberration which may indicate good centration of IOLs.

Conclusion

The two different designs of aspheric acrylic IOLs performed equally well in improving contrast sensitivity and subjective visual function, and providing significant reduction in spherical aberration and higher-order aberration.

Acknowledgement

The authors wish to thank Pornpen Jamkrajai, RN, Benjaporn Kosulwit, BSc, and Mr. Paradon Boonprom for their devoted work on patients' data collection.

Disclosure

The authors have no financial support or conflict of interest in any materials or methods mentioned.

References

1. Packer M, Fine IH, Hoffman RS, Piers PA. Improved functional vision with a modified prolate intraocular lens. J Cataract Refract Surg 2004;30:986-92.
2. Bellucci R, Scialdone A, Buratto L, Morselli S, Chierego C, Criscuoli A, et al. Visual acuity and contrast sensitivity comparison between Tecnis and AcrySof SA60AT intraocular lenses: A multicenter randomized study. J Cataract Refract Surg 2005;31:712-7.
3. Sandoval HP, Fernández de Castro LE, Vroman DT, Solomon KD. Comparison of visual outcomes, photopic contrast sensitivity, wavefront analysis, and patient satisfaction following cataract extraction and IOL implantation: aspheric vs spherical acrylic lenses. Eye 2008;22:1469-75. Epub 2007 Jul 6.
4. Tzelikis PF, Akaishi L, Trindade FC, Boteon JE. Spherical aberration and contrast sensitivity in eyes implanted with aspheric and spherical intraocular lenses: a comparative study. Am J Ophthalmol 2008;145:827-33. Epub 2008 Mar 4.
5. Rocha KM, Soriano ES, Chalita MR, Yamada AC, Bottós K, Bottós J, et al. Wavefront analysis and contrast sensitivity of aspheric and spherical intraocular lenses: a randomized prospective study. Am J Ophthalmol 2006;142:750-6.
6. Munoz G, Albarran-Diego C, Montes-Mico R, et al. Spherical aberration and contrast sensitivity after cataract surgery with the Tecnis Z9000 intraocular lens. J Cataract Refract Surg 2006;32:1320-7.
7. Steinberg EP, Tielsch JM, Schein OD, Javitt JC, Sharkey P, Cassard SD, et al. The VF-14. An index of functional impairment in patients with cataract. Arch Ophthalmol 1994;112:630-8.
8. Sornpaisarn C, Jenchitr W, Yenjitr C, Tangcharoensthian V. Measurment of quality of vision for cataract patients in rural area. Thai J PBI Ophthalmol 2002;16:69-94
9. Kasper T, Buhren J, Kohnen T. Visual performance of aspherical and spherical intraocular lenses: intraindividual comparison of visual acuity, contrast sensitivity, and higher-order aberrations. J Cataract Refract Surg 2006;32:2022-9.
10. Sparrow JR, Miller AS, Zhou J. Blue light-absorbing intra-ocular lens and retinal pigment epithelium protection in vitro. J Cataract Refract Surg 2004;30:873- 8.
11. Mester U, Holz F, Kohnen T, Lohmann C, Tetz M. Intraindividual comparison of a blue-light filter on visual function: AF-1 (UY) versus AF-1 (UV) intraocular lens. J Cataract Refract Surg 2008;34:608-15
12. Eberhard R, Roberti P, Prünte C. Intraindividual comparison of color perception and contrast sensitivity with and without a blue light-filtering intraocular lens. Eur J Ophthalmol 2009;19:235-9.
13. Bhattacharjee H, Bhattacharjee K, Medhi J. Visual performance: Comparison of foldable intraocular lenses. J Cataract Refract Surg 2006;32:451-5.
14. Wirtitsch MG, Schmidinger G, Prskavec M, Rubey M, Skorpik F, Heinze G, et al. Influence of blue-light-filtering intraocular lenses on color perception and contrast acuity. Ophthalmology 2009;116:39-45.
15. Dietze HH, Cox MJ. Limitations of correcting spherical aberration with aspheric intraocular lenses. J Refract Surg 2005;21:S541-6.