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Factors affecting changes in the intraocular pressure after phacoemulsification surgery

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超声乳化术后眼压变化的影响因素

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摘要
目的:探讨行超乳手术患者前房参数的变化及影响眼压变化的因素。
方法:本文对 82 例 105 眼行白内障手术的非青光眼患者临床资料进行了纵向分析。研究术后3wk 内前房参数、白内障分级、人口统计学资料和眼压变化之间的关系。并评估眼压-前房深度(PD)比率与此期间眼压变化之间的关系。
结果:纳入的 82 例患者平均年龄为 60.1±7.8 岁。术前平均 IOP 为 15.06±3.36 mmHg;术后 1d 增加到 15.75±4.21 mmHg (P=0.20)。在多因素模型中,与术前值比较,术后 21±5d 平均 IOP 变化为-1.715 mmHg(95% CI: -2.795, -0.636)。前房深度(ACD)、眼轴长度、年龄、性别和白内障分级与眼压变化无显著相关。PD 比率每增加一个单位,平均眼压就增加 1.289 mmHg(95% CI: 0.906, 1.671)。对术前 PD 值进行校正后,ACD、眼轴长度、颞侧房角与平均 IOP 无显著相关性。
结论:PD 比值是影响术后 3wk 眼压变化的单一重要因素。
关键词:眼压;前房参数;眼压-前房深度比值;纵向研究

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Abstract
• AIM: To assess the changes in anterior chamber parameters and examine the factors associated with changes in the intraocular pressure (IOP) in individuals who have undergone phacoemulsification surgery.
• METHODS: It was a longitudinal analysis of secondary clinical data collected from 105 non-glaucomatous eyes (of 82 patients) undergoing a cataract surgery. We studied the association between anterior chamber parameters, grade of cataract, demographics, and changes in the IOP over a period of 3wk. We also evaluated the association between the pressure-depth (PD) ratio and changes in the IOP during this time.
• RESULTS: The mean age [standard deviation (SD)] of the 82 patients was 60.1 (7.8) years. The mean SD IOP was 15.06 (3.36) mmHg pre-operatively; it increased to 15.75 (4.21) mmHg on day one (P = 0.20). In the multifactorial models, the mean IOP was -1.715 [95% confidence intervals (CI): -2.795, -0.636] mmHg on day 21 (±5) compared with the pre-operative values. The anterior chamber depth (ACD), axial length, age, sex, and grade of cataract were not significantly associated with changes in the IOP. Each unit increase in the PD ratio was associated with an increase in the mean IOP by 1.289 mmHg (95% CI: 0.906, 1.671). After adjusting for pre-operative PD ratio, none of the other variables (ACD, axial length, temporal angle) were significantly associated with changes in mean IOP.
• CONCLUSION: The PD ratio was the single most important factor associated with the changes in post-operative IOP over 3wk post surgery.
• KEYWORDS: intraocular pressure; anterior chamber parameters; pressure-depth ratio; longitudinal analysis
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INTRODUCTION

Phacoemulsification accompanying intraocular lens implantation is a common ocular surgery. It has been suggested that the intraocular pressure (IOP) decreases after phacoemulsification surgery in normal eyes, eyes with ocular hypertension, and in glaucomatous eyes (both closed angle and open angle glaucoma)[1-6]. Some authors have found that the reduction in IOP was higher in eyes with ocular hypertension and glaucoma[6-7]. Furthermore, Hayashi *et al*[2] found that the percentage reduction in the IOP was higher in individuals with angle closure glaucoma (ACG) compared with those with open angle glaucoma (OAG).

Previous studies have reported changes in the anterior chamber parameters after phacoemulsification surgery. For instance, some studies have shown that there is an increase in the angle width after surgery[7-9]. Another study by Nonaka *et al*[10] found that cataract surgery had changed the anterior position of the ciliary processes along with dissolution of lens volume–they proposed that these factors contribute to widening of the angle in these patients. Even though reduction in IOP after cataract surgery has been well documented in literature[11-16], not all studies have supported this finding. For instance, Turk *et al*[17] did not find any change in the IOP in normotensive eyes after phacoemulsification surgery.

The changes in the anterior chamber outcomes and ocular haemodynamics have been assessed using numerous parameters[2,4,6-10,17-20]. Some authors have reported that pre-operative IOP is an important predictor of post-operative reduction in the IOP[11-12]. However, Issa *et al*[21] suggested a unique ratio–the pressure/depth ratio (PD Ratio). It is the ratio of the pre-operative intraocular pressure to pre-operative anterior chamber depth. It has been shown that PD ratio is a useful predictor of changes in the IOP post-surgery[18,21]. Most of these studies have just analysed pre-and post-surgery parameters or used multiple cross-sectional data. However, some of the factors that influence the IOP (such as anterior chamber parameters) change over time. Thus, longitudinal analyses that take into account these changes over time will be useful to understand the factors associated with IOP after phacoemulsification. Thus, we designed the present study to assess the changes in anterior chamber parameters and examine the factors associated with changes in IOP in individuals who have undergone phacoemulsification surgery.

SUBJECTS AND METHODS

The present study is a longitudinal analysis of secondary clinical data collected from 105 non-glaucomatous eyes (of 82 patients) undergoing a cataract surgery.

Study Site　The study was conducted at Laxmi Eye Institute. It is a private tertiary care centre in Panvel (about 50 km from Mumbai, Maharashtra), India. The institute evaluates about 150-200 patients on an outdoor basis and has a range of sub-specialties such as cataract, vitreo-retinal ophthalmology, glaucoma, neuro-ophthalmology, community ophthalmology, and paediatric ophthalmology.

Study Participants　All patients who had an uneventful phacoemulsification cataract surgery were included for the present analysis. All the surgeries were conducted using Infiniti Vision System (Alcon, USA) by single surgeon (Haldipurkar SH). We included the following participants for the study: 1) those between the ages of 40 and 70 years; 2) those with an IOP of less than 22 mmHg; 3) those with nasal and temporal angles greater than 18°; 4) axial length between 21 and 26 mm; 5) no history of ocular intervention or trauma. We excluded the following participants from the study: 1) known cases of glaucoma, chronic uveitis, ocular surface pathology, or recurrent uveitis; 2) patients with previous ocular surgeries; 3) patients who experienced intraoperative or postoperative complications such as posterior capsular rent, zonular dialysis, or prolonged postoperative inflammation.

We abstracted the following variables from the: 1) demographics (age, sex); 2) eye (right or left); 3) best corrected visual acuity (BCVA) using logMAR values; 4) anterior chamber depth (ACD); 5) nasal and temporal anterior chamber angles (ACA); 6) intraocular pressure. The Haag Streit anterior segment optical coherence tomography (AS-OCT) (Heidelberg Engineering, Germany) was used to assess the anterior chamber morphology. All the patients were instructed to keep the head erect on the chinrest, use a forehead strap, and look straight. All the readings were measured by a single observer. A slit lamp biomicroscopy attached to the OCT was used for assessing the parameters. The IOP was measured on Goldmann applanation tonometry on the slit lamp biomicroscopy by a single observer in a time frame of 10a. m. to 2p. m. We abstracted these data points for the following days: pre-operative, day 1, day 7 (±3), and day 21 (±5).

Variables and Statistical Analysis　The primary outcome variable was IOP. We used the following explanatory variables for the analysis: anterior chamber depth, nasal angle, temporal angle, grade of cataract, age, and sex. We also evaluated the association between the PD ratio and changes in the IOP over a period of 3wk.

We calculated the means and SDs for continuous variables and proportions for the categorical variables. We calculated the medians and interquartile range (IQR) for non-parametric data. The means were compared using *t*-test for two groups and the Analysis of Variance (ANOVA) across the four data points. We used the Kruskal-Wallis test for non-parametric data. We then used random effects linear regression models for analysis of changes in the IOP over a period of 21d. The ordinary regression model will consider each data point as separate. However, in the random effects model, we can account for the fact that multiple observations come from the same individual, and the multiple observations in the same individual are correlated. Thus, these models account for between-and within-individual correlation and are a useful alternative for longitudinal data with time varying variables[22-23]. We built the models in the following sequence: 1) null model with no variables; 2) univariate models; 3) multivariate models with explanatory variables and potential confounders (grade of cataract, age, and sex). We built separate multivariate models for each of the primary explanatory variables (anterior chamber depth, nasal angle, and temporal angle). We used Akaike Information Criteria for assessing the different models.

The study was approved by the Institutional Ethics Committee of Laxmi Eye Institute.

RESULTS

The mean age (SD) of the 82 patients was 60.1 (7.8) years.

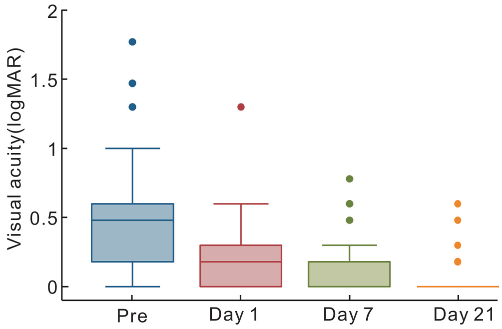

Figure 1　Box Plot showing the change in the median logMAR values of BCVA in 105 patients over a 21-day follow-up, Mumbai, India.

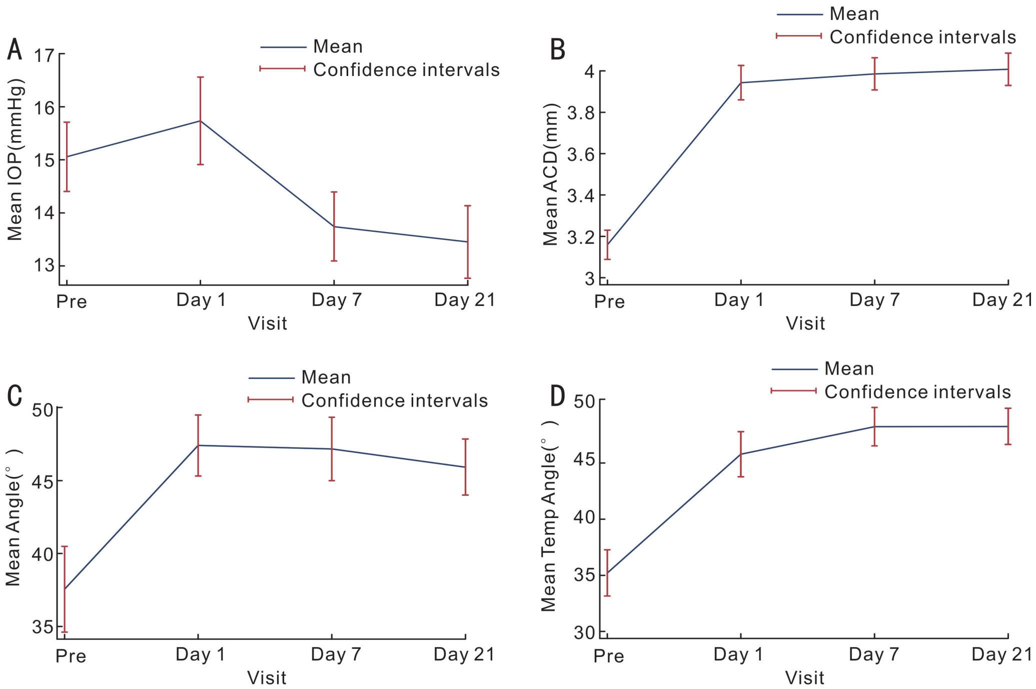

Figure 2　Figures showing the changes in parameters in 105 eyes over a 21-day follow-up, Mumbai, India　A: the change in the mean IOP; B: the change in the mean ACD; C: the change in the mean anterior chamber nasal angle; D: the change in the mean anterior chamber temporal angle. IOP: Intraocular pressure; ACD: Anterior chamber depth.

About 52% of the patients were men and 48% were women; the mean (SD) age of 43 males was 58.8 (8.0) years and of 39 females was 61.6 (7.5) years (P=0.10). In our study, about 24% of the eyes had Grade Ⅰ cataract, 48% had Grade Ⅱ cataract, 15% had Grade Ⅲ cataract, 4% had Grade Ⅳ cataract, and 10% had other forms of cataract. The proportion of right eyes was 54% and left eyes were 46%. The mean axial length (SD) of all the eyes was 23.4 (0.98) units. The median BCVA[IQR (SD)] pre-operatively was 0.53 (0.44) logMAR values (Figure 1).

The mean (SD) IOP was 15.06 (3.36) mmHg pre-operatively. The mean (SD) IOP increased to 15.75 (4.21) mmHg in the immediate post-operative period; this increase, however, was not statistically significant (P=0.20). By the third visit the mean (SD) IOP, however, reduced to 13.45 (3.31) mmHg; the mean changes over these four observations was statistically significant (P<0.001) (Figure 2A). The mean (SD) of the ACD was 3.16 (0.37) units in the pre-operative. The mean values increased in every post-operative visit and it was 4.01 (0.38) units at the third follow-up visit; the difference across all these four visits was statistically significant (P<0.001) (Figure 2B). There were significant increases in the mean nasal and temporal angle chamber angles across the four observation points (Table 1 and Figures 2C and 2D). There was a significant reduction (P<0.001) in the logMAR values of the BCVA over the three post-operative visits (Figure 1). Additional data on the means and standard deviations are presented in Table 1, and Figures 1, 2 and 3.

In the unifactorial random effects models, we found that there was an increase in the IOP on day one post-operatively [0.678, 95% confidence intervals (CI): -0.023, 1.379] compared with the pre-operative levels, even though this change was not statistically significant. However, there was a significant reduction in the IOP in the second (-1.338, 95% CI: -2.051, -0.625) and third visits (-1.756, 95% CI: -2.478, -1.033) compared with pre-operative levels. This relation was maintained even after adjusting for potential

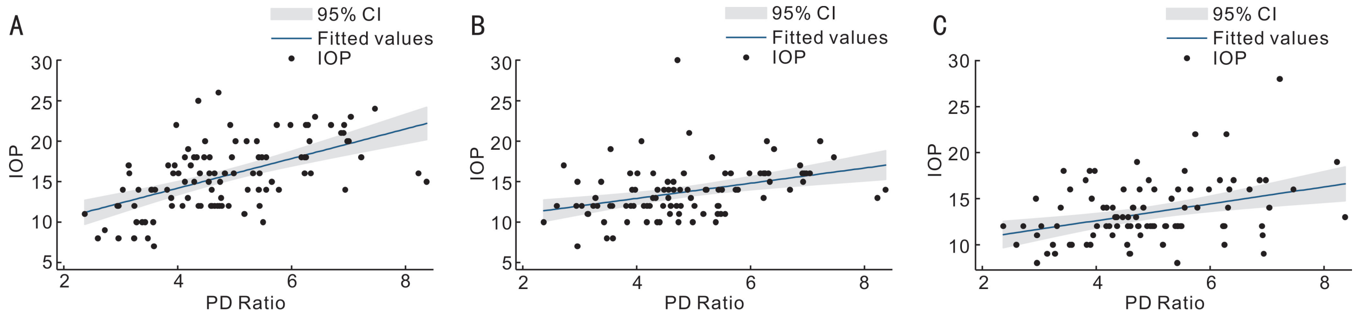

Figure 3　Figures showing relationship between the pressure to depth ratio (PD ratio) and intraocular pressure (IOP) in 105 eyes over the first 21 post-operative days, Mumbai, India　A: the relation between the PD ratio and IOP intraocular pressureon day 1; B: the relation between the PD ratio and IOP intraocular pressure on day 7; C: the relation between the PD ratio and IOP intraocular pressure on day 21.

Table 1　Various ocular parameters in 105 eyes that underwent phacoemusification surgery, Mumbai, India　mean (SD)

Ocular parameters	Pre-operative	Visit 1	Visit 2	Visit 3	*P*
Anterior chamber depth	3.16 (0.37)	3.94 (0.42)	3.99 (0.39)	4.01 (0.38)	<0.001
Intraocular pressure	15.06 (3.36)	15.74 (4.21)	13.74 (3.24)	13.45 (3.31)	<0.001
Nasal-anterior chamber angle	37.54 (14.85)	47.40 (10.47)	47.16 (10.78)	45.92 (9.30)	<0.001
Temporal-anterior chamber angle	35.21 (10.40)	45.80 (10.12)	48.25 (8.48)	48.27 (7.80)	<0.001
Best corrected visual acuity[a]	0.48(0.18, 0.60)	0.18 (0.00, 0.30)	0.18 (0.00, 0.18)	0.00 (0.00, 0.00)	<0.001

Visit 1: Day 1 (±1); Visit 2: Day 7 (±3); Visit 3: Day 21 (±5); [a]Median (inter-quartile range); Compared using the Kruskal-Wallis test.

Table 2　Estimates and confidence intervals from linear random effects models for intraocular pressure in 105 eyes, Mumbai, India

Parameters	Unifactorial models	Multifactorial models		
		Model Ⅰ	Model Ⅱ	Model Ⅲ
	Estimate(95% *CI*)	Estimate(95% *CI*)	Estimate(95% *CI*)	Estimate(95% *CI*)
Intraocular pressure				
Pre-operative	Reference	Reference	Reference	Reference
Visit 1	0.678 (-0.023, 1.379)	0.750(-0.264, 1.764)	0.345 (-0.423, 1.113)	0.906 (0.105, 1.706)
Visit 2	-1.338 (-2.051, -0.625)[a]	-1.299 (-2.347, -0.250)[a]	-1.641 (-2.412, -0.871)[a]	-1.050 (-1.902, -0.199)[a]
Visit 3	-1.756(-2.478, -1.033)[a]	-1.715 (-2.795, -0.636)[a]	-1.975 (-2.742. -1.208)[a]	-1.427 (-2.287, -0.568)[a]
Anterior chamber depth (per unit increase)	-0.756 (-1.352, -0.160)	-0.025 (-0.955, 0.905)	-	-
Nasal angle (per unit increase)	0.019 (-0.011, 0.048)	-	0.038 (0.008, 0.069)	-
Temporal angle (per unit increase)	-0.044 (-0.073, -0.014)[a]	-	-	-0.018 (-0.053, 0.017)
Axial length (per unit increase)	-0.471 (-1.009, 0.068)	-0.520 (-1.090, 0.050)	-0.570 (-1.120, -0.020)[a]	-0.459 (-1.019, 0.099)
Age (per year increase)	0.002 (-0.068, 0.073)	0.015 (-0.058, 0.087)	0.012 (-0.060, 0.084)	0.017 (-0.056, 0.090)
Sex				
F	Reference	Reference	Reference	Reference
M	-0.068 (-1.133, 0.997)	0.056 (-1.018, 1.130)	0.064 (-1.004, 1.132)	0.147 (-0.933, 1.227)
Grade of cataract				
Grade Ⅰ	Reference	Reference	Reference	Reference
Grade Ⅱ	-0.794 (-2.125, 0.537)	-1.083 (-2.446, 0.280)	-1.153 (-2.497, 0.190)	-1.117 (-2.478, 0.242)
Grade Ⅲ/Ⅳ	-0.286 (-1.910, 1.337)	-0.307 (-1.909, 1.294)	-0.742 (-2.367, 0.884)	-0.712 (-2.356, 0.933)
Others	-0.104 (-2.110, 1.903)	-0.402 (-2.402, 1.598)	-0.519 (-2.491, 1.452)	-0.447 (-2.441, 1.548)

Visit 1:Day 1 (±1); Visit 2:Day 7 (±3); Visit 3:Day 21 (±5); [a]*P*<0.05.

confounders (Table 2 - Models Ⅰ, Ⅱ, and Ⅲ). After adjusting for potential confounders (demographics, grade of cataract, anterior chamber depth, and axial length) we found that mean IOP was higher by 0.750 mmHg (95% *CI*: -0.264, 1.764) on post-operative day one compared with the pre-operative levels. The mean IOP, however, was -1.299(95% *CI*: -2.347, -0.250) mmHg on post-operative day seven (±3d) compared with the pre-operative values. Similarly, the mean IOP was -1.715 (95% *CI*: -2.795, -0.636) mmHg on day 21 (±5d) compared with the pre-operative values. Furthermore, the anterior chamber depth, axial length, age, sex, and grade of cataract were not significantly associated with changes in the IOP in our participants.

In the unifactorial random effects models in which the pre-operative PD ratio was included as an explanatory variable, we found that the mean IOP was significantly lower in the second and third visits (Table 3, Unifactorial Models). Further each

Table 3 Estimates and confidence intervals from linear mixed effects models for association between intraocular pressure and pressure to depth ratio (PD ratio) in the post-operative period in 105 eyes, Mumbai, India

Parameters	Unifactorial models	Multifactorial models			
	Estimate(95% *CI*)	Model Ⅰ	Model Ⅱ	Model Ⅲ	Model Ⅳ
		Estimate(95% *CI*)	Estimate (95% *CI*)	Estimate(95% *CI*)	Estimate(95% *CI*)
Intraocular pressure					
Visit 1	Reference	Reference	Reference	Reference	Reference
Visit 2	-2.003 (-2.737, -1.269)[a]	2.280 (-0.497, 5.058)	2.081 (-0.705, 4.868)	2.136 (-0.636, 4.908)	1.942 (-0.851, 4.734)
Visit 3	-2.424 (-3.170, -1.678)[a]	1.772 (-1.071, 4.614)	1.582 (-1.270, 4.434)	1.499 (-1.334, 4.332)	1.317 (-1.539, 4.174)
PD Ratio (per unit increase)	1.289 (0.906, 1.671)[a]	1.839 (1.334, 2.343)[a]	1.810 (1.304, 2.316)[a]	1.817 (1.307, 2.327)[a]	1.741 (1.221, 2.261)[a]
Anterior chamber depth (per unit increase)	-0.832 (-2.019, 0.353)	-	0.291 (-0.764, 1.346)	-	-
Nasal angle (per unit increase)	0.057 (0.011, 0.102)[a]	-	-	0.060 (0.021, 0.099)[a]	-
Temporal angle (per unit increase)	-0.058 (-0.106, -0.010)[a]	-	-	-	-0.017 (-0.060, 0.025)
Axial length (per unit increase)	-0.550 (-1.096, -0.004)[a]	-0.104 (-0.617, 0.409)	-0.076 (-0.596, 0.443)	-0.154 (-0.639, 0.331)	-0.036 (-0.553, 0.480)
Age (per year increase)	0.018 (-0.057, 0.092)	0.016 (-0.049, 0.082)	0.021 (-0.044, 0.086)	0.020 (-0.044, 0.084)	0.022 (-0.044, 0.088)
Sex					
F	Reference	Reference	Reference	Reference	Reference
M	-0.016 (-1.132, 1.101)	0.127 (-0.836, 1.089)	0.210 (-0.751, 1.170)	0.064 (-0.869, 0.997)	0.197 (-0.775, 1.169)
Grade of cataract					
Grade Ⅰ	Reference	Reference	Reference	Reference	Reference
Grade Ⅱ	-0.541 (-1.964, 0.881)	-0.345 (-1.593, 0.902)	-0.510 (-1.760, 0.740)	-0.362 (-1.579, 0.855)	-0.479 (-1.737, 1.213)
Grade Ⅲ/Ⅳ	-0.255 (-1.983, 1.472)	-0.089 (-1.549, 1.369)	-0.236 (-1.695, 1.223)	-0.071 (-1.513, 1.370)	-0.287 (-1.787, 0.779)
Others	0.139 (-1.989, 2.267)	0.259 (-1.547, 2.065)	0.160 (-1.634, 1.953)	0.199 (-1.535, 1.932)	0.128 (-1.683, 1.938)
Interaction terms					
PD Ratioat Visit 2	-	-0.886 (-1.439, -0.332)[a]	-0.855 (-1.409, -0.300)[a]	-0.853 (-1.407, -0.299)[a]	-0.808 (-1.367, -0.248)[a]
PD Ratioat Visit 3	-	-0.866 (-1.428, -0.304)[a]	-0.838 (-1.402, -0.275)[a]	-0.783 (-1.345, -0.222)[a]	-0.756 (-1.324, -0.189)[a]

Visit 1: Day 1 (±1); Visit 2: Day 7 (±3); Visit 3: Day 21 (±5); [a]$P<0.05$.

unit increase in the pre-operative PD ratio was associated with an increase in the mean IOP by 1.289 mmHg (95% *CI*: 0.906, 1.671). After adjusting for other potential confounders, we found that there was an interaction between visit and the pre-operative PD ratio. Thus, even though the mean IOP increased significantly with a unit increase in the pre-operative PD ratio (1.839, 95% *CI*: 1.334, 2.343), the mean reduction was significantly higher with a per unit increase in the PD ratio in visit two (-0.886, 95% *CI*: -1.439, -0.332) and three (-0.866, 95% *CI*: -1.428, -0.304) respectively compared with visit one. Furthermore, after adjusting for pre-operative PD ratio, none of the other variables (anterior chamber depth, axial length, temporal angle) were significantly associated with changes in mean IOP. A unit increase in the nasal angle, however, was associated with a mean increase of 0.060 mmHg (95% *CI*: 0.021, 0.099) in the IOP.

DISCUSSION

Thus, we found that after a transient increase in the IOP in patients on 1d following phacoemulsification, there was a significant reduction in the IOP over a period of 3wk. These changes in IOP were not associated with anterior change depth, axial length, or grade of cataract. The interaction between PD ratio and post-operative time was statistically significant: the mean increase in IOP was significantly higher with per unit increase in PD ratio; however, the mean reduction was significantly higher in individuals with higher PD ratios on post-operative day seven and day 21.

It is well documented that optical parameters change after cataract surgery. Kucumen *et al*[9] measured the angle-referenced, pupil referenced, and lens referenced values of ACD. They found that even though the ACD increased in all these three types of measurements, the increase stabilised after 1wk. We observed that the increase was more marked on the first day after surgery and in smaller amounts later on. These changes were also observed by multiple researchers in patients with glaucoma[24-25]. The changes in angle, however, have had mixed outcomes. Some authors have reported that the width of the angle increased post-operatively and it was associated with pre-operative angle measurement[26-27]. However, Hayashi *et al*[24] did not report any significant differences the angles in patients with normal or glaucomatous eyes. Though, we did find that the width of the temporal and nasal angles increased, the width of the nasal reduced a bit after reaching the peak values on the first post-operative day. However, the width of the temporal angle increased progressively during the follow-up period.

As discussed earlier, phacoemulsification is known to reduce IOP in cataract patients (with or without glaucoma)[2,12,15]. A proposed hypothesis for this reduction is facilitation of aqueous flow due to changes in the angle[21,24,28]. The effect on the ciliary body is another potential reason for the reduction in aqueous humour[21,29]. As observed in our data, the reduction in IOP was not significantly associated with changes in ACD or the width of the temporal angle. Though many authors have found no association between ACD and IOP, others have found an association between them[11,12,30]. Kashiwagi *et al*[31] reported that the ACD increased and IOP decreased significantly in patients in whom the pre-operative ACD was shallow. However, Altan *et al*[11] found that there was no association between the decrease in IOP, and ACD or the iridocorneal angle.

In our study, we found that pre-operative PD ratio was consistently associated with changes in the IOP. In general, higher the preoperative PD ratio, higher was the IOP at each follow-up visit (multifactorial models). However, with each successive visit the reduction was faster in individuals with a higher pre-operative PD ratio. Though, in our study we had included only individuals in whom the pre-operative IOP was not high. Zamani *et al*[6] found that IOP reduced in individuals with and without ocular hypertension. Thus, pre-operative PD ratios could be an important predictor of changes of the IOP in individuals with ocular hypertension and should be considered as an important variable in predicting the post-operative IOP.

The study was not without its limitations. This was a clinic-based study; hence, the results may have limited generalisability. Furthermore, we included only individuals with normal IOP in the current analysis. Thus, some of the estimates may not be similar in patients with ocular hypertension. In addition, we had follow-up data for the first three weeks; the long terms changes in IOP have not been assessed by the present study.

Nonetheless, in spite of the above limitations, the present study is a useful contribution to the literature on the changes of IOP after uneventful phacoemulsification surgery. We performed a longitudinal analysis of changes in the ocular parameters and IOP over a period of three-week post-surgery. Thus, we accounted for the longitudinal changes of the ACD, axial length, and the angles. After accounting for potential confounders, we found that the PD ratio appears to be an important factor associated with the changes in post-operative IOP. Even though, the mean IOP is higher in individuals with a high PD ratio, the reduction is significantly faster on days 15 and 21 in these individuals.

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