Lens Position Parameters as Predictors of Intraocular Pressure Reduction After Cataract Surgery in Nonglaucomatous Patients With Open Angles

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PURPOSE. To evaluate the relationship between lens position parameters and intraocular pressure (IOP) reduction after cataract surgery in nonglaucomatous eyes with open angles.

METHODS. The main outcome of the prospective study was percentage of IOP change, which was calculated using the preoperative IOP and the IOP 4 months after cataract surgery in nonglaucomatous eyes with open angles. Lens position (LP), defined as anterior chamber depth (ACD) + 1/2 lens thickness (LT), was assessed preoperatively using parameters from optical biometry. Preoperative IOP, central corneal thickness, ACD, LT, axial length (AXL), and the ratio of preoperative IOP to ACD (PD ratio) were also evaluated as potential predictors of percentage of IOP change. The predictive values of the parameters we found to be associated with the primary outcome were compared.

RESULTS. Four months after cataract surgery, the average IOP reduction was 2.03 ± 2.42 mm Hg, a 12.74% reduction from the preoperative mean of 14.5 ± 3.05 mm Hg. Lens position was correlated with IOP reduction percentage after adjusting for confounders ($P = 0.002$). Higher preoperative IOP, shallower ACD, shorter AXL, and thicker LT were significantly associated with percentage of IOP decrease. Although not statistically significant, LP was a better predictor of percentage of IOP change compared to PD ratio, preoperative IOP, and ACD.

CONCLUSIONS. The percentage of IOP reduction after cataract surgery in nonglaucomatous eyes with open angles is greater in more anteriorly positioned lenses. Lens position, which is convenient to compute by basic ocular biometric data, is an accessible predictor with considerable predictive value for postoperative IOP change.

Keywords: intraocular pressure reduction, cataract surgery, predictors, lens position parameters, open angles

Phacoemulsification cataract surgery impacts many facets of glaucoma care. Numerous studies have demonstrated sustained intraocular pressure (IOP) reduction after routine cataract extraction in eyes with and without ocular hypertension or glaucomatous disease.^{1–9} There are greater IOP reductions after cataract extraction among patients with secondary and narrow-angle glaucoma compared to those with open-angle disease.^{10,11} In eyes with narrow-angle glaucoma, the level of IOP lowering after cataract surgery is proportional to the resultant widening of the angle.^{7,12,13} Thus, patients with the narrowest angles preoperatively may benefit the most from cataract extraction as a single procedure.¹⁴ This may be due to greater changes in the anterior segment configuration after cataract surgery in eyes with shallower angles. An IOP reduction effect is also found in patients with open angles, although the mechanism remains poorly understood and the magnitude of this effect is highly variable and unpredictable. Cataract surgery is not currently part of the open-angle glaucoma treatment paradigm, largely due to difficulty in

determining which open-angle patients will benefit from cataract surgery.

There has been a substantial effort to find preoperative factors that can predict the level of IOP reduction after cataract surgery. Studies have demonstrated that in patients with open angles at baseline, the level of IOP lowering is proportional to the preoperative IOP.^{6,9,12} Shallower anterior chamber depth (ACD) has also been found to be a predictor of postoperative IOP reduction.^{7,12,13} In 2005, Issa et al.¹² described a novel index for predicting the degree of IOP reduction based on the ratio of the preoperative IOP and ACD, which they termed the pressure-to-depth ratio (PD ratio). With the advent of anterior segment optical coherence tomography (AS-OCT), angle parameters such as angle opening distance (AOD) have also been reported to be associated with IOP reduction after phacoemulsification.^{8,15–17}

Few studies have examined the relationship between lens parameters and the change in IOP after cataract surgery. The crystalline lens plays a pivotal role in narrowing the angle by

pushing the peripheral iris anteriorly and causing pupillary block. While many of the anatomical factors such as axial length (AXL) and anterior chamber width cannot be changed, the lens remains one of the few modifiable factors that can secondarily influence the anterior chamber and thus the IOP. Yang et al.¹⁶ demonstrated that lens thickness (LT) is associated with a reduction in IOP after cataract surgery in normal eyes.¹⁶ A number of new lens position parameters assessed by AS-OCT have also been evaluated as potential predictors of IOP reduction. For example, lens vault (LV), defined as the perpendicular distance between the line joining the two scleral spurs and the anterior pole of the lens,¹⁸ has been shown to be a preoperative predictor in angle widening and IOP reduction after cataract surgery in normal eyes.¹⁷ In addition, the amount of IOP reduction is related to the anterior vault, which is defined as the maximum perpendicular distance between the posterior corneal surface to the horizontal line connecting the two scleral spurs. However, these parameters rely on AS-OCT scanning, which is not universally available to physicians, so more accessible and convenient predictors of postoperative IOP reduction are needed.

In 1970, Lowe¹⁹ introduced lens position (LP)—defined as $LP = ACD + 1/2 LT$ —and relative lens position (RLP)—defined as $RLP = LP/AXL$ —as new characteristics of angle closure glaucoma.¹⁹ Although subsequent studies did not reproduce this finding,^{20–22} lens position and RLP could potentially be used to understand how the lens affects IOP in open angles. Lens position and RLP are similar ocular biometric parameters to LV and anterior vault in the sense that they are dependent on how anteriorly positioned the lens is relative to other structures in the anterior chamber. Lens position and RLP are more easily computed by optical ocular biometry, which is routine scanning for intraocular lens (IOL) power calculations prior to cataract surgery. Therefore, if these parameters show some significant association with IOP reduction after cataract surgery, they would be more accessible predictors.

The purpose of the present study was to evaluate LP, RLP, and other predictors of IOP reduction after cataract surgery in nonglaucomatous eyes with open angles.

METHODS

Study Design

In this prospective study, patients were consecutively recruited from the glaucoma clinics of the University of California-San Francisco (UCSF), from June 1, 2012 to December 31, 2014. Approval from the UCSF Committee on Human Research was obtained, and this study followed the tenets of the Declaration of Helsinki. Patients were enrolled if they met the inclusion and exclusion criteria, and written informed consent was obtained from all patients prior to enrollment.

Inclusion criteria included (1) age ≥ 18 years; (2) visually significant cataracts with best-corrected visual acuity (BCVA) equal to or worse than 20/40; (3) standard cataract surgeries without adjunctive procedure (e.g., pupil stretching or iris hooks). Exclusion criteria included (1) major intraoperative or postoperative complications from cataract surgery; (2) glaucomatous optic neuropathy determined by optic disc cupping or glaucomatous visual field loss; (3) preoperative IOP ever measured >23 mm Hg; (4) use of any glaucoma medications; (5) occludable angles (Shaffer classification with a grade of 0 or 1 in at least two quadrants); (6) peripheral anterior synechiae (PAS); (7) uveitis, severe retinal diseases, or congenital anomalies; (8) history of ocular trauma or any intraocular surgery; or (9) pseudoexfoliation. Eyes that had undergone laser peripheral iridotomy (LPI) were not excluded.

Data Collection

Demographic information, including age and sex, was obtained via chart review. In the preoperative assessment, which occurred 1 to 3 weeks before surgery, ocular biometry, BCVA testing, IOP measurement, complete slit-lamp and fundus examination, and gonioscopy examination were performed. Intraocular pressure was measured using Goldmann applanation tonometry by a single trained ophthalmologist (SCL), and all the measurements were done during afternoon hours (2–5 PM). Gonioscopy was performed using a Zeiss-style four-mirror goniolens (model G-4; Volk Optical, Mentor, OH, USA) in low light conditions and primary position by the same ophthalmologist (SCL). The angle was graded using the Shaffer grades, and the eye was interpreted as having an occludable angle if there was a grade of 0 or 1 in at least two quadrants; otherwise, the eye was interpreted as open angle. Indentation gonioscopy was performed to rule out PAS. For ocular biometry, the LENSTAR LS 900 (Haag-Streit, Inc., Koeniz, Switzerland) was used to measure AXL, ACD, LT, and central corneal thickness (CCT). Five readings were taken for each eye. After omitting the highest and lowest values, the mean of the other three readings was used for analysis.

Surgical Technique

Surgery was performed by a single surgeon (SCL) in all subjects under topical or sub-Tenon's anesthesia. Surgery consisted of routine phacoemulsification via a 3.2-mm temporal clear corneal incision, with in-the-bag one-piece acrylic intraocular lens (AcrySof SA60AT or AcrySof IQ SA60WF; Alcon Laboratories, Inc., Fort Worth, TX, USA) implantation.

Postoperatively, patients received topical antibiotics four times a day for 1 week, as well as 0.5% ketorolac tromethamine and topical 1% prednisolone acetate, which were tapered gradually over 1 month.

Postoperative follow-up time points included 1 day, 10 days, 1 month, and 4 months after surgery. Best-corrected visual acuity testing, IOP measurement, and complete slit-lamp and fundus examination were performed at each of these time points.

Statistical Analysis

Statistical analysis was performed using SPSS software, version 21 (SPSS, Inc., Chicago, IL, USA). Because 20 patients had both eyes included in the study, linear mixed-effects regression models were used to assess the correlation between IOP change and baseline parameters. Multivariate models were then created to adjust for potential confounders, which included all variables with $P < 0.10$ in the univariate regression model.

Linear mixed-effects regression models were used to evaluate LP and RLP as predictors for percent IOP change after cataract surgery. Multivariate models were created to adjust for potential confounders. Sex, age, preoperative IOP, LPI, and AXL were adjusted for when evaluating LP. Sex, age, preoperative IOP, and LPI were adjusted for when evaluating RLP.

Due to the relatively small sample size, and to minimize bias using mixed-effects models, we also selected 75 eyes from the 75 patients to reevaluate the results using general linear regression models. We used one eye for each patient for this part of the analysis. When both eyes were eligible, the right eye was selected.

The statistical test we used to compare different predictors does not account for mixed effects. Therefore, we used the selected 75 eyes to compare preoperative IOP, ACD, PD ratio,

TABLE 1. Analyses for Baseline Predictors of Percent IOP Change After Phacoemulsification Cataract Surgery

Parameters	Mixed-Effects Linear Regression, 95 Eyes				Multiple Linear Regression, 75 Eyes			
	Univariate		Multivariate		Univariate		Multivariate	
	<i>B</i> ± SE	<i>P</i> Value	<i>B</i> ± SE	<i>P</i> Value	<i>B</i> ± SE	<i>P</i> Value	<i>B</i> ± SE	<i>P</i> Value
Sex	−0.070 ± 0.336	0.041	0.022 ± 0.027	0.424	0.068 ± 0.036	0.059	−0.029 ± 0.028	0.307
Age	−0.003 ± 0.002	0.178	0.007 ± 0.001	0.625	−0.002 ± 0.002	0.292	0.000 ± 0.002	0.937
Pre-op IOP	−0.023 ± 0.005	<0.001	−0.013 ± 0.004	0.002	−0.021 ± 0.005	<0.001	−0.013 ± 0.004	0.006
AXL	0.056 ± 0.010	<0.001	0.024 ± 0.011	0.028	0.057 ± 0.011	<0.001	0.023 ± 0.012	0.052
ACD	0.212 ± 0.029	<0.001	0.146 ± 0.052	0.007	0.217 ± 0.032	<0.001	0.693 ± 0.392	0.003
CCT	1.179 ± 0.448	0.010	0.647 ± 0.355	0.073	1.237 ± 0.484	0.010	0.179 ± 0.059	0.082
LT	−0.075 ± 0.031	0.020	−0.073 ± 0.036	0.043	−0.078 ± 0.035	0.029	−0.091 ± 0.038	0.020
LPI	0.154 ± 0.030	<0.001	0.057 ± 0.031	0.068	−0.169 ± 0.035	<0.001	−0.056 ± 0.035	0.119

Pre-op IOP, preoperative IOP; *B*, regression coefficient.

and LP as predictors for percent IOP change. Linear regression analysis was performed to assess the association between each parameter and percent IOP change. Multivariate models were created to adjust for potential confounders, including sex, age, LPI, and AXL. We used the Fisher's *z* transformation test to evaluate the difference between regression coefficients in multivariate models.

The majority of prior studies on this topic used absolute IOP change as their main outcome.^{7–12,13,16,17} In order to compare our results with these previous studies, we also evaluated absolute IOP change as an outcome. In addition, we compared the absolute IOP change and percent IOP change as outcomes for predictors of interest. For all analyses, a *P* value of less than 0.05 was considered statistically significant.

RESULTS

This study included 95 eyes of 75 consecutive patients who underwent phacoemulsification cataract surgery. The mean age was 75.32 ± 8.06 years. Thirty patients were male and 45 were female. Thirty-one eyes had undergone LPI. Preoperative IOP ranged from 8 to 23 mm Hg, and the average was 14.5 ± 3.05 mm Hg. The average IOP at 4 months (mean 122.25 days) after surgery was 12.47 ± 2.75 mm Hg, resulting in a 2.03 ± 2.42 mm Hg (12.74%) reduction compared to baseline IOP.

Table 1 shows the association between percent IOP change and baseline ocular parameters using linear mixed-effects regression models (95 eyes) and general multiple linear regression models (75 eyes). In the univariate mixed-effects models, sex, preoperative IOP, AXL, ACD, CCT, LT, and LPI were found to be significant predictors of percent IOP change. After adjusting for confounders, preoperative IOP (regression coefficient, *B* = −0.013, *P* = 0.002), AXL (*B* = 0.024, *P* = 0.028), ACD (*B* = 0.146, *P* = 0.007), and LT (*B* = 0.073, *P* = 0.043) were associated with percent IOP change after cataract surgery. Similar associations were found using general multiple linear regression models.

Table 2 shows the association between LP, RLP, and percent IOP change using linear mixed-effects regression models (95 eyes) and general multiple linear regression models (75 eyes). In the mixed-effect models, LP was associated with percent IOP change after adjusting for sex, age, preoperative IOP, AXL, and LPI (*B* = 0.165, *P* = 0.002). The RLP was not associated with percent IOP change after adjusting for sex, age, preoperative IOP, and LPI (*B* = 0.231, *P* = 0.849). Similar associations were found using general multiple linear regression models.

Table 3 shows the association between the predictors (LP, preoperative IOP, ACD, PD ratio) and percent IOP change after cataract surgery. In the univariate analysis (Figs. 1–4), all the predictors were associated (*P* < 0.001). According to the *r*² value, LP (*r*² = 45.5%) was the best predictor of percentage change in IOP, followed by PD ratio, ACD, and preoperative IOP (*r*² = 39.0%, 38.3%, and 18.5%, respectively). After adjusting for age, sex, LPI, and AXL, LP was still the parameter with the best predictive value for the outcome (standardized coefficient, *β* = 0.457, *P* < 0.001, *r* = 0.717, *r*² = 51.4%), followed by PD ratio (*β* = −0.400, *P* = 0.001, *r* = 0.703, *r*² = 49.4%), preoperative IOP (*β* = −0.269, *P* = 0.006, *r* = 0.682, *r*² = 46.5%), and ACD (*β* = 0.335, *P* = 0.018, *r* = 0.670, *r*² = 45.0%). However, using Fisher's *z* transformation test, the result showed that there was no statistically significant difference between the coefficients of LP and other parameters in such a limited sample size (preoperative IOP, *z* = 1.48, *P* = 0.0694; ACD, *z* = 0.98, *P* = 0.1635; PD ratio, *z* = 0.47, *P* = 0.3192).

Table 4 compares absolute IOP change and percent IOP change as outcomes. When using absolute IOP change as the primary outcome, PD ratio was a more predictive parameter (Pearson's correlation, *r* = −0.727, *r*² = 52.9%, *P* < 0.001) than LP (*r* = 0.691, *r*² = 47.8%, *P* < 0.001). When percent IOP change was used as the outcome, LP was relatively better as a predictor (*r* = 0.674, *r*² = 45.4%, *P* < 0.001) than PD ratio (*r* = −0.625, *r*² = 39.0%, *P* < 0.001).

TABLE 2. Analyses for Lens Position Parameters as Predictors of Percentage Change in IOP After Cataract Surgery

Lens Position Parameters	Adjusted Factors	Mixed-Effects Linear Regression, 95 Eyes		Multiple Linear Regression, 75 Eyes	
		<i>B</i> ± SE	<i>P</i> Value	<i>B</i> ± SE	<i>P</i> Value
LP	Sex, age, pre-op IOP, LPI, AXL	0.165 ± 0.051	0.002	0.206 ± 0.056	<0.001
RLP	Sex, age, pre-op IOP, LPI	0.231 ± 1.210	0.849	0.532 ± 1.328	0.690

Pre-op IOP, preoperative IOP; *B*, regression coefficient.

TABLE 3. Predictability Comparison Between “Significant” Predictors of Percentage Change of IOP After Cataract Surgery

Predictors	Univariate			Multivariate, Adjusted for Sex, Age, LPI, AXL		
	β	P Value	r^2	β	P Value	r^2
Pre-op IOP	-0.430	<0.001	18.5%	-0.269	0.006	46.5%
ACD	0.619	<0.001	38.3%	0.335	0.018	45.0%
PD ratio	-0.625	<0.001	39.0%	-0.400	0.001	49.4%
LP	0.674	<0.001	45.5%	0.457	<0.001	51.4%

Pre-op IOP, preoperative IOP; β , standardized regression coefficient.

DISCUSSION

In this prospective study, we observed that phacoemulsification cataract surgery with IOL implantation lowers IOP by an average of 2.03 mm Hg, resulting in a 12.74% decrease from preoperative IOP in nonglaucomatous patients with open angles. Lens position, computed by ACD and LT, is a parameter with predictive value for the amount of IOP reduction among nonglaucomatous patients with open angles.

There is strong evidence supporting the idea that IOP is reduced following phacoemulsification in patients with or without glaucomatous disease. The effects of cataract extraction on nonglaucomatous eyes were first described in 1996, when Matsumura et al.²³ prospectively demonstrated an average IOP reduction of 1.5 mm Hg at 3 years. In the years following, numerous other studies consistently showed approximately 2 mm Hg of reduction in IOP in patients undergoing routine extracapsular cataract extraction or clear cornea cataract extraction.^{24–26} Patient-specific factors, including angle anatomy and lens factors, are likely important predictors of the expected postoperative reduction. However, elucidation of such factors has been suboptimal to date, and little is known about the magnitude and duration of the IOP reduction.

One fairly consistent finding is that patients with higher preoperative IOP have greater IOP reductions postoperatively.^{6,9,12} In addition, among patients with narrow-angle glaucoma, the level of IOP lowering after cataract surgery is proportional to the resultant widening of the angle.^{7–10} We would therefore expect the smallest reduction in IOP among patients with open angles and “normal” IOP. However, as far as we are aware, there is still no good predictor for the expected amount of IOP reduction in this specific group of patients, and the mechanism for the effect remains poorly understood. In this study, we excluded patients with occludable angles and

high IOP measurements in order to specifically analyze how cataract extraction affects IOP in this population.

We observed a mean IOP decrease of 2.03 mm Hg, a 12.74% reduction from baseline (mean, 14.5 mm Hg; range, 8–23 mm Hg), after uneventful phacoemulsification cataract surgery with 4 months follow-up. These findings were comparable with those of previous studies on nonglaucomatous eyes.^{12,15,16,25,26} For example, Tennen and Masket²⁵ reported a mean IOP reduction of 2.19 mm Hg (14.1%) at 1 year from baseline (mean 15.57 mm Hg), and Singleton et al.²⁶ reported a mean IOP reduction of 2.04 mm Hg (12.42%) at 6 months from baseline (mean 16.42 mm Hg).²⁶ The majority of prior studies evaluating the relationship between predictors and IOP reduction after cataract surgery did not subdivide their subjects into groups based on angle assessment. However, Huang et al.⁸ used gonioscopy to separately study nonglaucomatous eyes with narrow and open angles, making their study most similar in design to the present study. They reported a mean IOP reduction of 1.95 mm Hg (13.39%) from baseline (mean, 14.68; range, 9–20 mm Hg) after uneventful cataract extraction in the open-angle group.⁸

Given the variability of the postoperative IOP response reported, there has been significant effort to find predictors of IOP reduction. There is increasing evidence to suggest that the postoperative IOP reduction is correlated with the preoperative IOP such that patients with higher preoperative IOP obtain larger-magnitude sustained reductions in IOP postoperatively, relative to those with lower preoperative IOP.^{6,9,15} However, this observation may be partly due to the statistical phenomenon known as regression to the mean caused by an inadequate number of baseline preoperative IOP measurements, especially among the patients with high-pressure IOPs.¹ In addition, eyes with higher baseline IOP measurements tend to have greater absolute IOP reductions compared to eyes with lower baseline IOP measurements. However, the percent change in IOP may be similar among eyes with different baseline IOP measurements; thus we used percent IOP change as our main outcome.

Prior studies have shown associations between IOP change and various ocular biometric parameters. Preoperative ACD was reported to be a predictor of postoperative IOP reduction. Issa et al.¹¹ reported that the IOP reduction was weakly inversely related to preoperative ACD ($r = 20.455$, $r^2 = 21\%$).¹¹ Yang et al.¹⁶ reported that ACD was not associated with IOP decrease after adjusting for other parameters such as preoperative IOP, LT, and anterior chamber area change. Lens thickness was reported to be an effective predictor among nonglaucomatous patients.¹⁶ Studies have shown that AXL was associated with postoperative IOP reduction in nonglaucomatous eyes.²⁷ By AS-OCT, angle parameters such as AOD and LV

FIGURE 1. Preoperative IOP as predictor of percent IOP change after cataract surgery.

FIGURE 2. Preoperative ACD as predictor of percent IOP change after cataract surgery.

have also been reported to be strongly associated with IOP reduction after phacoemulsification.^{8,16,17}

In our study, we found preoperative IOP, AXL, ACD, and LT to be associated with percent IOP reduction after phacoemulsification. The results were comparable to previous studies (Table 1). Another novel index, called the PD ratio, was introduced by Issa et al.¹² and strongly predicts IOP reduction after cataract surgery ($r = 0.852$; $r^2 = 73\%$; $P < 0.01$). The utility of the PD ratio has since been confirmed by Dooley et al.¹⁵ with slightly weaker predictability ($r = 0.56$; $r^2 = 34.1\%$; $P < 0.001$). In our study, PD ratio was also shown to be an index with good predictive value for both absolute IOP change (following previous studies) and percent IOP change as outcomes ($r = -0.727$; $r^2 = 56.9\%$; $P < 0.001$ and $r = -0.625$; $r^2 = 39.0\%$; $P < 0.001$, respectively).

In the present study, we also found that the predictive value of LP for IOP reduction after phacoemulsification cataract surgery was very useful in nonglaucomatous patients with open angles.

We also compared the strength of previously studied predictors of IOP change.^{12,15} Using percent IOP change as the outcome in univariate and multivariate analyses, we found preoperative IOP, ACD, PD ratio, and LP to be parameters with good predictability (all with P values < 0.05). However, LP showed the greatest predictive value (standardized coefficient, $\beta = 0.674$ and 0.457 , $r^2 = 45.5\%$ and 51.4% , in the univariate and multivariate models, respectively) compared to preoperative IOP, ACD, and PD ratio (Table 3). Although there was no statistically significant difference between the predictive coefficients of the predictors using Fisher's z transformation test, LP was thought to be a potentially stronger predictor in this group of patients. Further studies with larger sample sizes are needed to assess this relationship.

Among nonglaucomatous patients with open angles, there are some advantages to using LP as a predictor of reduction in IOP after cataract surgery. First, LP appears to show great predictive value. Second, given that AS-OCT scanning is not readily available to all physicians who perform phacoemulsification, the availability of LP as a predictive parameter may be superior to that of other predictors such as AOD, ACA, and LV, which can be measured only by AS-OCT.^{8,16,17} Third, because ocular biometry measurement is required before any cataract surgery for IOL power calculation, LP is a convenient and simple parameter to obtain and calculate. Finally, the diurnal fluctuation in IOP has been well described, and this variation makes other predictors, such as preoperative IOP and PD ratio, less reliable. Lens position is computed by ACD and LT, which are more stable parameters and may thus be more accurate.

As with many factors that have been found to be associated with IOP reduction after cataract surgery, LP and ACD may have limited use in an individual given the variability observed in our study. However these factors in combination with other predictors such as preoperative IOP may help the clinician in deciding whether to utilize cataract surgery alone as a way to significantly lower IOP.

Most glaucoma studies evaluating the effect of any medical or surgical treatment use percent IOP reduction as the main outcome. Percent IOP reduction was therefore used as the main outcome for all the analyses in this study. However, it is noteworthy that absolute IOP change has been used as the main outcome in most of the previous studies on this topic.^{7-12,13,16,17} We compared absolute IOP change and percent IOP change as outcome variables and found that they were associated with different predictor variables. When using percent IOP change as the outcome, LP was the best predictor ($r = 0.674$; $r^2 = 45.5\%$; $P < 0.001$), followed by PD ratio ($r =$

FIGURE 3. PD ratio (preoperative IOP/preoperative ACD) as predictor of percent IOP change after cataract surgery.

FIGURE 4. Lens position (ACD + 1/2 lens thickness) as predictor of percent IOP change after cataract surgery.

−0.625; $r^2 = 39.0\%$; $P < 0.001$). However, when using absolute IOP change as outcome, PD ratio showed better predictability ($r = 0.727$; $r^2 = 52.9\%$; $P < 0.001$) than LP ($r = 0.691$; $r^2 = 47.8\%$; $P < 0.001$).

We conclude that LP is strongly associated with the IOP reduction after phacoemulsification surgery in nonglaucomatous patients with open angles. One possible explanation for this phenomenon is that the more anteriorly positioned the lens is, the more likely it is to result in “partial pupillary block.” According to the iris-lens canal theory,²⁸ the posterior chamber–anterior chamber pressure gradient is inversely proportional to the height of the iris-lens canal. When the lens is more anteriorly positioned and the height is decreased, the higher pressure gradient will cause a situation similar to pupillary block. Such a partial blockage may be relieved with lens extraction, which could be a potential mechanism of IOP reduction after cataract surgery for eyes with open-angle configuration.

This study has several limitations. First, we had a relatively small sample size (95 eyes). To increase the statistical power, we included both eyes of the patients when eligible and created a linear mixed-effects regression model. However, all the results were very similar to the results we obtained when only one eye was selected from each patient (Tables 1, 2). Second, 31 eyes that had undergone LPI were included. It is unclear what effect preoperative LPI has on IOP in patients after cataract surgery. However, we adjusted for LPI in every multivariate analysis when estimating the predictive value of this parameter. Third, when comparing the predictability between preoperative IOP, ACD, PD ratio, and LP, we selected 75 eyes from the 75 patients for the analysis due to the fact that the definition of r^2 becomes problematic in linear mixed-effects regression models. Thus, we had a reduced sample size for that analysis. Fourth, the follow-up time was only 4 months, and it is possible that the IOP reductions we found after cataract surgery may change over time, although prior studies

have found that IOP reduction after cataract surgery is typically long-lasting. Finally, we selected only nonglaucomatous patients with open angles and relatively low IOP. Therefore, a rather small absolute IOP reduction was noted after cataract surgery. Clinically, glaucomatous patients are those who require reductions in IOP, so future studies will show whether similar relationships and IOP reductions are observed among glaucomatous eyes.

In conclusion, the percentage of IOP reduction after cataract surgery in nonglaucomatous eyes with open angles is significantly greater in more anteriorly positioned lenses. Lens position, which is simple to calculate by basic optical biometric data, is a widely available parameter with relatively better predictive value for postoperative IOP change. The result could explain a potential mechanism for IOP reduction after cataract surgery for eyes with open-angle configuration. Future studies will show whether similar relationships exist in glaucomatous eyes undergoing cataract surgery.

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TABLE 4. Correlation between Predictors and the Outcomes Absolute IOP Change and Percentage of IOP Change

Predictors	Absolute IOP Change as Outcome			Percentage of IOP Change as Outcome		
	P Value	r	r ²	P Value	r	r ²
LP	<0.001	0.691	47.8%	<0.001	0.674	45.5%
PD ratio	<0.001	−0.727	52.9%	<0.001	−0.625	39.0%
Pre-op IOP	<0.001	−0.549	30.1%	<0.001	−0.430	18.5%

Pre-op IOP, preoperative IOP.

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