Correlation of Binocular Refractive Errors and Calculation of Intraocular Lens Power for the Second Eye

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Research article

Keywords: Bilateral sequential cataract surgery, IOL power calculation, Refractive errors, Second eye

Posted Date: April 20th, 2020

DOI: https://doi.org/10.21203/rs.2.24136/v2

Version of Record: A version of this preprint was published on June 18th, 2020. See the published version at https://doi.org/10.1186/s12886-020-01496-9.

Abstract

Background: How to reduce the refractive error has always been a tricky problem. The aim of this study was to verify the correlation between binocular refractive errors (RE) after sequential cataract surgery and explore the individualized calculation method of intraocular lens (IOL) for the second eye.

Methods: This is a prospective study. One hundred eighty-eight affected eyes of 94 age-related cataract patients with sequential cataract surgery from the Department of Ophthalmology, Tangdu Hospital, china, were recruited. Complete case data of 94 patients were included for correlation analysis of binocular RE. Thereafter, data of patients with RE values greater than 0.50 diopter (D) in the first eyes were extracted and divided randomly into two groups- Group A and B. As the adjustment group, in group A we modified the IOL power for the second eyes according to 50% of the RE of the first eye, and group B was the control group without modify. The mean absolute refractive error (MARE) values of the second eyes were evaluated one month after surgery.

Results: The correlation coefficient of binocular RE after sequential cataract surgery was 0.760 ($P <$ 0.001). After the IOL power of the second eyes were adjusted, the MARE of the second eyes was 0.57±0.41 D while MARE of the first eyes was 1.18±0.85 D, and the difference was statistically significant (P<0.001).

Conclusions: Binocular REs were correlated positively after sequential cataract surgery. The RE of the second eye can be reduced by adjusting the IOL power based on 50% of the postoperative RE of the first eye.

Background

Cataract is the main cause of blindness worldwide, accounting for 51% of blindness cases reported by the World Health Organization in 2010 [1]. Moreover, the percentage exceeds 60% in some Chinese elderly populations [2]. With the rapid development of cataract surgery techniques, the expectations of both patients and ophthalmologists have risen greatly. Currently, phacoemulsification and IOL implantation has moved from vision recovery into refractive surgery as an essential treatment for cataract.

Bilateral sequential cataract surgery has been widely applied in the pursuit of better visual quality. In early 2008, Norrby S. [3] concluded that preoperative estimation of the postoperative IOL position, postoperative refraction determination, and preoperative axial length (AL) measurement were the critical factors for RE (35%, 27%, and 17%, respectively). Refractive myopia shift or hyperopia shift after cataract surgery is mainly caused by the prediction error of postoperative anterior chamber depth (ACD), i.e. the effective lens position (ELP) [4, 5]. Refraction shifted more than 0.32 diopters (D) if the postoperative ACD varied 1mm [6]. It is therefore imperative to explore the IOL calculation method for the second eyes not only due to the patients' need for clear vision, but also because it can remedy problems of poor visual recovery caused by RE of the first eyes by calculating the IOL power using better test parameters. Whether this methodology can be widely used on patients in our country with different ALs is still unclear.

The objective of this study was to assess the RE of the second eye during bilateral sequential cataract surgery when the IOL power was modified according to 50% of the RE from the first eye when this error exceeded 0.50 D. In order to test whether this method can reduce RE in the second eye, we collected and tracked at least 1 month the data of patients to analyze the correlation between binocular REs after sequential cataract surgery which unified surgery and surgeon, and to explore the choice of operation time for the second eye. These results are meaningful and may provide a reference for more accurate clinical refractive cataract surgery.

Methods

Study design and patient eligibility

In a prospective study from July 2015 to January 2017, data from a total of 94 patients with bilateral sequential phacoemulsification cataract surgery referred to Tangdu Hospital affiliated to the Fourth Military Medical University in Xi'an, China, were recruited. Complete case data of 94 patients were included for correlation analysis of binocular RE. Thereafter, data of patients with RE values greater than 0.50 diopter (D) in the first eyes were extracted and divided randomly into two groups- Group A and B. As the adjustment group, in group A we modified the IOL power for the second eyes, and group B was the control group without modify. The target refractive outcomes of the second eyes were modified according to 50% of the error from the first eyes one month after surgery. That is, the predicted postoperative spherical equivalence (PPSE) of the second eyes was obtained by subtracting 50% of the RE of the first eyes from the PPSE of the first eyes. The actual postoperative spherical equivalence (APSE) in the second eyes one month after surgery was evaluated. All research and measurements followed the principles expressed in the Declaration of Helsinki, and the protocol was reviewed and approved by the Ethics Committee of Tangdu Hospital (TDLL 201506-05). Informed consent was obtained before the research from all patients. Inclusion criteria were patients who underwent bilateral sequential phacoemulsification combined with in-the-bag IOL implantation without any operative accident. The exclusion criteria included a history of diseases affecting refraction, such as ocular trauma, keratoconus, corneal pannus, pterygium, glaucoma, vitreous haemorrhage, laser therapy or intraocular surgery; a history of fundus diseases, such as retinal splitting, retinal detachment, or choroidal neovascularization; a history of high myopia, diabetes, and patients who have difficulties in follow-up.

Surgical procedure

All surgeries were conducted via the same micro-incision phaco machine (Bausch&lomb, USA) by the same senior surgeon (Hong Yan). After topical anesthesia with 1.0% tetracaine eye drops (Alcon, USA), a 2.5 mm clear corneal incision was made at the steep meridian. Then a medical sodium hyaluronate gel (Bausch&lomb, USA) was used to protect corneal endothelium and maintain the anterior chamber space. A centred circular continuous capsulorhexis (CCC) with a diameter of 5.0 mm was conducted using capsulorhexis forceps. Thereafter, nucleus was rotated freely by thorough hydrodissection, after which nuclear fracturing and removing was performed. After phacoemulsification, a posterior chamber IOL was implanted into the capsule, which was chosen depending on the different requirements of patients. Last, patients were treated with levofloxacin eye drops 0.5% (Cravit, Santen, Japan) and prednisolone acetate ophthalmic suspension 1% (Pred Forte, Allergan, Ireland) 4 times per day for 2 weeks after surgery to safeguard against complications.

Data collection

A questionnaire that contained data about age, sex, AL, PPSE and APSE was completed for each patient based on inquiry and examination. The AL was measured with IOL Master 500 (Carl Zeiss, Germany) for formula optimization, which was repeated five times for each patient. IOL power was calculated for a PPSE of around -0.50 D by using the Hoffer Q (AL<22.0mm), SRK/T (22.0mm≤AL≤30.0mm), or Haigis (AL>30.0mm) formulae [7]. The RE calculated as the arithmetic deviation of the APSE and PPSE. The absolute RE in the second eyes one month after surgery were evaluated.

Statistical Analysis

Data analysis was performed using SPSS version19.0 (IBM Corporation, USA). The Pearson correlation coefficient was calculated to analyze the relationship between the quantitative data that satisfied a bivariate normal distribution. Quantitative data were expressed as means with standard deviations, and the results were compared using Student's *t*-test. A coefficient r of less than 0.30 is considered to be uncorrelated, r from 0.30 to 0.49 means a low correlation, from 0.50 to 0.79 a moderate correlation, and more than 0.80 a high correlation. A *P*-value of less than 0.05 was considered statistically significant.

Results

Complete case data of 94 patients, encompassing 43 males and 51 females with an average age of 66.8±11.4 years, were included for correlation analysis of binocular refraction errors. Thereafter, data of 34 patients (68 affected eyes) were extracted as adjustment group. This group encompassed 14 males and 20 females with a mean age of 65.7±12.3 years. Otherwise, data of 36 patients (72 affected eyes) without modify of the IOL power for the second eyes as the control group (Tab. 1).

Table 1 Descriptive statistics of binocular refractive errors

		Complete cases	Adjustment group	Control group
N (patients)		94	34	36
Males/Females		43/51	14/20	18/18
N (eyes)		188	68	72
Age (years)		66.8±11.4	65.7±12.3	66.1±11.4
RE (D)	1st eye	0.19±0.88	0.26±1.24	0.25±0.96
	2nd eye	0.33±0.84	0.14±0.70	0.19±0.87
MARE (D)	1st eye	0.57±0.69	1.18±0.85	1.08±0.54
	2nd eye	0.68±0.59	0.57±0.41	1.01±0.47
AL (mm)	1st eye	24.08±2.38	24.61±3.43	24.09±2.39
	2nd eye	23.97±2.15	24.46±3.03	24.12±2.10

Binocular REs after sequential cataract surgery were correlated (r=0.760, *P*< 0.001) (Fig. 1). Binocular ALs were highly correlated (r=0.970, *P*<0.001) (Fig. 2). In terms of exploring individualized calculations of IOL for the second eye, the data were assigned to two groups (A and B), either modified or not. In group A (adjustment group), the MARE values of the bilateral eyes were 1.18±0.85 and 0.57±0.41 D, respectively, and the difference was statistically significant (t=3.748, P<0.001). The MARE of the modified second eyes was significantly lower than that of the uncorrected first ones. In group B (control group), the MARE values were 1.08±0.54 and 1.01±0.47 D, respectively. The difference was not statistically significant (t=0.578, P>0.05) (Fig. 3). The binocular ALs are highly correlated when the IOL power was adjusted for the second eye (r=0.984, P<0.001) (Fig. 4).

Discussion

With the increasing incidence of cataracts, the pressure is rising to achieve better vision in patients who requiring bilateral cataract surgery. Multiple studies [8-12] reported on the positive correlation of binocular REs after sequential cataract surgery and effectiveness of adjusting the target RE in the second eyes by correcting 50% of the errors from the first eyes for improving visual quality. Scholars [10, 13] speculated that this finding may be attributed to the revision of predictive errors from post-operative ACD. However, in China there are few reports focused on this. Our previous observation verified that modifying the IOL power in the second eyes based on 50% of RE from the first eyes can reduce the error of the second eyes [14]. However, the fluctuation of refraction was only observed for 1 day, it is difficult to evaluate stability, and that is our motivation for this work.

In this study, 94 RE data of patients after bilateral cataract surgery with stable refraction more than 1 month after surgery were selected first. It was found that the RE values of both eyes were closely related (r=0.760, P<0.001). It means that the postoperative refractive shift of the second eye can refer to the corresponding first eye. In 2010, Landers and Goggin [11] found a statistically significant correlation between RE values in both eyes (P=0.003). Covert et al. [12] confirmed that there was a positive correlation between binocular RE values after sequential cataract surgery and the refractive status of the second eyes were improved successfully by adjusting the IOL power according to 50% of the RE of the first eye. In 2011, Olsen [10] showed that the correlation coefficients of the binocular RE for the SRK, SRK/T and Olsen formulas were 0.56, 0.38 and 0.27, respectively (P<0.001). Aristodemou et al. [15] further verified Covert's conclusion after comparing the adjustment coefficient from 10% to 90%. At the same time, the influence of measurement errors was excluded and they insisted that the RE was mainly originated from post-operative effective lens position (ELP).

But our research differs from the above studies which employed multiple surgeons and IOL power formulas. This study used optimized formula based on AL, excluding the effects of ocular surface and intraocular diseases, performed by the same surgeon (Hong Yan). Therefore, the factors affecting the RE value can be reduced, and a high positive correlation between the binocular RE values is demonstrated. In addition, this study showed that there is a high positive correlation between the AL values of both eyes (r=0.970, P<0.001), which was consistent with Covert's result (r=0.979) [12].

Second, our study selected the RE data of patients with large RE (greater than 0.5 D) from the original data for second eye correction. We compared the absolute RE values of bilateral eyes between adjusted and the control groups, indicating that the MARE of the adjusted second eyes is significantly lower than that of the corresponding eyes, amounting to approximately half of the MARE of the first eyes. This result was consistent with an earlier study [16]. While the difference between MARE values of both eyes without adjustment was not statistically significant. Fraser et al. [17] proposed that contrast sensitivity and stereopsis rather than vision are the key factors affecting the improvement of vision-related quality of life after cataract surgery. Jivrajka et al. [8] also reported that the substitution of half of the error from the first eyes into the calculation of IOL power of the respective second eyes can improve their outcomes. However, the difference between binocular diopters should be considered carefully to avoid visual discomfort due to monovision or anisometropia [18]. Our research showed that the binocular ALs are highly correlated when the IOL power was adjusted for the second eye, which may be a main reason for the useful adjustment.

Furthermore, there is an essential question about how to assure an adequate time interval between bilateral cataract surgeries, i.e. how to choose the operation time for the second eye. The preceding debates [19-21] do not advocate simultaneous bilateral cataract surgery, not only due to ethical constraints, but it is more important to take into account the severe consequences of post-operative endophthalmitis. Our previous study on bilateral sequential cataract surgery showed the aqueous humor of the second eye had a higher level of TGF-β_2, but not of proinflammatory cytokines or chemokines compared with those in the first eye, implying a protective mechanism preventing the sympathetic immune reaction induced by the first-eye cataract surgery [22]. However, immediate sequential bilateral cataract surgery is becoming popular in recent years [23, 24]. With the increasing expectation for post-operative visual quality, the focus of the operation is not only safety, but also the best possible visual recovery. Many studies [13, 25, 26] suggested that refractive status was stable one month after operation. Thus, bilateral surgery should be performed over 4 weeks, rather than simultaneously or in a short time span [27].

Last but not the least, multiple studies reported that the IOL power in the second eyes can be calculated according to the ACD of the first eyes. Muthappan et al. [28] studied the effect of post-operative ACD of lateral eyes on the refractive outcome of the second eyes and it indicated that the refractive outcome can be improved when the RE is relatively large in the first eyes. Our follow-up study will focus on the improvement of refractive outcome in the second eyes according to the post-operative ACD in the respective first eyes. If this hypothesis can be verified, it will provide a scientific basis for clinical application and promotion.

Conclusions

In summary, we are the first to verify a positive correlation between binocular REs after sequential cataract surgery in China. Results from this work showed that RE of the second eye can be reduced by adjusting the IOL power based on 50% of the postoperative RE value of the first eye when it is larger than

0.50 D. Besides, a partial adjustment of ACD may be beneficial to predicting refractive outcomes. Further studies are necessary to identify a widely scientific calculation for clinical guidance of bilateral sequential cataract surgery.

List Of Abbreviations

ACD: Anterior chamber depth; APSE: Actual post-operative spherical equivalence; ELP: Effective lens position; MARE: Mean absolute refractive error; PPSE: Predicted post-operative spherical equivalence; IOL: Intraocular lens; RE: Refractive errors

Declarations

Ethics approval and consent to participate

The study protocol was reviewed and approved by the Ethics Committee of Ethics Committee of Tangdu Hospital of the Fourth Military Medical University, Xi'an, China (TDLL 201506–05). Written informed consent was obtained from all participants prior to study enrolment.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that there is no competing interest regarding the publication of this article.

Funding

Funding was provided by the National Nature Science Foundation of China (No. 81873674) and Xi'an Fourth Hospital Research Incubation Fund (LH-6). The funding body had no role in study design, data analysis, data interpretation, or manuscript writing.

Authors' contributions

PC and YY collected and analysed the data of patients. PC wrote the manuscript. JZ and WY advised on the data analysis and edited the manuscript. HY supervised the project and edited the manuscript. All authors have read and approved the final manuscript.

Acknowledgements

This research was supported by the Tangdu Hospital Grant for Clinical Innovation.

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Figures

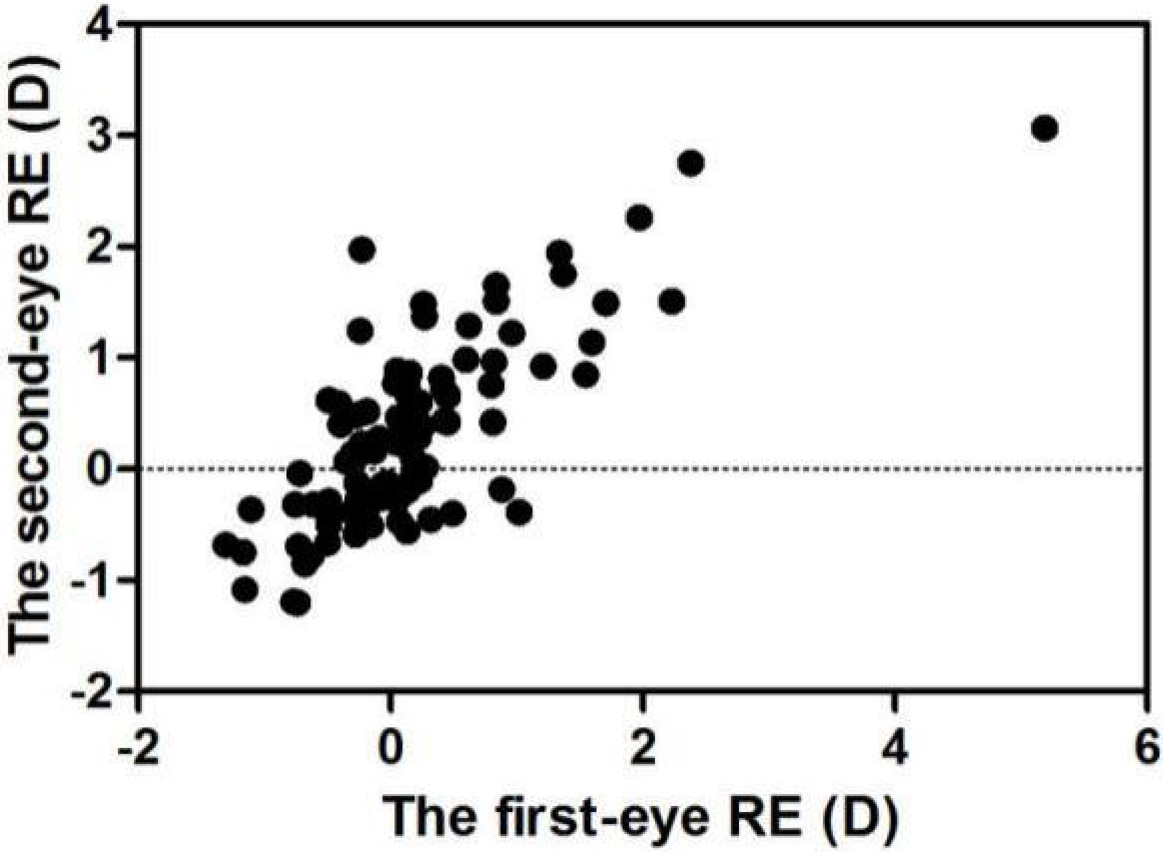

Figure 1

Scatter plot of the relationship between binocular RE values (n94, P<0.001).

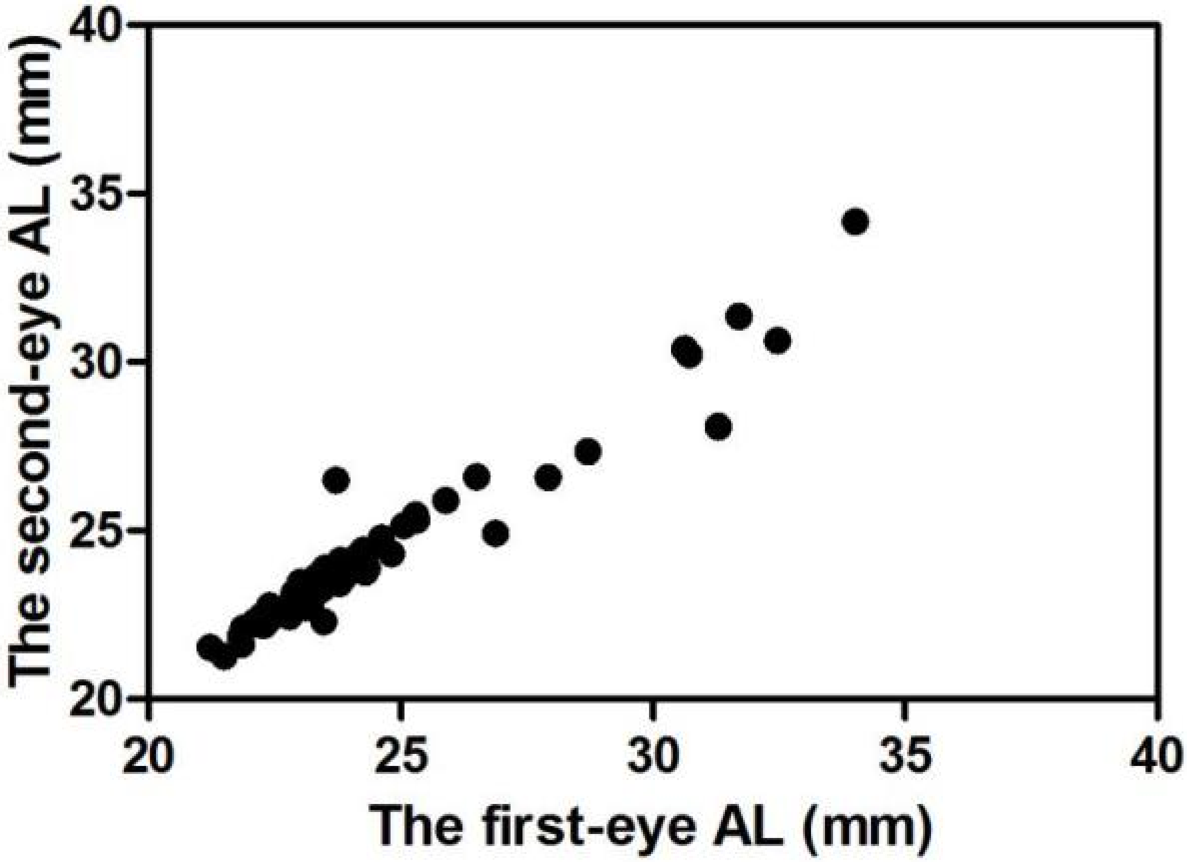

Figure 2

Scatter plot of the relationship between binocular axial lengths (n=94, P<0.001).

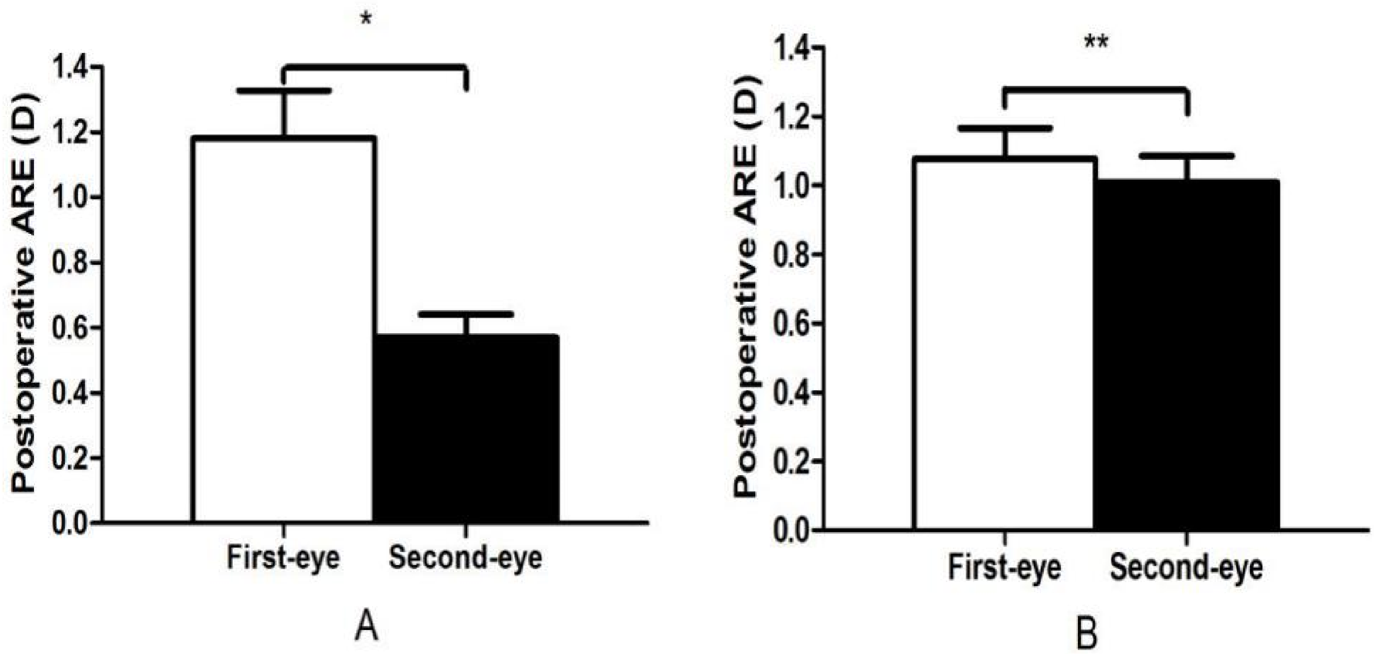

Figure 3

Comparison of Absolute RE values of bilateral eyes between (Group A) adjusted and (Group B) unadjusted second eyes (*n＝34, *P<0.001; **n=36,**P>0.05).

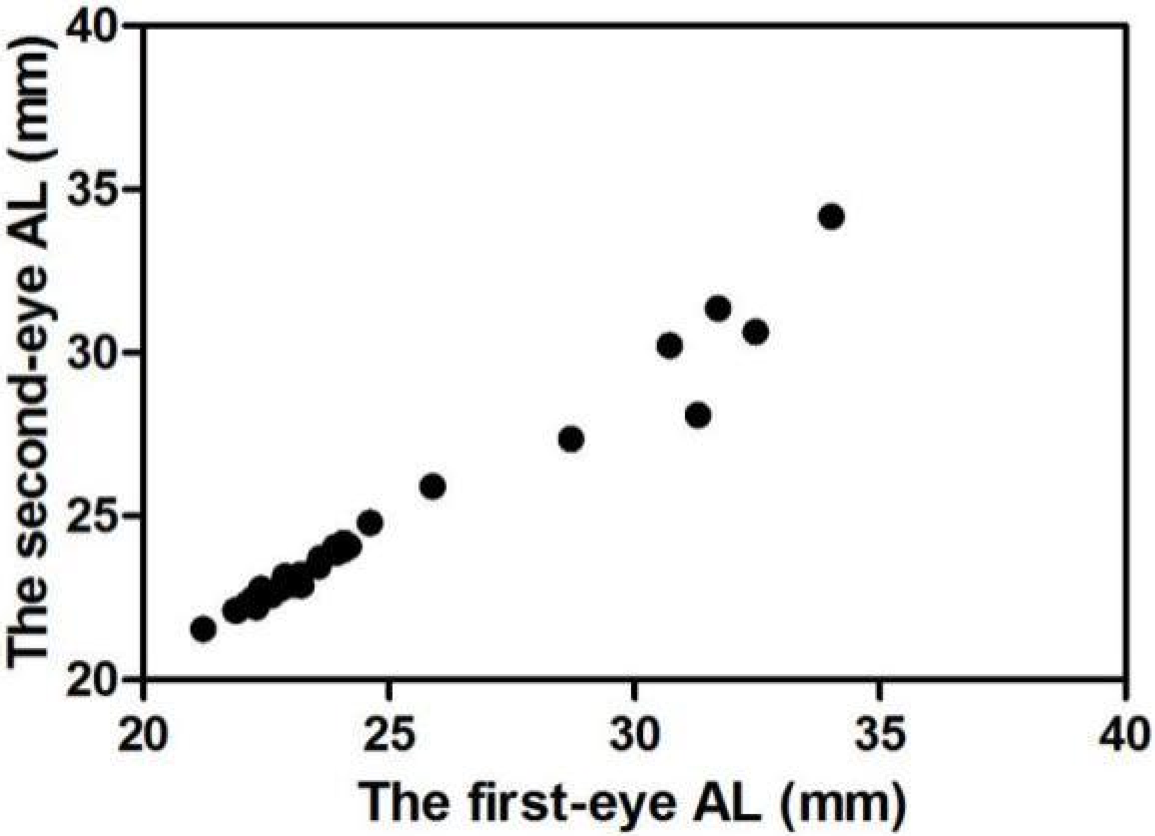

Figure 4

Scatter plot of the relationship between binocular ALs after adjustment (n34, P<0.001).