# Wavefront and Ocular Spherical Aberration after Implantation of Different Types of Aspheric Intraocular Lenses Based on Corneal Spherical Aberration

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***Background:*** *To determine the ocular spherical aberration after using preoperative corneal spherical aberration guided aspheric IOL selection for cataract surgery.*
***Material and Method****: Twenty-six eyes of cataract patients were scheduled for cataract surgery with aspheric IOL implantation based on preoperative corneal spherical aberration (SA) measured by Galilei corneal topography. The target postoperative total wavefront spherical aberration was zero. Three types of IOL were used in this study: TecnisZA9003 (Abbott Medical Optics Inc) with spherical aberration of -0.27 µm; Acrysof IQ SN60WF (Alcon Inc.) with spherical aberration of -0.20 µm and B&L Akreos with zero spherical aberration. Ocular spherical aberration was measured with a Wave Light machine 3 months postoperatively to demonstrate the total ocular spherical aberration.*
***Results:*** *The preoperative mean corneal spherical aberration in the 3 groups was 0.351 $\pm$ 0.08, 0.181 $\pm$ 0.04, and 0.056 $\pm$ 0.03 microns respectively. All 26 eyes of 26 patients completed the 3-month follow-up visit. Postoperative ocular spherical aberration of the 3 groups were: TecnisZA9003 (10 eyes) +0.023 $\pm$ 0.011 µm.; Acrysof IQ SN60WF (11 eyes) +0.045 $\pm$ 0.018 µm; and B&L Akreos (5 eyes) +0.018 $\pm$ 0.008 µm. These values were significantly lower than the predicted values in the Tecnis and Akreos groups and there was no correlation between the actual postoperative ocular spherical aberration and the predicted ocular spherical aberration in all groups.*
***Conclusion:*** *The implantation of an aspheric intraocular lens based on preoperative corneal spherical aberration is effective in reducing total ocular spherical aberration and improving visual function.*

***Keywords:*** *Spherical aberration, Aspheric intraocular lens, Wavefront analysis, Higher order aberration*

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The study was approved by the Research Ethics Committee of the Rajavithi hospital. Developments in cataract surgery have led to significant improvement in postoperative visual acuity. Today, the goal of cataract surgery is not only to achieve good visual acuity but also to improve contrast sensitivity by correcting higher order aberrations. Higher order aberrations, especially spherical aberration, have an impact on contrast sensitivity and functional vision[1-4],which can be measured by wavefront-sensing techniques and can be described by Zernike polynomials[5]. It has been shown that, at least for young eyes, a proportion of the corneal aberrations are compensated by aberrations of the crystalline lens[6]. The fact that the spherical aberration of the cornea is typically positive, while the spherical aberration of the crystalline lens tends to be negative, has been shown[7].

Nowadays, in all cataract procedures, the natural crystalline lens is replaced by an artificial intraocular lens. The conventional spherical IOLs have positive spherical aberration, do not compensate for the corneal aberration, and cannot refract all parallel rays of incoming light to a single focal point, resulting in reduction of visual quality[8]. Several commercially available aspheric IOLs have been designed either to avoid increasing the positive spherical aberration of the cornea, or to compensate for it, thereby eliminating total ocular spherical aberration and improving the quality of vision in pseudophakic eyes. The absolute value of zero total spherical aberration was shown to be the best result of visual function measured by contrast sensitivity[9]. Based on this concept, we selected aspheric IOLs based on corneal wavefront

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spherical aberration. The goal of this study was to determine the predictability of corneal wavefront-guided selection of aspheric intraocular lenses for appropriated eyes.

## Material and Method

This was a prospective case series study of patients who had been scheduled for cataract extraction by the phacoemulsification technique at Rajavithi Hospital, Thailand. The inclusion criteria were cataract patients aged more than 18 years with corneal astigmatism less than 1.0 diopters (D). The exclusion criteria were any ocular diseases other than cataract and glaucoma which could interfere with the measuring of corneal and ocular aberration, such as corneal opacities and retinal abnormality. The research protocol was approved by the Rajavithi Hospital Ethics Committee. All patients were informed about the study and the possible complications of surgery. Twenty-six patients were selected to receive 1 of the following aspheric IOLs: Tecnis ZA9003 (Abbott Medical Optics Inc.), which has a spherical aberration of -0.27 µm, for patients who had preoperative corneal spherical aberration of >+ 0.235 µm; Acrysof IQ SN60WF (Alcon Inc.), which has a spherical aberration of -0.20 µm, for patients who had preoperative corneal spherical aberration of more than +0.10 µm and less than +0.235 µm and Akreos (Bausch & Lomb), which has a zero spherical aberration, for patients who had preoperative corneal spherical aberration of less than +0.10 µm. The detailed data on the three IOL are shown in Table 1.

### *Surgical procedure*

All surgical procedures were performed by 1 of 3 experienced surgeons. After topical or retrobulbar anesthesia of lidocaine 2% had been administered, a temporal corneal incision of 2.75 or 3.0 mm was created. Viscoelastic (Viscoat (Alcon Inc.) or IAL-F (TRB Chemedica)) was injected to hold open the space between the cataract and the cornea. Continuous curvilinear capsulorhexis was created by capsulorhexis forceps with an approximate diameter of 5.5-6.0 mm. The phacoemulsification procedure was carried out by standard techniques using an Infiniti (Alcon Inc.).The selected IOLs were implanted in the capsular bag. The ophthalmic viscoelastic device was completely removed at the end of the procedure.

### *Wavefront Map Analysis*

The preoperative corneal wavefront map was analyzed up to the 4$^{th}$ order of Zernike coefficients at a 6.0 mm optical zone using Dual Scheimpflug Analyzer Corneal topography (GALILEI ,Ziemer Ophthalmic System). The postoperative total ocular spherical aberration was analyzed at 6.0 mm optical zone using LADAR Vision wavefront analyzer (Alcon Inc.)

### *Clinical Examination*

All patients were examined preoperatively 1, 7, 30 and 90 days postoperatively by the infiniti (Alconhad operated on the eye. An ophthalmological examination was performed, including best-corrected visual acuity (BCVA), refraction and fundus examination. Corneal aberration was measured preoperatively to select IOL and total ocular aberration was measured 90 days postoperatively.

### *Main measure outcomes*

Preoperative corneal spherical aberration.

Postoperative total ocular spherical

**Table 1.** Features of the three intraocular lenses used in this study

| Parameter | TecnisZA9003 | Acrysof IQ SN60WF | B&L Akreos |
|---|---|---|---|
| Overall length(mm) | 13.0 | 13.0 | 11.0 |
| Optic diameter (mm) | 6.0 | 6.0 | 6.0 |
| Haptic angulation | 0 degree | 0 degree | 0 degree |
| Optic design | Biconvex,anterior aspheric shape , square optic edge | Biconvex, posterior aspheric shape, square optic edge | Biconvex, anterior and posterior aspheric surface , square optic edge |
| Material | UV-blocking hydrophobic acrylic | UV and blue light-filtering chromophores | Hydrophilic acrylic |
| Refractive index | 1.47 | 1.55 | 1.46 |
| Estimated A-constant | 118.8 | 118.7 | 118.0 |
| Spherical aberration (µm) | -0.27 | -0.20 | 0 |

aberration.

***Statistical analysis***

All statistical analyses were performed using SPSS 17.0 (for Windows, SPSS Inc). Description analysis, number and mean $\pm$ standard deviation (SD) was used to evaluate demographic data. ANOVA was used to compare means between the IOL groups. Pearson correlation was used to evaluate the relationship between the prediction error of postoperative total spherical aberration and preoperative corneal spherical aberration. Paired t-test was used to compare between two means pre and post operative. P-value was set at less than 0.05 for statistical significance difference.

**Results**

The study evaluated 26 eyes of consecutive patients, including 10 eyes for TecnisZA9003, 11 eyes for Acrysof IQ SN60WF and 5 eyes for B&L Akreos. Table 2 shows the number of eyes, mean age, sex, mean spherical equivalent, axial length, IOL power and preoperative corneal SA by IOL group. There was no statistical difference between age, axial length and IOL power ($p > 0.05$). Preoperatively, the mean corneal spherical aberration was +0.351 $\pm$ 0.089 with TecnisZA 9003, +0.181 $\pm$ 0.041 with Acrysof IQ SN60WF and +0.056 $\pm$ 0.032 with B&L Akreos. The mean postoperative total ocular spherical aberration of TecnisZA9003, Acrysof IQ SN60WF and B&L Akreos were + 0.023 $\pm$ 0.011 µm, + 0.045 $\pm$ 0.018 µm and +0.018 $\pm$ 0.008 µm respectively (Fig. 1). The mean predicted postoperative total SA of TecnisZA9003, Acrysof IQ SN60WF and B&L Akreos were +0.081 $\pm$ 0.089-0.019 $\pm$ 0.041 and +0.056 $\pm$ 0.032 respectively (Table 3). The results of postoperative actual SA and postoperative VA are shown in Fig. 2. The results of postoperative actual SA and postoperative predicted SA are shown in Fig. 3.

**Discussion**

Many advanced techniques have been developed to achieve the best possible results from cataract surgery, the aspheric foldable IOL being an example of a recent innovation. The only accurate IOLs power calculation which compensates for defocus or lower aberration and gain in the Snellen visual acuity is no longer enough. We also know that higher order aberrations (HOA) are the major factors affecting quality of vision and the most important HOA is spherical aberration[1-4]. The conventional spherical IOL has positive spherical aberration and if added to

**Table 2**. Patient demographic data by group (n = 26 eyes)

| | IOL group | | |
|---|---|---|---|
| | TecnisZA9003 | Acrysof IQ SN60WF | B & L Akreos |
| Spherical aberration correction (µm) | -0.27 | -0.20 | 0 |
| Eyes (n) | 10 | 11 | 5 |
| Age (y) | | | |
| Mean $\pm$ SD* | 66.10 $\pm$ 6.38 | 63.45 $\pm$ 12.21 | 73.60 $\pm$ 4.336 |
| Sex (n) | | | |
| Male | 3 | 5 | 3 |
| Female | 7 | 6 | 2 |
| Mean spherical equivalent (SE) $\pm$ SD* | +0.82 $\pm$ 1.4 | -0.28 $\pm$ 1.09 | +0.75 $\pm$ 0.91 |
| Axial length(mm) | | | |
| Mean $\pm$ SD* | 23.28 $\pm$ 0.71 | 23.27 $\pm$ 0.66 | 22.37 $\pm$ 0.65 |
| IOL power (D) | | | |
| Mean $\pm$SD* | 21.20 $\pm$ 1.79 | 20.81 $\pm$ 2.40 | 23.10 $\pm$ 0.65 |
| Range | 18.5-24.0 | 15.0-24.5 | 22.5-24.0 |
| Preoperative corneal SA (µm) | | | |
| Mean $\pm$ SD* | +0.351 $\pm$ 0.089 | +0.181 $\pm$ 0.041 | +0.056 $\pm$ 0.032 |
| Range | 0.24-0.55 | 0.15-0.23 | 0.02-0.09 |

* Standard deviation

**Table 3.** The mean predicted postoperative total SA of TecnisZA9003, Acrysof IQ SN60WF and B&L Akreos (n =26 eyes)

| | Mean (µm) ± SD | | |
|---|---|---|---|
| IOL Group | Postoperative Predicted SA | Post Operative Actual SA | p-value |
| Acrysof | -0.019 ± 0.041 | 0.045 ± 0.017 | 0.001* |
| Tecnis | +0.081 ± 0.089 | 0.023 ± 0.010 | 0.058 |
| Akreos | +0.056 ± 0.032 | 0.018 ± 0.008 | 0.038* |

* Significant at $p < 0.05$, SD = Standard deviation

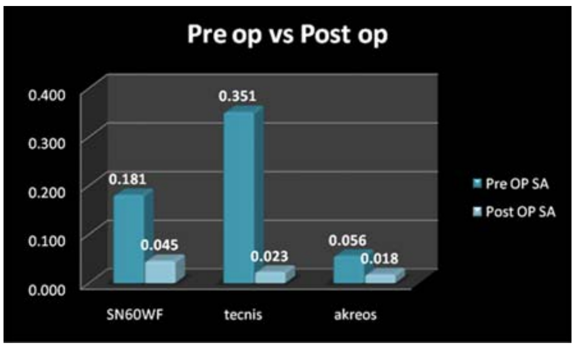


**Fig. 1** Shows mean preoperative corneal SA and post-operative total ocular SA by IOL group

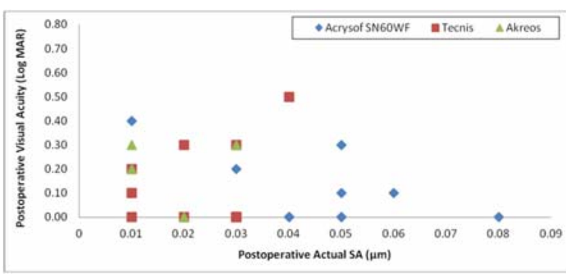


**Fig. 2** The results of postoperative actual SA and post-operative VA

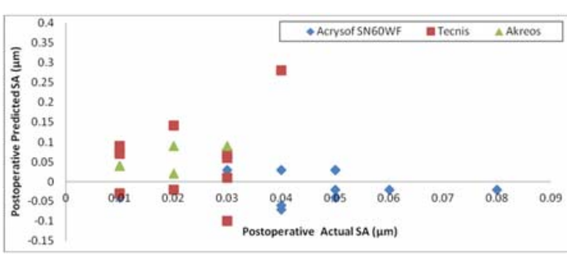


**Fig. 3** The results of postoperative actual SA and post-operative predicted SA

the positive spherical aberration of the cornea, the total ocular aberration will be even more positive after cataract surgery. Many factors influence postoperative spherical aberration. With small cataract incision surgery, the difference in surgically induced spherical aberration between the preoperative and postoperative state is not statistically significantly, so the remaining manipulability factor is IOLs spherical aberration. In theory, ocular spherical aberration can be reduced by IOLs with appropriate aspheric surfaces[10,11]. Although the mean corneal spherical aberration has been reported to be +0.27 µm[12] the standard deviation varies in many studies[12,13]. In our study we used three commercially available IOLs with negative spherical aberration of 0.27, 0.20 and 0.00, which limited our selection. The patients implanted with the Tecnis lens and the Akreos lens had post operative total spherical aberration close to the predicted value, whereas the patients implanted with the IQSN60WF lens did not. This may be explained by the wider age range of patients selected for IQ lens implantation and the negative spherical aberration of 0.20 µm maybe the mean of population in this age range matched. However, the postoperative visual acuity in all 3 groups were correlated to the post operative total spherical aberration. Mesopic contrast sensitivity was measured in some cases and the data were also well parallel with total spherical aberration. In our study, we used a Galilei machine to determine preoperative corneal spherical aberration and we used a Wave-Light machine to determine postoperative total ocular spherical aberration; differences in the alignment of the wavefront sensing device may have caused some errors in results.

## Potential conflicts of interest

None.

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## *การศึกษาหน้าคลื่นและ spherical aberration ก่อนและหลังการผ่าตัดใส่เลนส์แก้วตาเทียม ชนิด aspheric โดยใช้ค่า spherical aberration ของกระจกตา*

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***ภูมิหลัง***: *วิธีการผ่าตัดต้อกระจกและเลนส์แก้วตาเทียมมีการพัฒนาอย่างมาก การแก้ไขสายตาให้ปกติไม่เพียงพอต่อคุณภาพที่ดีของการมองเห็น (quality of vision) การแก้ไขการเบี่ยงเบนของแสงด้วยเลนส์เทียมชนิด aspheric จะช่วยแก้ spherical aberration ซึ่งโดยทั่วไปไม่มีการวัดค่านี้ก่อนผ่าตัดในผู้ป่วยแต่ละราย*
***วัตถุประสงค์***: *เพื่อศึกษาค่าการเบี่ยงเบนของแสงของลูกตาหลังผ่าตัดโดยใส่เลนส์แก้วตาเทียมที่มีค่า spherical aberration ที่เหมาะสมสำหรับผู้ป่วยแต่ละราย โดยใช้เครื่องมือ wavefront analysis ในการวิเคราะห์*
***วัสดุและวิธีการ***: *ผู้ป่วยที่เป็นต้อกระจกที่จะรับการผ่าตัดที่โรงพยาบาลราชวิถี 26 ราย วัดค่าเบี่ยงเบนของแสงบริเวณกระจกตาด้วยเครื่อง Gallilei เพื่อเลือกชนิดของเลนส์, กำลังขยาย และspherical aberrationให้เหมาะสม คำนวณค่าคาดการณ์ และตรวจวัดค่าเบี่ยงเบนของแสงทั้งหมดด้วยเครื่อง wavefront analysis ที่ 3 เดือนหลังการผ่าตัด*
***ผลการศึกษา***: *ผู้ป่วยทั้งหมด 26 คน แบ่ง 3 กลุ่มตามค่า spherical aberration ของกระจกตาเลือกใช้เลนส์ที่มีค่า spherical aberration -0.27, -0.20 และ 0 ไมครอนตามลำดับ พบว่า ค่าเบี่ยงเบนแสงหลังผ่าตัดเฉลี่ยในแต่ละกลุ่มคือ* $+0.023 \pm 0.01\ \mu m$, $+0.045 \pm 0.01\ \mu m$ *และ* $+0.018 \pm 0.01\ \mu m$ *ซึ่งน้อยกว่าค่าที่คาดการณ์ไว้อย่างมีนัยสำคัญ* $p < 0.05$
***สรุป*** : *การเลือกใส่เลนส์แก้วตาเทียมโดยใช้ข้อมูลของกระจกตาสามารถลดค่าเบี่ยงเบนของแสงในผู้ป่วยหลังผ่าตัดต้อกระจก*

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