Factors affecting changes in the intraocular pressure after phacoemulsification surgery

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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 is a longitudinal analysis of secondary clinical data collected from 105 non-glaucomatous eyes (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 three weeks. We also evaluated the association between the pressure-depth (PD) ratio and changes in the IOP during this time.

• RESULTS: The mean age (SD) of the 82 patients was 60.1±7.8y. The mean±standard deviation (SD) IOP was 15.06±3.36 mm Hg pre-operatively; it increased to 15.75±4.21 mm Hg on day one ($P=0.20$). In the multifactorial models, the mean IOP was -1.715 (95%CI: -2.795, -0.636) mm Hg 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 mm Hg (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 three weeks 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 (IOP) pressure 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 consider 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

Ethical Approval The study was approved by the Institutional Ethics Committee of Laxmi Eye Institute. Written informed consent was obtained from the patients.

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

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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 pediatric 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 70y; 2) those with an IOP of less than 22 mm Hg; 3) those with nasal and temporal angles greater than 18°; 4) axial length between 21 and 26 mm; and 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; and 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); and 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 10 a.m. to 2 p.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 standard deviations (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. We built the models in the following sequence: 1) null model with no variables; 2) univariate models; and 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.

**RESULTS**

The mean age ±SD of the 82 patients was 60.1±7.8y. About 52% of the patients were men and 48% were women; the mean±SD age of 43 males was 58.8±8.0y and of 39 females was 61.6±7.5y (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 (IQR) ±SD BCV A pre-operatively was 0.53±0.44 logMAR values (Figure 1). The mean±SD IOP was 15.06±3.36 mm Hg pre-operatively. The mean±SD IOP increased to 15.75±4.21 mm Hg 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 mm Hg; 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, Figures 2C, 2D). There was a significant reduction (P<0.001) in the logMAR values of the BCV A over the three post-operative visits (Figure 1). Additional data on the means and standard deviations are presented in Table 1, 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%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 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 mm Hg (95%CI: -0.264, 1.764) on post-operative day one compared with the pre-

![Figure 1 Box Plot showing the change in the median logMAR values of best corrected visual acuity in 105 patients over a 21-day follow-up, Mumbai, India.](image)

**Table 1 Various ocular parameters in 105 eyes that underwent phacoemulsification surgery, Mumbai, India**

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

Visit 1: Day 1±1; Visit 2: Day 7±3; Visit 3: Day 21±5. *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**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unifactorial models estimate (95%CI)</th>
<th>Multifactorial models Estimate (95%CI)</th>
<th>Multifactorial models Estimate (95%CI)</th>
<th>Multifactorial models Estimate (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intraocular pressure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-operative</td>
<td>Reference</td>
<td>0.678 (-0.023, 1.379)</td>
<td>0.750 (-0.264, 1.764)</td>
<td>0.345 (-0.423, 1.113)</td>
</tr>
<tr>
<td>Visit 1</td>
<td>0.750 (-0.264, 1.764)</td>
<td>-1.299 (-2.347, -0.250)</td>
<td>-1.641 (-2.412, -0.871)</td>
<td>-1.050 (-1.902, -0.199)</td>
</tr>
<tr>
<td>Visit 2</td>
<td>-1.299 (-2.347, -0.250)</td>
<td>-2.051 (-3.103, -1.001)</td>
<td>-2.542 (-3.594, -1.489)</td>
<td>-1.902 (-2.754, -1.049)</td>
</tr>
<tr>
<td>Visit 3</td>
<td>-2.051 (-3.103, -1.001)</td>
<td>0.019 (-0.011, 0.048)</td>
<td>0.338 (0.009, 0.669)</td>
<td>-</td>
</tr>
<tr>
<td>Anterior chamber depth (per unit increase)</td>
<td>-0.756 (-1.352, -0.160)</td>
<td>-0.025 (-0.955, 0.905)</td>
<td>-0.038 (0.008, 0.069)</td>
<td>-</td>
</tr>
<tr>
<td>Nasal angle (per unit increase)</td>
<td>0.019 (-0.011, 0.048)</td>
<td>0.015 (-0.058, 0.087)</td>
<td>0.012 (-0.060, 0.084)</td>
<td>0.017 (-0.056, 0.090)</td>
</tr>
<tr>
<td>Temporal angle (per unit increase)</td>
<td>-0.044 (-0.073, -0.014)</td>
<td>-0.025 (-0.955, 0.905)</td>
<td>-0.038 (0.008, 0.069)</td>
<td>-</td>
</tr>
<tr>
<td>Axial length (per unit increase)</td>
<td>-0.471 (-1.009, 0.068)</td>
<td>-0.520 (-1.090, 0.050)</td>
<td>-0.570 (-1.120, -0.020)</td>
<td>-0.459 (-1.019, 0.099)</td>
</tr>
<tr>
<td>Age (per year increase)</td>
<td>0.002 (-0.068, 0.073)</td>
<td>-0.025 (-0.955, 0.905)</td>
<td>-0.038 (0.008, 0.069)</td>
<td>-</td>
</tr>
<tr>
<td>Sex</td>
<td>F</td>
<td>Reference</td>
<td>0.056 (-1.018, 1.130)</td>
<td>0.064 (-1.004, 1.132)</td>
</tr>
<tr>
<td>Grade of cataract</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade I</td>
<td>Reference</td>
<td>-0.668 (-1.133, 0.997)</td>
<td>0.056 (-1.018, 1.130)</td>
<td>0.064 (-1.004, 1.132)</td>
</tr>
<tr>
<td>Grade II</td>
<td>-1.083 (-2.446, 0.280)</td>
<td>-0.123 (-1.180, 1.000)</td>
<td>-0.133 (-1.199, 0.936)</td>
<td>-0.133 (-1.199, 0.936)</td>
</tr>
<tr>
<td>Grade III/IV</td>
<td>-1.083 (-2.446, 0.280)</td>
<td>-0.123 (-1.180, 1.000)</td>
<td>-0.133 (-1.199, 0.936)</td>
<td>-0.133 (-1.199, 0.936)</td>
</tr>
<tr>
<td>Others</td>
<td>-0.104 (-2.110, 1.903)</td>
<td>-0.402 (-2.402, 1.598)</td>
<td>-0.519 (-2.491, 1.452)</td>
<td>-0.447 (-2.441, 1.548)</td>
</tr>
</tbody>
</table>

Visit 1: Day 1±1; Visit 2: Day 7±3; Visit 3: Day 21±5. *P<0.05.
operative levels. The mean IOP, however, was -1.299 (95% CI: -2.347, -0.250) mm Hg on post-operative 7±3d compared with the pre-operative values. Similarly, the mean IOP was -1.715 (95% CI: -2.795, -0.636) mm Hg 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 unit increase in the pre-operative PD ratio was associated with an increase in the mean IOP by 1.289 mm Hg (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 mm Hg (95% CI: 0.021, 0.099) in the IOP.

DISCUSSION
Thus, we found that after a transient increase in the IOP in patients on day one 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 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). A proposed hypothesis for this reduction is facilitation of aqueous flow due to changes in the angle. The effect on the ciliary body is another potential reason for the reduction in aqueous humour. 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. Kashwagi et al. reported that the ACD increased and IOP decreased significantly in patients in whom the pre-operative ACD was shallow. However, Altan et al. 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 successive visit the reduction was faster in individuals with a higher preoperative PD ratio on the first post-operative day and in smaller amounts later. These changes were also observed by multiple researchers in patients with glaucoma. 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. However, Hayashi et al. 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.
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 generalizability. 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 weeks 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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Conflicts of Interest: Dhamankar R, None; Chandok N, None; Haldipurkar SH, None; Haldipurkar T, None; Shetty V, None; Setia MS, None.


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