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# Lens Position Parameters as Predictors of Intraocular Pressure Reduction After Cataract Surgery in Glaucomatous Versus Nonglaucomatous Eyes

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**PURPOSE.** To evaluate the relationship between lens position parameters and intraocular pressure (IOP) reduction after cataract surgery in patients with primary open-angle glaucoma (POAG) and in nonglaucomatous patients.

**METHODS.** The main outcomes of this prospective study were percent and absolute IOP change, which were calculated using the preoperative IOP and the IOP 4 months after cataract surgery in POAG and nonglaucomatous eyes. Lens position (LP), defined as anterior chamber depth (ACD) + one-half lens thickness (LT), was assessed preoperatively using parameters from optical biometry. Preoperative IOP, axial length (AL), ACD, LT, relative lens position (RLP), and the ratio of preoperative IOP to ACD (PD ratio) were also evaluated as potential predictors of IOP change.

**RESULTS.** Four months postoperatively, the average IOP reduction was  $2.80 \pm 3.83$  mm Hg (15.79%) from the preoperative mean of  $14.73 \pm 2.89$  mm Hg for nonglaucomatous eyes. The average IOP reduction was  $2.66 \pm 2.07$  mm Hg (16.98%) from the preoperative mean of  $14.86 \pm 2.97$  mm Hg for POAG eyes. Preoperative IOP, sex, AL, ACD, PD ratio, and LP predicted IOP change in nonglaucomatous eyes. Preoperative IOP and PD ratio predicted IOP change in POAG eyes.

**CONCLUSIONS.** Intraocular pressure reduction after phacoemulsification cataract surgery in nonglaucomatous eyes is significantly greater in more anteriorly positioned lenses. Though it did not reach statistical significance in patients with glaucoma, the association of LP with IOP reduction is in the same direction as in nonglaucomatous patients where smaller LP appears to predict greater IOP reduction. Lens position is a simple, easily calculable, accurate, and widely available parameter, which clinicians can potentially utilize in managing glaucoma.

**Keywords:** lens position, intraocular pressure, pressure reduction, predictors, biometry

Glaucoma is the second leading cause of blindness worldwide. It is also the leading cause of global irreversible blindness.<sup>1,2</sup> Clinical care of glaucoma involves managing a healthy level of intraocular pressure (IOP) through use of medications or surgery. Numerous studies have found that cataract surgery is effective at lowering IOP for the majority of patients.<sup>3–20</sup> The exact mechanism of this is still not yet fully understood.

Several predictors have been identified with lowering pressure. Preoperative IOP has been found to be a significant predictor of IOP reduction after cataract surgery. In fact, patients with higher levels of preoperative IOP obtain greater averages of postoperative IOP reduction.<sup>4,6,7,9,11,20–22</sup> Another predictor is the shallowness of the anterior chamber depth (ACD).<sup>20–22</sup> Pressure-to-depth ratio (PD ratio) was also identified as a novel index for predicting the degree of IOP reduction based on the ratio of the preoperative IOP and ACD.<sup>22</sup>

Furthermore, our previous studies have also identified angle opening distance (AOD) and preoperative lens vault (LV) to be associated with IOP reduction in nonglaucomatous eyes.<sup>23,24</sup>

In our previous study of nonglaucomatous eyes, lens position (LP) was found to be an effective predictor of IOP reduction.<sup>25</sup> Lens position is defined as the sum of ACD and one-half lens thickness (LT). Relative lens position (RLP) is defined as LP divided by axial length (AL). The roles of LP and RLP in predicting eye pressure reduction have not been fully explored in subjects with primary open-angle glaucoma (POAG). To our knowledge, there have been no prospective studies showing an association between LP, RLP, and IOP reduction in POAG patients. The aim of this study was to determine if LP, RLP, and IOP are related in POAG patients and to compare these findings with those from normal control patients.

## METHODS

Institutional review board approval for this prospective study was obtained from the University of California–San Francisco (UCSF) Committee on Human Research (CHR). The study followed the tenets of the Declaration of Helsinki. Patients were enrolled from the glaucoma service at UCSF from September 16, 2011 to November 30, 2015. Written informed consent was obtained prior to participation.

The study's inclusion criteria for the POAG group included age  $\geq 18$  years; visually significant cataracts; uncomplicated cataract surgeries without adjunctive procedures (e.g., pupil stretching, use of iris hooks or Malyugin rings); and patients in whom POAG had been determined. Glaucoma in POAG patients had been determined if there was use of glaucoma medications plus one of the following scenarios: (1) visual field loss consistent with glaucoma and cup-to-disc ratio  $\geq 0.7$  or (2) cup-to-disc ratio  $\geq 0.9$  if the patient was unable to perform visual field examination in the affected eye.

The exclusion criteria for the POAG group consisted of (1) intraoperative or postoperative complications related to the cataract surgery (e.g., posterior capsule rupture, vitreous loss); (2) history of trabeculectomy or other intraocular glaucoma surgeries; (3) occludable angles with a Shaffer classification grade of 0 or 1 in at least two quadrants; (4) peripheral anterior synechiae (PAS); (5) uveitis, severe retinal diseases, or congenital abnormalities; (6) history of ocular trauma; (7) history of intraocular surgery; and (8) pseudoexfoliation or pigment dispersion. Eyes with history of laser peripheral iridotomy (LPI) or selective laser trabeculoplasty (SLT) were not excluded. Both eyes of a patient were included in the study if they met the criteria.

Inclusion criteria for nonglaucomatous ("control") patients included age  $\geq 18$  years; visually significant cataracts; and uncomplicated cataract surgeries without adjunctive procedures. The exclusion criteria included major intraoperative or postoperative complications resulting from cataract surgery; glaucomatous optic neuropathy shown by optic disc cupping or glaucomatous visual field loss; preoperative IOP over 23 mm Hg; the use of glaucoma medications; occludable angles; PAS; uveitis, severe retinal diseases, or congenital abnormalities; history of ocular trauma; history of intraocular surgery; and pseudoexfoliation or pigment dispersion.

The preoperative evaluation, which occurred 1 to 3 weeks before surgery, included complete slit-lamp and fundus examination, ocular biometry measurements, visual acuity testing, gonioscopy, and IOP determination. Intraocular pressure was measured using Goldmann applanation tonometry by the same observer (SCL) in a masked fashion. Two values were obtained, and the mean value was used for analysis. A third value was obtained, and the median value was chosen if the two values differed by more than two points. Gonioscopy was performed using a Zeiss-style 4-mirror gonioscope (Model G-4; Volk Optical, Mentor, OH, USA) by the same glaucoma specialist (SCL). Angles were graded in all four quadrants (superior, nasal, temporal, and inferior) based on the Shaffer method. Ocular biometry was obtained with the LENSTAR LS 900 (Haag-Streit, Inc., Koeniz, Switzerland) to measure AL, ACD, LT, and central corneal thickness (CCT).

## Surgical Technique

All operations were performed by the same surgeon (SCL). Conventional surgical procedures were used in all subjects under topical or sub-Tenons anesthesia. Phacoemulsification was performed via a 2.8-mm temporal clear corneal incision, with in-the-bag one-piece acrylic intraocular lens implantation

(models AcrySof SA60AT or AcrySof IQ SN60WF; Alcon Laboratories, Inc., Fort Worth, TX, USA).

Patients were prescribed topical antibiotics, 0.5% ketorolac tromethamine, and topical 1% prednisolone acetate and tapered over 1 month. Postoperative follow-up visits were performed at 1 day, 10 days, 1 month, and 4 months after surgery. During each visit, visual acuity testing, IOP measurement, and complete slit-lamp examination were performed. Best-corrected visual acuity and dilated fundus examination were also conducted at selected visits.

## Statistical Analysis

We characterized the study population by calculating mean and standard deviation for continuous data and summary percentages for categorical data for the control and POAG groups. We compared any potential differences between the groups using the Student's *t*-test for continuous variables and the  $\chi^2$  test for categorical variables.

Within each group, we used linear mixed effects regression to assess the relationship of preoperative IOP, age, sex, and other ocular parameters with percent and absolute IOP change, in both univariate analysis and multivariate analysis adjusting for the effects of preoperative IOP, age, and sex. The use of mixed models adjusts for the use of both eyes in some subjects.

Multivariate linear mixed effects regression was also used to assess any interaction of glaucoma diagnosis with the associations between ocular parameters (AL, ACD, LT, LP, RLP, PD ratio) and IOP change (i.e., whether the difference in correlation coefficients significantly varied between the control and POAG groups). These mixed models adjusted for preoperative IOP, age, sex, and glaucoma diagnosis. In all models assessing PD ratio and IOP change, preoperative IOP was not included because it is part of the calculation of PD ratio.

*P* values less than 0.05 were considered to be significant. All statistical analyses were conducted using R statistical software, version 3.1 for Macintosh (R Foundation for Statistical Computing, Vienna, Austria).

Based on the standard deviation of the IOP change, which was 2.42 mm Hg in the study by Hsu et al.,<sup>25</sup> we cite this study as a rough guide to statistical power.<sup>25</sup> We note that a sample size of 64 eyes in each of the two groups would provide approximately 80% power to detect an effect size of 1.21 mm Hg, that is, half the standard deviation observed.

## RESULTS

The study sample included 97 eyes of 73 nonglaucomatous patients and 76 eyes of 57 POAG patients. The mean age of the control and POAG groups was  $76.03 \pm 8.90$  and  $77.62 \pm 7.41$  years, respectively. The control group was 62% female compared to 61% of the POAG group. For the control group, the mean IOP was  $14.73 \pm 2.89$  mm Hg at the preoperative visit and  $11.93 \pm 2.65$  mm Hg at 4 months postoperatively, representing a  $2.80 \pm 3.83$  mm Hg (15.79%) reduction. For the POAG group, the mean IOP was  $14.86 \pm 2.97$  mm Hg at the preoperative visit and  $12.19 \pm 2.41$  mm Hg at 4 months postoperatively, representing a  $2.66 \pm 2.07$  mm Hg (16.98%) reduction (Table 1).

Preoperative IOP, sex, AL, ACD, LP, and PD ratio were significant predictors of both percent and absolute IOP change for the control group. Age, LT, and RLP were not associated with IOP reduction. In the POAG group, preoperative IOP and PD ratio were significant predictors of both percent and absolute IOP change. Age, sex, AL, ACD, LT, LP, and RLP were

TABLE 1. Demographic and Clinical Characteristics of the Sample Population

Variable	Normal Group	POAG Group	P Value
No. of patients, eyes	73, 97	57, 76	
Age, y, mean ± SD	76.03 ± 8.90	77.62 ± 7.41	0.207
Sex, F/M	61/36	46/30	0.751
Pre-op IOP, mean ± SD	14.73 ± 2.89	14.86 ± 2.97	0.779
AL, mean ± SD	23.68 ± 1.30	24.37 ± 1.43	0.001
CCT, mean ± SD	547.02 ± 38.06	529.84 ± 30.52	0.002
ACD, mean ± SD	2.96 ± 0.46	3.05 ± 0.34	0.176
LT, mean ± SD	4.71 ± 0.47	4.68 ± 0.38	0.679
PD ratio, mean ± SD	5.11 ± 1.36	4.94 ± 1.18	0.396
LP, mean ± SD	5.32 ± 0.31	5.39 ± 0.27	0.119
RLP, mean ± SD	0.22 ± 0.01	0.22 ± 0.01	0.092
Post-op IOP at 4 m, mean ± SD	11.93 ± 2.65	12.19 ± 2.41	0.510
Absolute IOP change, mean ± SD	-2.80 ± 3.83	-2.66 ± 2.07	0.787
% IOP change, mean ± SD	-15.79 ± 25.03	-16.98 ± 12.44	0.706

not associated with IOP reduction ( $P > 0.05$ ) in the POAG group. Tables 2 and 3 show the regression coefficients, standard errors, and  $P$  values describing the associations of predictors with percent and absolute IOP change in the control and POAG groups. The Figure shows the association between LP and percent IOP change for the control and POAG groups.

The correlation coefficients describing the association of AL, ACD, LP, and PD ratio with IOP change after phacoemulsification were different between the POAG and control groups ( $P < 0.05$ ). Tables 4 and 5 report the regression coefficients, standard errors, and  $P$  values of these relationships.

DISCUSSION

Our prospective study shows that after phacoemulsification cataract surgery with intraocular lens implantation, IOP decreased by 2.80 mm Hg (15.79%) in nonglaucomatous eyes and 2.66 mm Hg (16.98%) in eyes with controlled POAG. Preoperative IOP was a significant predictor of IOP reduction in both groups. Lens position was associated with IOP reduction in nonglaucomatous eyes but not POAG eyes. Though it did not reach statistical significance, the association of LP with IOP reduction is in the same direction as in nonglaucomatous patients, where smaller LP appears to predict greater IOP reduction.

Our study's findings of mean IOP reduction at 4 months after uneventful cataract surgery are consistent with prior studies demonstrating a clinically significant decrease in IOP after phacoemulsification cataract surgery in normal and glaucomatous eyes.<sup>3-20</sup> Studies consistently show an approximate 2 to 4 mm Hg reduction in IOP in patients undergoing extracapsular cataract extraction or clear corneal cataract extraction in nonglaucomatous patients.<sup>9,11,14,26</sup> Matsumura et al.<sup>15</sup> demonstrated a 1.5 mm Hg reduction of IOP in "cataract surgery-only" patients. They also found 2.5 and 5.5 mm Hg reductions in IOP for patients with controlled versus uncontrolled POAG, respectively, with 3-year postoperative follow-up.<sup>6</sup> Shingleton et al.<sup>13</sup> showed that at 1 year, the mean IOP was lower in both nonglaucoma and glaucoma groups, with mean IOP reductions of 2.05 and 1.11 mm Hg, respectively. The change was statistically significant in the nonglaucomatous group. In another study, Shingleton et al.<sup>8</sup> showed that IOP decreased by 1.7 and 1.4 mm Hg in nonglaucoma and glaucoma groups, respectively, at 3 years follow-up. They also showed a greater, although not statistically significantly greater, reduction in postoperative IOP for patients with cataract as well as POAG (1.8 mm Hg) versus those with cataract without coexistent POAG (1.5 mm Hg) at 5 years. Furthermore, Tong and Miller<sup>16</sup> reported a 2.1 to 2.8 mm Hg decrease at 6 to 8 months in nonglaucomatous, glaucoma suspect, and glaucoma-

TABLE 2. Association of Various Predictors of IOP Change Among Nonglaucomatous and Glaucomatous Subjects (Using % IOP Change as the Dependent Variable)

	No Glaucoma				Glaucoma			
	Univariate		Multivariate		Univariate		Multivariate	
	B (SE)	P Value	B (SE)	P Value	B (SE)	P Value	B (SE)	P Value
Pre-op IOP	-5.72 (0.69)	<0.001			-1.78 (0.46)	<0.001		
Age	-0.17 (0.32)	0.600			-0.21 (0.21)	0.329		
Sex	16.18 (5.44)	0.004			1.85 (3.16)	0.561		
AL	10.40 (1.92)	<0.001	9.13 (1.22)	<0.001	0.87 (1.07)	0.414	0.52 (1.11)	0.645
ACD	24.23 (5.50)	<0.001	18.78 (4.41)	<0.001	5.22 (4.47)	0.248	4.59 (4.95)	0.358
LT	-9.82 (5.54)	0.080	-6.95 (4.31)	0.111	0.01 (3.89)	0.895	1.13 (4.09)	0.783
LP	39.52 (7.91)	<0.001	29.46 (6.20)	<0.001	8.47 (5.38)	0.121	8.78 (6.10)	0.155
RLP	81.82 (244.91)	0.739	-107.185 (173.87)	0.539	31.79 (119.92)	0.792	57.29 (114.64)	0.619
PD ratio	-12.97 (1.42)	<0.001	-12.52 (1.45)	<0.001	-4.54 (1.16)	<0.001	-4.99 (1.26)	<0.001

Univariate mixed models correct for the use of both eyes in some subjects. For all parameters except PD ratio, multivariate mixed models adjust for the effects of preoperative IOP, age, sex, and the use of both eyes in some subjects. Multivariate mixed models for PD ratio adjust for the effects of age, sex, and the use of both eyes in some subjects.  $B$ , regression coefficient.

**TABLE 3.** Association of Various Predictors of IOP Change Among Nonglaucomatous and Glaucomatous Subjects (Using Absolute IOP Change as the Dependent Variable)

	No Glaucoma				Glaucoma			
	Univariate		Multivariate		Univariate		Multivariate	
	B (SE)	P Value	B (SE)	P Value	B (SE)	P Value	B (SE)	P Value
Pre-op IOP	-0.94 (0.10)	<0.001			-0.44 (0.07)	<0.001		
Age	-0.02 (0.05)	0.639			-0.04 (0.03)	0.270		
Sex	2.47 (0.84)	0.004			0.57 (0.52)	0.280		
AL	1.52 (0.30)	<0.001	1.32 (0.15)	<0.001	0.17 (0.18)	0.334	0.07 (0.16)	0.686
ACD	3.38 (0.86)	<0.001	2.51 (0.61)	<0.001	1.02 (0.74)	0.170	0.77 (0.72)	0.289
IT	-1.43 (0.85)	0.10	-1.08 (0.60)	0.07	0.17 (0.65)	0.791	0.23 (0.60)	0.706
LP	5.43 (1.25)	<0.001	3.71 (0.88)	<0.001	1.72 (0.88)	0.055	1.52 (0.88)	0.089
RLP	4.78 (37.25)	0.898	-29.01 (23.48)	0.220	7.18 (19.83)	0.719	12.07 (16.60)	0.470
PD ratio	-2.13 (0.20)	<0.001	-2.08 (0.20)	<0.001	-1.07 (0.17)	<0.001	-1.16 (0.19)	<0.001

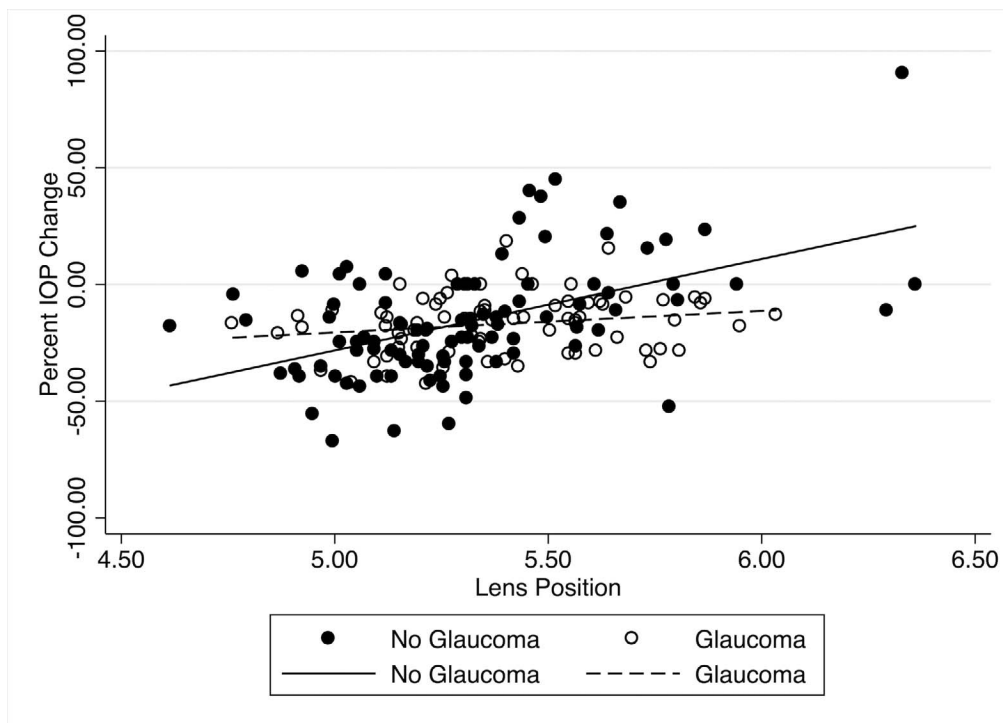
Univariate mixed models correct for the use of both eyes in some subjects. For all parameters except PD ratio, multivariate mixed models adjust for the effects of preoperative IOP, age, sex, and the use of both eyes in some subjects. Multivariate mixed models for PD ratio adjust for the effects of age, sex, and the use of both eyes in some subjects. *B*, regression coefficient.

tous eyes, without significant difference between the groups. Similarly to these studies, we included controlled glaucoma patients and found no significant difference in IOP reduction between nonglaucomatous and glaucomatous patients.

In these aforementioned studies, use of glaucoma medications was often changed as a result of cataract surgery. For example, Shingleton et al.<sup>13</sup> observed that glaucoma patients showed a statistically significant reduction in the number of glaucoma medications postoperatively. In other studies, the number of medications is not specified.<sup>16</sup> Unique to our study is the consistent use of the same type and number of medications preoperatively and postoperatively. The use of

the same medications was a deliberate effort to elucidate the amount of IOP change due to surgery alone.

The reasons behind why or how IOP is reduced after cataract extraction are not yet fully understood. However, theories have been proposed. Hypothetically, cataract surgery results in deepening of the ACD and widening of the anterior chamber angle (ACA). It would be expected that access of aqueous to the filtering portion of the trabecular meshwork would be improved due to widening of the drainage angle, representing one mechanism for IOP lowering.<sup>23</sup> Changes in angle configuration after cataract surgery have been studied using either Scheimpflug or ultrasound biomicroscopic images.



**FIGURE.** Relationship between LP and % IOP change in nonglaucomatous and glaucomatous subjects. LP is positively correlated with percent IOP change among the control group. There is a statistically significant difference between the correlation coefficients of the control and POAG groups.



**TABLE 4.** Comparison of Predictors of IOP Change in Relationship to Glaucoma Diagnosis (Using % IOP Change as the Dependent Variable); the Correlation Coefficients Describing the Relationships Between AL, ACD, LP, and PD Ratio With Percent IOP Change Differ Significantly Between the Control and POAG Groups

	Interaction With Glaucoma Diagnosis	
	B (SE)	P Value
AL	-10.16 (1.75)	<0.001
ACD	-17.63 (6.78)	0.010
LT	6.34 (6.474)	0.329
LP	-29.38 (8.68)	0.001
RLP	101.65 (232.21)	0.662
PD ratio	8.12 (1.91)	<0.001

For all parameters except PD ratio, multivariate mixed models adjust for the effects of preoperative IOP, age, sex, glaucoma diagnosis and the use of both eyes in some subjects. Multivariate mixed models for PD ratio adjust for the effects of age, sex, and the use of both eyes in some subjects. *B*, regression coefficient.

Hayashi et al.<sup>27</sup> demonstrated by Scheimpflug imaging that the width and depth of the ACA of angle-closure and open-angle glaucoma increase significantly after cataract extraction and IOL implantation.

In addition, there are other proposed contributory factors that may account for IOP lowering, such as ultrasound activation of cytokines, endogenous prostaglandin F<sub>2</sub> release, and increase in aqueous outflow by expansion of the trabecular meshwork and the lumen of Schlemm's canal. Phacoemulsification ultrasound activation of the interleukin 1 $\alpha$ /nuclear factor- $\kappa$ B/endothelial leukocyte adhesion molecule 1 pathway, which facilitates aqueous outflow and reduction in IOP as a result, was demonstrated by Wang et al.<sup>28</sup> Mathalone et al.<sup>17</sup> suggested that endogenous prostaglandin F<sub>2</sub> released postoperatively may enhance uveoscleral outflow. Shrinking of the lens capsule postoperatively can result in increased posterior traction on the scleral spur, expanding the trabecular meshwork and the lumen of Schlemm's canal.<sup>9,29,30</sup>

Preoperative IOP as a predictor of postoperative IOP reduction has been well documented, and such is the case in the present study in both nonglaucomatous and glaucomatous eyes. This was also true in our recent study with nonglaucomatous eyes,<sup>25</sup> and in other studies involving nonglaucomatous eyes<sup>6,8,11,22,31,32</sup> as well as eyes with POAG.<sup>5,6,8,9,13,17,27</sup> Furthermore, patients with higher preoperative IOP have larger IOP reductions postoperatively.<sup>9,11</sup> Another novel indicator, PD ratio—introduced by Issa et al.<sup>22</sup>—strongly predicts IOP reduction after cataract surgery ( $r = 0.852$ ;  $r^2 = 73\%$ ;  $P < 0.01$ ). The use of PD ratio has since been confirmed by Dooley et al.<sup>33</sup> with slightly weaker predictability ( $r = 0.56$ ;  $r^2 = 34.1\%$ ;  $P < 0.001$ ). Similar to observations in our previous study in nonglaucomatous eyes,<sup>25</sup> PD ratio was associated with IOP change in both nonglaucomatous and glaucomatous eyes.

In our study, preoperative ACD was predictive of IOP change in nonglaucomatous eyes but not POAG eyes. The role of ACD as a predictor of IOP change is controversial. In some studies, preoperative ACD did not have a significant relationship with postoperative IOP reduction in normal eyes<sup>23,31,32</sup> and primary angle-closure glaucoma (PACG) eyes.<sup>34</sup> However, Issa et al.<sup>22</sup> also demonstrated that IOP reduction is positively correlated to preoperative IOP and inversely related to preoperative ACD. Some studies have shown that along with high preoperative IOP, a shallow preoperative ACD is associated with a more pronounced IOP reduction after cataract surgery.<sup>6,11,20-22</sup>

**TABLE 5.** Comparison of Predictors of IOP Change in Relationship to Glaucoma Diagnosis (Using Absolute IOP Change as the Dependent Variable); the Correlation Coefficients Describing the Relationships of AL, ACD, LP, and PD Ratio With Absolute IOP Change Differ Significantly Between the Control and POAG Groups

	Interaction With Glaucoma Diagnosis	
	B (SE)	P Value
AL	-1.47 (0.24)	<0.001
ACD	-2.19 (0.95)	0.023
LT	0.98 (0.90)	0.281
LP	-3.48 (1.23)	0.005
RLP	31.39 (32.04)	0.329
PD ratio	1.01 (0.27)	<0.001

For all parameters except PD ratio, multivariate mixed models adjust for the effects of preoperative IOP, age, sex, glaucoma diagnosis and the use of both eyes in some subjects. Multivariate mixed models for PD ratio adjust for the effects of age, sex, and the use of both eyes in some subjects. *B*, regression coefficient.

In the present study, AL was associated with postoperative IOP change in control eyes but not POAG eyes. Hsu et al.<sup>25</sup> and Bilak et al.<sup>35</sup> found similar results for nonglaucomatous eyes, while Moghimi et al.<sup>31</sup> did not find a significant relationship between AL and IOP reduction in nonglaucomatous eyes.

The role of LT as a predictor of IOP reduction remains unclear. Some studies did not find any significant relationship,<sup>31,36,37</sup> while other studies show a significant relationship between LT and IOP reduction.<sup>25,32</sup> Yang et al.<sup>32</sup> reported that LT was an effective predictor of IOP drop among nonglaucomatous patients in both univariate ( $P < 0.05$ ) and multivariate analysis ( $P < 0.05$ ). In the present study, LT was not significantly associated with IOP lowering in either control or POAG eyes.

In our previous study, we found that LP was a clinically accessible parameter with considerable predictive value for postoperative IOP change in nonglaucomatous patients with open angles.<sup>25</sup> In the present study, we also found that LP is a significant predictor of IOP reduction in nonglaucomatous eyes. In the POAG group, there is a trend toward the same finding; however, a statistically significant relationship was not found. Relative lens position was not found to be a significant predictor of IOP reduction in both normal and POAG eyes. Future studies with a larger POAG sample and perhaps longer follow-up are needed to further evaluate these relationships. The parameters LP and RLP were originally introduced to address the effect of the lens on the anterior chamber.<sup>38</sup> However, there are conflicting reports regarding the clinical relevance of LP and RLP, in part because LT and ACD, which are the two constituents of these parameters, are interdependent.<sup>31,39-41</sup>

Lens position may still serve as a useful predictor of IOP reduction and may be potentially utilized as part of glaucoma management because of its several advantages. Lens position appears to show great predictive value regarding IOP reduction. Lens position is a convenient and simple parameter to calculate and obtain since ocular biometry measurements are required before any cataract surgery for IOL power calculation. In contrast, other predictors such as AOD, ACA, and LV require anterior segment optical coherence tomography (AS-OCT) scanning,<sup>23,24,32</sup> which may not be available at all facilities. Lastly, ACD and LT, which are used to compute LP, are reliable and accurate parameters. The diurnal fluctuation in IOP has been well described, making the preoperative IOP and PD ratio more variable.

How LP serves as a predictor of IOP reduction is not yet known, but a possible explanation may be that an anteriorly positioned lens may result in “partial pupillary block.” According to the iris-lens canal theory, the posterior chamber–anterior chamber pressure gradient is inversely proportional to the height of the iris–lens canal.<sup>42</sup> When the lens is more anteriorly positioned and the height of the iris–lens canal 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.<sup>25</sup>

Our interpretation of why LP is associated with IOP change in the control but not the POAG group is that the use of glaucoma medications may mask the true effect of LP by suppressing IOP. The medications may have a greater effect on IOP compared to LP or angle opening.

Perhaps a more indicative parameter of postoperative IOP reduction is LV, which describes lens protrusion into the anterior chamber. It is defined as the perpendicular distance between the line joining the two scleral spurs and the anterior pole of the lens. In angle-closure glaucoma, Tan et al.<sup>43</sup> showed LV to be an independent risk factor for angle-closure glaucoma, while other studies showed the opposite.<sup>34,36,37</sup> Although some studies such as the one performed by Huang et al.<sup>24</sup> have reported LV to be strongly associated with IOP reduction after phacoemulsification in normal eyes, others did not.<sup>31</sup> However, LV is not as easily obtainable compared to LP since not all facilities have access to AS-OCT scanning.

Limitations of this study include the relatively small sample size, particularly of the POAG group. We also acknowledge that the follow-up period was only 4 months. It is possible that the IOP reductions observed after cataract surgery may change and that a longer follow-up period may be desired to ensure more stable IOP measurements after surgery. However, prior studies have found IOP reduction after cataract surgery to be typically stable and long-lasting after 4 months.<sup>10,13,16,18,23</sup> Finally, patients in the POAG group had pressures that were controlled, which may have altered actual changes in IOP after surgery. Future studies implementing a medication washout period may be desired. On the other hand, one strength of our study was the fact that IOP measurements were consistently obtained during the same time of the day, typically between 1:00 and 5:00 PM.

Our study reports that the absolute and percentage of IOP reduction after phacoemulsification cataract surgery in non-glaucomatous eyes is significantly greater when the lens is more anteriorly positioned. There is a trend toward a similar effect in POAG eyes, but it is not statistically significant. Lens position is a simple, easily calculable, accurate, and widely available parameter that clinicians can potentially utilize when predicting a patient’s IOP response to phacoemulsification cataract surgery as part of glaucoma management.

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