Original Article/นิพนธ์ต้นฉบับ

Spherical Aberration in the Eyes with Aspheric and Spheric IOL

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Objective: To evaluate the spherical aberration in patients underwent cataract surgery with aspheric and spheric intraocular lens (IOL) implantation in terms of contrast sensitivity test and wavefront sensing.

Materials and methods: A prospective study consisted of 20 patients with bilateral cataracts underwent phacoemulsification surgery in both eyes with aspheric IOL (Alcon Acrysof HOA,SN60WF) implantation in one eye and spheric IOL (Acrysof, SA60AT) in the contralateral eye. Contrast sensitivity was measured by sinusoidal grating charts at photopic condition. Spatial frequency tests were 3,6,12 and 18 cycles per degree. Wavefront aberration was measured with wavefront sensing device at the pupil size of 5, 5.5 and 6 mm. The results were compared at 4 weeks after surgery.

Results: Contrast sensitivity test at photopic condition was better in eyes with aspheric IOL than in eyes with spheric IOL at all spatial frequency in 84% of patients. The wavefront measurements of each eye were decomposed in Zernike polynomial and it was found that the spherical aberration were lower in eyes with aspheric IOL in 90% of patients, the mean spherical aberration in eyes with aspheric IOL was significantly lower at pupil size of 5.5 and 6 mm. *($p<0.05$)*

Conclusion: The eyes with aspheric IOL implantation have better functional vision than eyes with spheric IOL due to lower spherical aberration measured by wavefront sensing device. **J Ophthalmol 2006 ; July-December 20(2) : 141-146.**

Keywords: *spherical aberration, aspheric IOL, spheric IOL, contrast sensitivity, wavefront*

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An achievement of 20/20 visual acuity is always the target of all cataract surgeons, the goal of higher quality vision is becoming increasingly important. The use of advance technology to address higher-order optical aberrations is emerging as a more comprehensive measurement than the Snellen chart. Contrast sensitivity test and wavefront aberrometer can be used to evaluate the quality of vision in these patients. Contrast sensitivity testing has an ability to detect differences in functional vision while Snellen visual acuity measurement cannot.[1] The wavefront aberrometer is a tool to objectively detect the aberration by Hartman-Shack Principle and can be used to analyze and interpret in term of wavefront and Zernike polynomial.

We designed a prospective study to evaluate contrast sensitivity and wavefront measurement in patients implanted with spherical IOL in one eye and aspherical IOL in the other.

Materials and Methods

Twenty patients with bilateral senile cataract, age between 55-85 years were enrolled in this nonrandomized clinical trial. All participants received the phacoemulsification surgery with implantation of spherical IOL in one eye and aspherical IOL in the contralateral eye. Inclusion criteria were as follows: cataract in both eyes with lens opacity grade II - III, visual acuity more than 0.54 logMAR unit, IOL power between +16 to +25 diopter. Exclusion criteria were: age under 50 years old, prior refractive surgery, glaucoma surgery, and eyes with other pathology. Preoperative evaluation was performed as standard ophthalmic examination, including visual acuity, manifest refraction, biomicroscopy, intraocular pressure measurement, keratometry and fundus examination. The IOL power calculation was targeted for emmetropia with SRK-II or SRK-T formula depend on the patient's axial length. Two separated settings of cataract surgery were done by the same surgeon. Two surgeons (PP and PN) in this study employed the same surgical techniques. 2.75-3 mm. temporally clear corneal incision was performed under topical anesthesia, 5-5.5 mm. round capsulorhexis was done, phacoemulsification was performed with Infiniti machine (Alcon) and an IOL was implanted through the injector into the capsular bag. The incision was left sutureless without any intraoperative complications. Postoperatively the patients received tobramycin combination with dexamethasone eyedrop 4 times a day for 4 weeks. Two models of the IOL were used in this study, Alcon Acrysof HOA(SN60WF) (one-piece acrylic, 6.0 mm. optic diameter) and Acrysof (SA60AT) (one-piece acrylic, 6.0mm. optic diameter). These two models IOL have identical shape and size, the difference is at posterior surface of the optic of SN60WF that is modified in order to reduce the power peripherally (negative spherical aberration). The patients were followed up at 3, 7, 14 and 30 days. Visual acuity, contrast sensitivity test and wavefront error were measured and recorded 1 month after surgery. Contrast sensitivity were tested monocularly with linear sine-wave grating charts (Ginsberg) at 3, 6, 12, 18 cycle per degree at uniform room illumination, and chart illuminace of 85 cd/m^2 with 1 metre of test distance, which was corresponds to spatial frequency of 1 cycle per degree. Wavefront measurement of the whole eye was performed with Hartmann-Shack sensor (Alcon Summit Autonomous custom cornea measurement device). The pupils were dilated with tropicamide 1% before the examinations. Wavefront measurement was done at virtual pupil diameter of 5, 5.5 and 6 mm. Total aberration and higher-order aberrations were evaluated, as well as the amount of spherical aberration. The examiners for visual acuity, contrast sensitivity and wavefront measurement did not know which eye was implanted by which type of IOL. Data processing and statistical analysis were

performed with the Mann-Whitney test for comparison of spherical aberration and student t-test for other data, the significant level of 2-sided statistical tests was set at $p < 0.05$.

Results

The mean age of patients was 64.3 ± 8.5 years. The mean preoperative best-corrected visual acuity was 0.83 ± 0.23 logMar units for the eyes implanted with aspheric IOL and 0.77 ± 0.24 logMar unit for the eyes implanted with spheric IOL. ($p = 0.17$)

The mean postoperative monocular uncorrected distance visual acuity was 0.07 ± 0.08 and 0.07 ± 0.06 logMar units respectively. ($p = 1.00$) The best corrected visual acuities were 0.02 ± 0.04 and 0.03 ± 0.04 logmar units which were not statistically significant different between both groups. ($p = 0.33$) The mean monocular uncorrected near visual acuity was better in the eyes implanted with spheric IOL than the eyes implanted with aspheric IOL but no statistically significant difference. ($P = 0.33$)

Contrast sensitivity at all spatial frequency were better in the eye implanted with aspheric IOL than the other eye implanted with spheric IOL of the same patients in 84% of patients. (Figure 1)

Normally the aberration value increases with increasing virtual pupil diameter. In the wavefront analysis, 18 in 20 patients (90%) have less spherical aberration value in eyes implanted with aspheric IOL than in eyes implanted with spheric IOL at pupil diameter of 6 and 5.5 mm. The mean spherical aberration were calculated and found that the eyes implanted with aspheric IOL induced statistically significant less spherical aberration than the eyes implanted with spheric IOL ($P < .05$) at the pupil size of 6 and 5.5 mm. and not significant at the pupil size of 5 mm. ($p = 0.09$). (Figure 2)

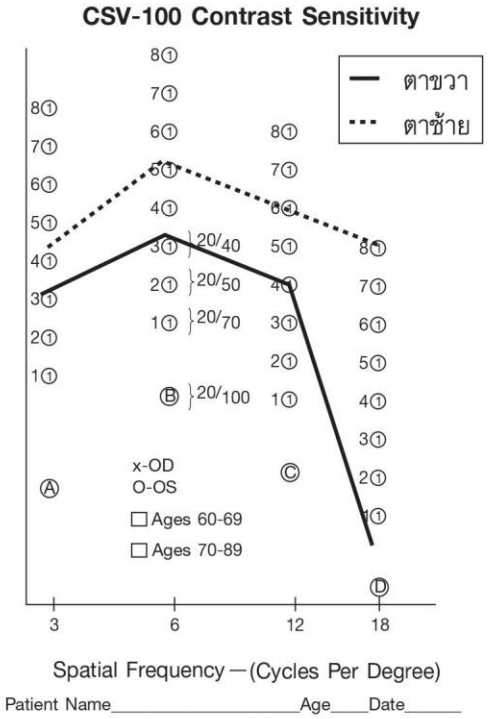

Figure 1. *The contrast sensitivity test results of a patient implanted with aspheric IOL in one eye (upper) and spheric IOL in the other eye (lower).*

Discussion

Contrast sensitivity declines with age, even in patients without ocular pathology. When people are young, the crystalline lens has negative spherical aberration while the cornea has positive spherical aberration. The balance of both reduces the total optical aberrations in the eye. There are evidence from wavefront aberration measurements combined with data from corneal topography that the optical characteristics of the youthful crystalline lens compensate for aberrations in the cornea. The pathogenesis of the decline in contrast sensitivity is partly due to changes in spherical aberration of the crystalline lens. Spherical aberration is a property of spherical lens. A spherical lens does not refract all parallel rays of incoming light to a single focal point.

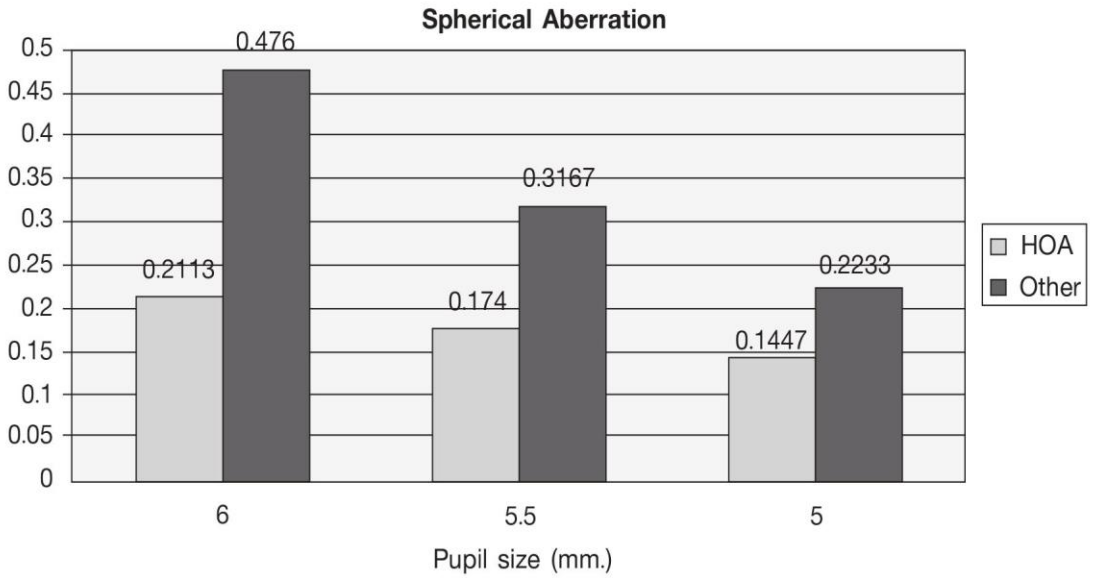

Figure 2. *The mean spherical aberration in eyes implanted with aspherical IOL compare to eyes implanted with spherical IOL with different pupil diameter*

The lens bends peripheral rays more strongly so that these rays cross the optical axis in front of the paraxial rays.[2] Spherical aberration of the crystalline lens is increasing while spherical aberration of the cornea changes little with ages. However, the total wavefront aberration of the eye increase more than three fold between ages 20 and 70 years.[3] Besides cataract, glaucoma and macular degeneration, these aberrations are the causes of degradation of optical quality of the aging eyes.

When a patient undergoes cataract surgery, the cataractous lens is removed and replaced by spherical IOL. The implanted IOL has positive spherical aberration, like the aging lens, the resulting visual outcome is no better than the visual quality of the age-matched eye without cataracts. This reduction in quality is more severe under low luminance conditions because ocular aberrations increase when the pupil size get larger. The newer aspheric IOL have modified the anterior or posterior surface to make the aspheric optic to compensate the positive spherical aberration of both the cornea and lens. The aspheric optic helps align the light rays that pass through both the center and periphery of the lens, thereby potentially creating the sharper image on the retina. The preliminary results indicated improved mesopic contrast sensitivity in many patients. The laboratory test by modulation transfer function (MTF) demonstrates higher optical efficiency over spheric IOL. Some authors believe that these new IOLs are designed to partially compensate for the average spherical aberration of the cornea. If implanted properly, it can improve the optical quality of the pseudophakic patients.[4] This improvement in optical quality of pseudophakic eyes can be measured in vivo by aberrometers[5].

Aspheric IOL have been shown to provide improved functional vision and enhanced contrast sensitivity compared to spherical IOL. The balance of spherical aberration between the cornea and the lens results in reducing spherical aberration of the whole eye and increasing in contrast sensitivity. The average spherical aberration of the cornea is + 0.27 □ m. The AcrySof SN60WF is a single-piece lens made of

hydrophobic acrylic, and it has a refractive index of 1.55. It adds 0.20 □m of negative spherical aberration to the eye. The theory is that counteracting this amount of spherical aberration will provide the vast majority of people with good functional vision.

Our results showed that the aspheric Acrysof SN60WF lens improved contrast sensitivity with a concomittant increase in image quality in 84% percent of patients in photopic condition. The spherical aberration measured by wavefront sensing device also showed the same results. This meant that the eyes implanted with these IOL were seeing with the same image quality and contrast perception as an 18-year-old during the day. However, we can not compensate the total spherical aberration of the cornea because the aberration can be induced by the operation. Higher-order aberrations such as coma and trefoid may be increased or decreased postoperatively, however, will produce spatial distortions that may have small effect on contrast sensitivity yet be bothersome to the patients in terms of ghosts and multiple images.

In some randomized, double-masked study[6] of other aspheric IOL, the Tecnis Z9000, a multipiece silicone lens, which introduces 0.27 □m of negative spherical aberration to the eye equal to the positive spherical aberration of the cornea. Twenty nine patients were implanted with the aspheric Tecnis IOL in one eye and the AcrySof SA60AT spherical IOL in the fellow eye. The testing was conducted with best-corrected visual acuity using one eye at a time in each testing condition, comprised of city and rural night driving conditions. The eye implanted with the aspheric IOL outperformed the eye implanted with the spherical IOL in 21 of 24 testing conditions, and the difference was statistically significant in 10 conditions.

We must also consider that the preoperative cornea is not always identical to the postoperative cornea. Higher-order aberrations in the cornea can be induced during surgery. Specifically, coma can be induced by the incision and the change is not always predictable. This is the reason why the customization is not always straight forward, it may be the future of cataract surgery.

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เปรียบเทียบ Spherical Aberration ของตาที่ฝังเลนส์แก้วตาเทียมชนิด Aspheric และชนิด Spheric

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษา Spherical aberration โดยตรวจ contrast sensitivity และ wavefront ของตาหลังผ่าตัดต้อกระจกที่ฝังเลนส์แก้วตาเทียมชนิด Aspheric และชนิด Spheric

วิธีการวิจัย: เป็นการศึกษาแบบมองไปข้างหน้าในผู้ป่วยต้อกระจก 20 ราย ที่ได้รับการผ่าตัดโดยวิธีสลายต้อกระจกและใส่เลนส์แก้วตาเทียมแบบ Spheric (Alcon Acrysof, SA60AT) ในตาข้างหนึ่ง และแบบ Aspheric (Alcon Acrysof, SA60WF) ในตาอีกข้างหนึ่ง หลังผ่าตัด 4 สัปดาห์ ได้ทำการวัด contrast sensitivity ที่ความถี่ 3, 6, 12, 18 รอบต่อองศาในที่มีแสงสว่าง และตรวจ wavefront aberration ที่ขนาดม่านตา 5, 5.5 และ 6 มิลลิเมตร

ผลการวิจัย: ตาที่ฝังเลนส์แก้วตาเทียมชนิด Aspheric มีค่า contrast sensitivity ในทุกความถี่ดีกว่า ตาที่ฝังเลนส์แก้วตาเทียมชนิด Spheric ใน 84% ของผู้ป่วย ผลการตรวจwavefront และกระจายค่าโดย Zernike polynomial พบว่าค่า spherical aberration ของตาข้างที่ฝังเลนส์ชนิด Aspheric มีค่าต่ำกว่าข้างที่ฝังเลนส์ชนิด spheric ใน 90% ของผู้ป่วย และค่าเฉลี่ยของ spherical aberration ของตาที่ฝังเลนส์ชนิด Aspheric ต่ำกว่าตาอีกข้างหนึ่งอย่างมีนัยสำคัญที่ขนาดรูม่านตา 5.5 และ 6 มิลลิเมตร *($p < 0.05$)*

สรุป: ตาที่ฝังเลนส์แก้วตาเทียมชนิด Aspheric มี functional vision ดีกว่าตาที่ฝังเลนส์แก้วตาเทียมชนิด Spheric จากการที่มี spherical aberration ต่ำกว่าที่แสดงได้จากการตรวจ wavefront sensing และ contrast sensitivity **จักษุเวชสาร 2549 ; กรกฎาคม-ธันวาคม 20(2) : 141-146.**

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