Original Article

Evaluation of the Consistency of Total Spherical Aberration before and after Aspherical Intraocular Lens Implantation

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Abstract

Purpose: To analyze the consistency between preoperatively estimated and postoperatively measured total spherical aberration and to evaluate the feasibility of personalized selection of an aspherical intraocular lens (IOL) based on the corneal spherical aberration measured by the Scheimpflug photography system (Pentacam).

Methods: A total of 47 patients (82 eyes) with age-related cataract received a comprehensive ophthalmologic examination. Corneal spherical aberration was measured by using the Scheimpflug photography system. Patients with corneal spherical aberration ≤0.3 μm were implanted with a zero-spherical aberration advanced optics (AO) aspherical intraocular lens and those with corneal spherical aberration >0.3 μm received a Tecnis ZA9003 aspherical lens (-0.27 μm spherical aberration). Preoperative total remnant spherical aberration was estimated and actual total spherical aberration was measured 3 months postoperatively. The consistency between preoperative and postoperative spherical aberration was analyzed by *t*-test, correlation analysis, and Blant-Altman plots.

Results: The estimated and measured values of total spherical aberration were (0.189±0.151) μm and (0.141±0.131) μm, with a statistical difference (t=5.347, P<0.01). For 45 eyes implanted with AO lenses, preoperatively estimated and postoperatively measured total spherical aberration were (0.268±0.137) μm and (0.214±0.103) μm. For 37 eyes implanted with Tecnis ZA9003, preoperative estimate of total spherical aberration was (0.092±0.103) μm and postoperative measured value was (0.054±0.106) μm. Statistical significance was noted, as was a positive linear correlation between preoperative and postoperative values (γ=0.846, P<0.01). Bland-Altman analysis showed high consistency between the estimated and measured spherical aberration.

Conclusion: The estimated total spherical aberration measured preoperatively differed from the value measured postoperatively, but the two values showed good agreement. It is clinically feasible to conduct personalized selection of aspherical IOL based on Scheimpflug photography system (Pentacam) to measure corneal spherical aberration. (***Eye Science 2013; 28: 129-133***)

Keywords: wavefront aberration; intraocular lens; cataract extraction; consistency

Previous researches[1,2] reported that selective implantation of an aspherical intraocular lens (IOL) based on the corneal spherical aberration measured before surgery is able to minimize the patient's total spherical aberration to a value close to zero following the procedure, thereby yielding better visual function[3,4]. The equipment used to measure corneal spherical aberration includes corneal topography systems, the iTrace wavefront aberration analyzer, and the Pentacam HR anterior segment analyzer. In this study, we utilized the Pentacam analyzer to measure patients' corneal spherical aberration preoperatively and conducted aspherical IOP implantation according to each individual situation. The consistency between preoperative estimates and actual total spherical aberration measured postoperatively was statistically compared.

Materials and methods

Study subjects

Forty-seven patients with age-related cataract admitted to the Department of Ophthalmology at our hospital were enrolled in this study, including 20 males and 27 females, aged 51 to 84 years, (average 67±9 years). Inclusion criteria: patients with age-related cataract aged from 50 to 85 years; preoperative axial length: 22~26 mm; normal cognitive ability; full exposure of palpebral fissure; normal tear film; and those who can be followed up over time. Exclusion criteria: those with a history of ocular

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trauma, fundus diseases, glaucoma, and corneal defects; those undergoing corneal refractive surgery; those with keratoconus or dry eyes; those with exclusion systemic connective tissue diseases and severe autoimmune diseases, such as systemic lupus erythematosus and rheumatoid arthritis, etc. Postoperative complications, such as IOP elevation and endophthalmitis, *etc.* were observed.

Clinical observations

1.Slit-lamp microscopy was conducted preoperatively and at 1 d, 1 week, and 3 months postoperatively to evaluate the severity of corneal edema, wound healing, and anterior chamber reaction. 2. The Pentacam HR anterior segment analyzer (Oculus, Germany) was used to measure corneal spherical aberration before and 3 months after surgery. No surface anesthesia was required for non-contact examinations. The examinees sat and gazed at the monochromatic slit blue light source at the center of rotating axis. The examiners utilized the controller to aim at and focus according to the instructions on the screen. Following the manufacturer's instructions, only measurements with an imaging quality of "OK" displayed on the screen were included. The diameter of corneal spherical aberration measurement was set at 6 mm. All procedures were completed by one single examiner. Three test results with good reproducibility and intact tear film (within 10 s) were obtained and averaged. 3. At postoperative 3 months, the degree of IOL tilt and decentration was measured with the Pentacam HR anterior segment analyzer. The subjects with a mean decentration ≤0.3 mm and an angle of tilt ≤5°were enrolled in this study. 4. An Allegretto Wave Analyzer was used to measure ocular wavefront aberrations and the corneal spherical aberration measured under 6 mm pupil diameter was analyzed with the installed software. Three best images were selected for each patient for parameter analysis and the average value was calculated.

IOL selection and objective of postoperative total spherical aberration

Aspherical IOL implantation was aimed to allow postoperative total spherical aberration to range from 0 to 0.3 μm and maintain the function of accommodation[5,6]. Methods: patients with corneal spherical aberration≤0.3 μm were implanted with Akreos AO lens with zero spherical aberration;those with corneal spherical aberration > 0.3 μm were implanted with Tecnis Z9003 lens with –0.27 μm spherical aberration;IOL refraction was calculated from the measurements by optical coherence interferometry. Eyes with 0 to -0.50 D refraction were chosen.

Estimates of postoperative total spherical aberration

Spherical aberration (SA) individual cornea was defined as the corneal spherical aberration under 6 mm diameter measured at 1 d preoperatively. Akreos AO_{lens} SA_{lens}=0 μm and Tecnis Z9003 lens SA_{lens}=–0.27 μm. The simplified formula[5], $SA_{eye} = SA_{individual\ cornea} + SA_{lens}$ was used to calculate postoperative total spherical aberration.

Surgical approach

All surgical procedures were conducted under ocular surface anesthesia. The pattern of transparent corneal incision was employed. The main incision was made at the 10 o'clock position by a 3.0 mm disposable keratome, and an assisted incision was created at the 2 o'clock position of corneal limbus using a corneal acupuncture needle at a 15° angle. After the injection of viscoelastic agents into the anterior chamber, continuous curvilinear capsulorhexis was performed with a diameter of approximately 5.5 to 6.5 mm, phacoemulsification was conducted after water detachment, the remnant cortex was removed, lens-in-the-bag implantation was performed, and the viscoelastic agents were cleaned. All surgeries were conducted successfully in all patients by one single experienced physician.

Statistical analysis

All data were analyzed using SPSS 17.0 statistical software. The data were expressed as mean±SD. Enumeration data were statistically analyzed by *t*-test. Correlation analysis and Blant-Altman plot were used to assess the consistency and degree of agreement between preoperative estimate and postoperative measurement of spherical aberration.

Results

General data

Among the 82 eyes, 45 were implanted with the Akreos Advanced Optic IOL (AO) and the other 37 with the TecnisZA9003 IOL. Regardless of the type

of IOL implant, all patients had a significant difference in corneal spherical aberration (6 mm diameter) before and after surgery ($P<0.05$), as shown in Table 1.

Differences between preoperative estimates and postoperative measurements of total spherical aberration

According to $SA_{eye}=SA_{individual\ cornea}+SA_{lens}$[7], the preoperative estimate of total spherical aberration is the sum of the preoperative corneal spherical aberration (6 mm in diameter) and the spherical aberration after the implantation with an aspherical IOL. The measurement value was the total spherical aberration measured by an aberrometer. The difference was the estimated value subtracted from the measurement value. The mean estimated total spherical aberration was (0.189±0.151) μm and the average measured val ue was (0.141±0.131) μm. The difference between the two values was statistically significant (t=5.347, P< 0.01). For patients implanted with the Akreos AO lens, the preoperative estimate significantly differed from the postoperative measurement as determined by a t-test (P<0.01). A statistical significance was equally noted in patients implanted with the Tecnis ZA9003 aspherical lens (P<0.05), as illustrated in Table 2.

Table 1 General data of cataract patients

IOL implants	Eyes (n)	Gender		Age ($x\pm s$)	Preoperative corneal spherical aberration (μm, $\bar{x}\pm s$)	Postoperative corneal spherical aberration (μm, $\bar{x}\pm s$)
		Male	Female			
AO	45	13	13	67±10.4	0.271±0.142	0.260±0.132
Tecnis	37	7	14	65±14.0	0.356±0.120	0.321±0.097

Table 2 Comparison of total spherical aberration before and 3 months after IOL implantation (μm, $\bar{x}\pm s$)

IOL implants	Eyes (n)	Preoperative corneal spherical aberration (μm, $\bar{x}\pm s$)	Postoperative corneal spherical aberration (μm, $\bar{x}\pm s$)	Difference between estimates and actual measurements (μm, $\bar{x}\pm s$)	t	P
AO	45	0.268±0.137	0.214±0.103	0.054±0.061	5.956	0.000
Tecnis	37	0.092±0.103	0.054±0.106	0.039±0.099	2.383	0.023

Note: P<0.05 indicates a statistical difference between the preoperative estimate and postoperative measurement of corneal spherical aberration.

Correlation between preoperatively estimated and postoperatively measured spherical aberration

Preoperative estimates and postoperative measurements of spherical aberration were positively correlated for all patients (γ=0.846, P<0.01), as shown in Figure 1.

Analysis of the degree of agreement between preoperatively estimated and postoperatively measured spherical aberration

A Bland-Altman plot indicated that 96.34% (79/82) of the points were distributed within 95% CI. A relatively high degree of agreement was found between preoperative and postoperative total spherical aberration in all patients.

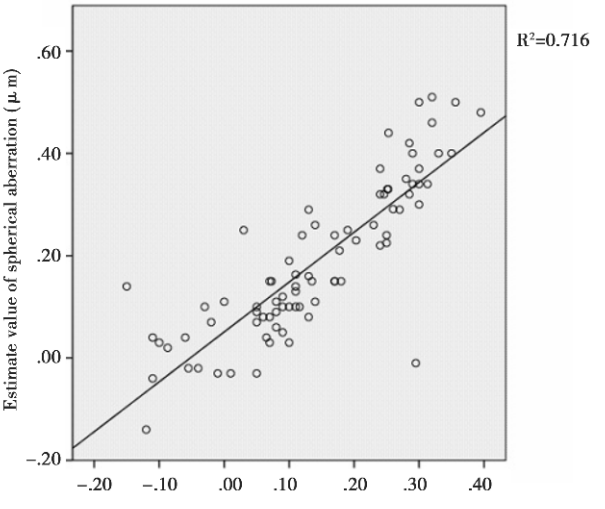

Figure 1 Correlation between estimated and measured spherical aberration

Discussion

Assessment of the degree of agreement

The paired t-test is used to assess the difference rather than the degree of agreement[8]. Consequently, the paired t-test has apparent limitations in evaluating the degree of agreement[9]. Bland-Altman plots are

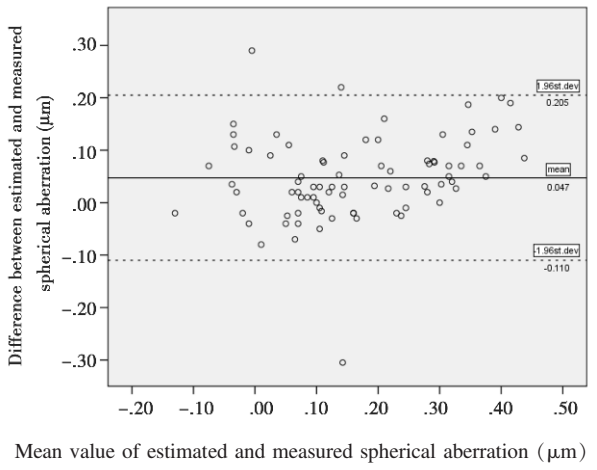

Figure 2 The solid line indicates the mean difference (d) between preoperative estimates and postoperative measurement. The dashed line represents the standard deviation of difference (SD=0.080) within 95% CI (d ±1.96× SD).

extensively used to evaluate the agreement among two different instruments or two measurements techniques by directly reflecting the outcomes[9,10]. In the present study, the Bland-Altman plot indicated a high degree of agreement between preoperative estimates and postoperative actual measurement of total spherical aberration, suggesting that the preoperative estimates of total spherical aberration can be used to evaluate patients′ postoperative total spherical aberration.

Factors related to the difference between preoperative estimates and postoperative actual measurements of total spherical aberration

A relatively high agreement was noted between preoperative estimates and postoperative measurement of total spherical aberration, and a t-test indicated a statistical significance between them. For patients implanted with the Akreos AO lens, the postoperative actual measurement was(0.054±0.061) μm less than the preoperative estimate. Patients with the Tecnis ZA9003 aspherical lens also had actual measurements lower than preoperative estimates, with a mean difference of (0.039±0.099)μm. These differences may arise for the following reasons. First, the changes in corneal spherical aberration before and after surgery cause a deviation in the estimated total spherical aberration. For all patients, postoperative corneal spherical aberration significantly decreased compared with the preoperative value (P <0.05), which may reduce total spherical aberration and lead to a difference between preoperative estimates and postoperative actual measurement. Second, SAeye= SAindividual cornea+ SAlens is a simplified formula[7] and consequently is not accurate. The calculated results may cause a deviation between the estimated value and actual measurement. Third, sampling and systematic errors equally lead to a difference between preoperative estimates and postoperative measurements. Fourth, a mydriasis test is required for aberrometer measurements. Although the pupil diameter exceeded 6 mm in all patients, the diameter of the light hole did not reach 6 mm during the measurement of total spherical aberration as a result of the diameter of capsulorhexis ranged from 5 mm to 6 mm. Hence, the original images of the ALLEGRETTO wavefront analyzer showed a loss of light spots and caused errors in measurement of total spherical aberration.

Clinical significance of the purpose of postoperative total spherical aberration and accuracy of the postoperative estimated value

A desirable measurement outcome is one where the aberration value approaches zero, which is theoretically applicable to human eye measurement. However, Levy Y et al[11]. measured aberration in 35 teenagers (70 eyes) with supernormal visual acuity, aged (24.3±7.7) years, and found a mean spherical aberration of (0.110±0.077) μm. No convincing evidence indicated that supernormal visual acuity was associated with low positive spherical aberration, but this study provided a useful clinical reference for spherical aberration in juveniles. Beiko GH[12] preoperatively measured the corneal spherical aberration of cataract patients under 6 mm pupil diameter. Patients with a corneal spherical aberration of > +0.33 μm were assigned to one group. The control group did not receive corneal spherical aberration measurement. Tecnis IOLs with a spherical aberration of-0.27 μm were implanted in patients in both groups. After surgery, patients implanted with aspherical IOLs had better visual contrast sensitivity than those in the control group. Postoperative remnant total spherical aberration approached 0.1 μm. Packer et al[1]. recommended setting the postoperative total spherical aber-

ration as zero when a personalized aspherical IOL was implanted. The findings in the present study indicate a relatively high degree of agreement between preoperative estimates and postoperative measurements of total spherical aberration and therefore provide a useful clinical reference for personalized implantation of aspherical IOLs. Preoperative measurement of corneal spherical aberration, combined with implantation of an aspherical IOL, can adjust the postoperative total spherical aberration to close to zero or approaching 0.1 μm. Wang[13] analyzed the total spherical aberration and evaluated the quality of retinal images in 94 patients(154 eyes) and proposed that optimal image quality can be obtained at a total spherical aberration of −0.10 to 0.00 μm, + 0.15 to 0.30 μm and −0.40 to −0.20 μm when the total defocus was 0.00D, −0.50D and +0.50D, respectively. Hence, an error of approximately 0.1 μm is acceptable when establishing postoperative total spherical aberration. In the present study, the mean differences of spherical aberration in both groups were (0.054±0.061) μm and (0.039±0.099) μm, which is clinically acceptable based on previous findings.

Disclosure statement

There is no conflict of interest to declare.

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