Anterior Segment Parameters as Predictors of Intraocular Pressure Reduction After Cataract Surgery in Patients without Glaucoma

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ABSTRACT

Purpose: To investigate the factors that affect the decrease in intraocular pressure (IOP) after cataract surgery.

Materials and Methods: Single-center, retrospective, observational case series. Preoperatively, lens thickness (LT), anterior chamber depth (ACD), angle open distance (AOD), lens vault (LV), iris curvature (IC) and iris thickness (IT) were measured. Pressure/depth ratio (PDR), ACD/LT ratio and lens position (LP) were calculated. Pre- and post-surgical IOP were analyzed as absolute value difference and percent change. The effect of each parameter on IOP change was evaluated with a linear regression model.

Results: Forty-four eyes of 44 patients (23 female, 52.2%) were analyzed. The mean IOP decreased from 17.47±2.99 mmHg to 15.11±2.34 mmHg in the second postoperative month (p <0.001). The absolute IOP difference was 2.36±1.52 mmHg, and the percent change was 0.13±0.07 %. According to the multivariate linear regression analysis, preoperative IOP and ACD/LT were significant predictors of absolute IOP change (p<0.004, p=0.016, respectively, R2=68.5%). According to the percent IOP change, only preoperative IOP was significant (p=0.031, R2=58.6%).

Conclusion: Preoperative IOP and ACD/LT ratio are essential indicators of intraocular pressure change in the non-glaucomatous patient group after cataract surgery. It may be essential to consider these factors for clinical follow-up in patients with a significant reduction in intraocular pressure following cataract surgery.

Keywords: Angle opening distance, Anterior chamber depth, Intraocular pressure reduction, Lens thickness, Pressure/depth ratio.

INTRODUCTION

The effects of cataract surgery on lowering intraocular pressure (IOP) and the preoperative variables that predict this decrease have been the subject of numerous studies.[1-5] In these studies, it is emphasized that the most crucial predictor of IOP decrease is preoperative IOP.[6-11] Especially in primary angle closure glaucoma, the increase in the anterior chamber depth after lens extraction may explain this decrease.[12] However, when the anterior chamber angle is large, the mechanism by which IOP decreases is not precise. With the development of anterior segment OCT and Scheimpflug imaging techniques, the lens and anterior chamber structures can be examined in more detail. In this way, various studies have been conducted to understand the decrease in IOP after cataract surgery by evaluating lens and anterior segment parameters. The parameters such as anterior chamber depth (ACD), lens thickness (LT), lens vault (LV), angle open distance (AOD), and iris thickness (IT), as well as combined parameters such as pressure/depth ratio (PDR) and lens position (LP), have also been shown to be predictive.[6-11]

Studies demonstrate that cataract surgery provides a reduction in IOP. It is less clear how much IOP reduction is expected in which anterior segment morphology. It is still

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a subject of research which of these parameters provide the best prediction. However, this decrease is variable in patients with various anterior segment morphologies; for example, it is more pronounced in narrow-angle glaucoma.[12] It is vital to estimate the amount of IOP reduction after cataract surgery, especially in glaucoma patients' management and treatment plan.

This study aims to find the most specific parameter with the highest accuracy for postoperative IOP reduction after cataract surgery.

MATERIALS AND METHODS

Patients who underwent phacoemulsification surgery in Balıkesir University Faculty of Medicine, Department of Ophthalmology between May 2019 and February 2020 were consecutively included in this retrospective study. Written permission was obtained from the local ethics committee, and this study was performed in accordance with the Declaration of Helsinki.

Inclusion criteria were age >18 years, patients with the best corrected visual acuity (BCVA) level of 0.6 logMAR or less due to cataracts, patients without complications during and after surgery, and patients with IOP 10-21 mmHg. The first eye of the patients who had surgery on both eyes during this period was included in the study. Exclusion criteria were glaucomatous changes in the optic disc, antiglaucomatous medication, pseudoexfoliation, history of ocular trauma, absence of scleral spur on Scheimpflug imaging, and presence of narrow-angle detected by gonioscopy.

Demographic data of the patients, BCVA measured with Snellen chart, the data from slit lamp and fundus examination were recorded. IOP was measured with a Goldmann applanation tonometry in the morning and afternoon by the same ophthalmologist before and two months after the surgery, and the averages of the measurements were recorded.

A-scan biometry (IOL Master 500, Carl Zeiss Meditec, Germany) was used to measure lens thickness (LT) and ACD. Three measurements were taken for each eye, and the average of these values was recorded.

Anterior chamber cross-section images after full mydriasis were taken from vertical and horizontal meridians with a Sirius Scheimpflug camera (CSO, Florence, Italy). This study used an image processing technique previously described by Castro et al.[13] All images were processed by the same ophthalmologist (S.O.) using the same method. AOD, LV, iris curvature (IC), and IT were calculated with this method. AOD was measured as the distance between the posterior corneal surface and the iris surface on a line perpendicular to the trabecular meshwork at a distance of 500 µm in the scleral spur. ACD was the distance between the corneal endothelium and the anterior surface of the lens. Lens vault (LV) was defined as the maximum vertical distance between the horizontal line connecting the two scleral spurs and the anterior lens surface on horizontal Scheimpflug images. IC was calculated as the perpendicular distance from a line between the iris pigment epithelium's most central and most peripheral points to the posterior iris surface at the point of greatest convexity. IT was measured at a distance of 750 µm from the scleral spur. PDR was calculated as preop IOP and ACD ratio. LP was defined as LP= ACD+1/2LT. In addition, ACD/LT was also used in the analysis as a different parameter. Central corneal thickness were also recorded.

Standard phacoemulsification was performed by a single surgeon (MMU), and intracapsular IOL was placed in all patients. Postoperatively, topical moxifloxacin and dexamethasone were administered for three weeks.

Statistical analysis was performed using SPSS software, version 21 (SPSS, Inc., Chicago, IL, USA). Paired t-test was used to compare preoperative and postoperative IOP. Pre- and post-surgical IOP were calculated as absolute value difference and percent change. The effect of each parameter on IOP was evaluated with a linear regression model. Statistical significance was accepted as a p-value of 0.05 or less.

RESULTS

Due to inappropriate Scheimpflug image quality, 21 of 65 patients were excluded from the study. Forty-four patients included in the analysis had a mean age of 68.70±7.56 years, and 23 (52.2%) were female. The mean BCVA before surgery was 0.68±0.32 logMAR and increased to 0.18±0.12 logMAR at two months postoperatively ($p<0.001$). The mean IOP decreased from 17.47±2.99 mmHg to 15.11±2.34 mmHg in the second postoperative month ($p<0.001$). The absolute IOP difference was 2.36±1.52 mmHg, and the percent change was 0.13±0.07 %. Table 1 shows preoperative ocular parameters measured by Scheimpflug images and A-scan biometry.

According to the multivariate linear regression analysis, preoperative IOP and ACD/LT were significant predictors of absolute IOP change ($p<0.004$, $p=0.016$, respectively,

Table 1: *Patient characteristics and ocular parameters befrore surgery*	
Parameter	Mean±SD
Age (years)	68.70±7.56
Gender (female/male)	23/21
CCT (µm)	538.50±33.61
Preop IOP (mmHg)	17.47±2.99
AOD (mm)	0.25±0.08
ACD (mm)	3.22±0.70
LT (mm)	4.92±0.95
LV (mm)	0.52±0.17
IC (mm)	0.30±0.09
IT (mm)	0.39±0.02
PDR	5.66±1.49
LP	5.68±0.85
ACD/LT	0.67±0.18

CCT: central cornea thickness, IOP: intraocular pressure, AOD: angle open distance, ACD: anterior chamber depth, LT: lens thickness, LV: lens vault, IC: iris curvature, IT: iris thickness, PDR: pressure/depth ratio, LP: lens postion

R2=68.5%). According to the percent IOP change, only preoperative IOP was significant (p=0.031, R2=58.6%). Table 2 and Table 3 show univariate and multivariate analysis results according to absolute and percent IOP change.

DISCUSSION

The present study investigated the factors that may affect the decrease in IOP after cataract surgery. As a result, we found that the preoperative IOP and ACD/LT ratio affected the postoperative IOP reduction, and together the R2 value was 68.5%.

It has been reported in many studies that IOP decreased after cataract surgery.[1-5] In the present study, an average of 2.36±1.52 (13%) mmHg IOP decrease was observed, consistent with the literature. The mechanism of phacoemulsification surgery to lower IOP has been the subject of much research but is still not fully understood. Molecular, physiological and biomechanical theories are prominent theories to illuminate this issue.[14,15] In molecular theory, it is stated that ultrasound energy used in surgery causes an increase in IL-1 in the trabecular meshwork, which causes an increase in aqueous flow.[16] Physiological theory is the most supported theory based on increased aqueous flow after widening the anterior chamber angle.[9-12,14] The biomechanical theory, on the other hand, is primarily valid for patients with pseudoexfoliation or pigmentation at the angle. It is based on the effect of washing the angle with the fluid used during surgery.[15]

Table 2: *Univariate and multivariate analysis of the association between preoperative parameters and changes in absolute IOP change*

	Univariate		Multivariate	
	ß (95% CI)	p value	ß (95% CI)	p value
Age (years)	0.092 (0.044 to 0.081)	0.552		
Gender (female/male)	0.101 (-0.629 to 1.241)	0.512		
Preop IOP (mmHg)	0.637 (0.202 to 0.446)	<0.001	0.790 (0.136 to 0.667)	0.004
ACD (mm)	-0.522 (-1.709 to -0.557	0.001	-0.492 (-2.353 to 0.220)	0.101
AOD (mm)	-0.388 (-12.003 to -1.796)	0.009	-0.088 (-5.209 to 2.086)	0.392
LT (mm)	0.253 (-0.077 to 0.884)	0.097		
ACD/LT	-0.560 (-6.653 to -2.458)	0.001	-0.338(-4.966 to -0.531)	0.016
LV (mm)	0.203 (-0.897 to 4.474)	0.186		
IC (mm)	0.156 (-2.453 to 7.466)	0.311		
IT (mm)	-0.193 (-25.947 to 5.826	0.208		
PDR	0.753 (0.561 to 0.980)	<0.001	-0.395 (-1.252 to 0.443)	0.340
LP	-0.289 (-1.054 to 0.016)	0.057		

IOP: intraocular pressure, ACD: anterior chamber depth, AOD: angle open distance, LT: lens thickness, LV: lens vault, IC: iris curvature, IT: iris thickness, PDR: pressure/depth ratio, LP: lens position

Table 3: *Univariate and multivariate analysis of the association between preoperative parameters and changes in percentage IOP change*

	Univariate		Multivariate	
	ß (95% CI)	p value	ß (95% CI)	p value
Age (years)	0.160 (-0.001 to 0.005)	0.301		
Gender (female/male)	0.100 (-0.031 to 0.060)	0.517		
Preop IOP (mmHg)	0.365 (0.002 to (0.016)	0.015	0.675 (0.002 to 0.032)	0.031
ACD (mm)	-0.623 (-0.091 to -0.040)	<0.001	-0.363 (-0.173 to 0.249)	0.717
AOD (mm)	-0.375 (-0.571 to -0.074)	0.012	-0.132 (-0.319 to 0.092)	0.269
LT (mm)	0.226 (-0.006 to 0.041)	0.140		
LV (mm)	0.212 (-0.039 to 0.220)	0.167		
IC (mm)	0.139 (-0.131 to 0.348)	0.367		
IT (mm)	-0.195 (-1.258 to 0.277)	0.204		
ACD/LT	-0.621 (-0.340 to -0.148)	<0.001	-0.996(-0.820 to 0.037)	0.072
PDR	0.651 (0.020 to 0.044)	<0.002	-0.647 (-0.080 to 0.016)	0.182
LP	-0.389 (-0.059 to -0.009	0.009	-0.820 (-0.190 to 0.048)	0.235

IOP: intraocular pressure, ACD: anterior chamber depth, AOD: a ngle open distance, LT: lens thickness, LV: lens vault, IC: iris curvature, IT: iris thickness, PDR: pressure/depth ratio, LP: lens position

In numerous studies, preoperative IOP has been cited as the most reliable predictor of IOP decrease, and R2 between 20-45% has been reported.[7,17,18] The present study confirmed that preoperative IOP was the most influential factor in absolute IOP change, and the R2 value was 40.5%. However, in the IOP percentage change, the R2 value decreases to 13.3% in the preoperative IOP. A previous study stated a similar predictability of preoperative IOP in percent IOP change with an R2 value of 18.5%.[17] This difference in R2 value between absolute and percent IOP change arises because the percentage change reduces the effect of the baseline IOP value. In addition, the differences between the mean preoperative IOP values in the studies may also cause this difference.

Anterior segment parameters have been discussed in many studies to predict IOP reduction. Although ACD was found to be significant in a few studies [6,7], on the contrary, others showed that it was not an indicator on its own.[9-11] The present study revealed that ACD was significant only in univariate analysis for absolute and percent IOP change. This difference is because the ACD indirectly indicates the anterior chamber angle. This effect is particularly increased in patients with a lower preoperative ACD. Another parameter considered is AOD, an essential parameter for showing the angle.[19] The crystalline lens pushes the peripheral iris forward, narrowing the anterior chamber angle, but this angle may widen after cataract surgery.[11,20,21]

The reduction in IOP after cataract surgery has been demonstrated in patients with narrow-angle glaucoma. The amount of IOP decrease is more tremendous at narrow and wide angles.[12,13] Our results differ slightly because the predictive effect of AOD was detected only in univariate analysis. Different amounts of AOD change after surgery in patients with narrow and wide angles may explain the different results in our study. LT is an essential parameter with contradictory outcomes regarding its ability to predict changes in absolute IOP.[9,10,22] In our study, LT was not a significant independent predictor, either. On the other hand, LV represents the portion of the lens anterior to the scleral spur, may represent the lens' role in angle-closure more than LT, and has been shown to be an independent risk factor for angle-closure glaucoma.[23] Although LV was predictive regarding IOP reduction in some studies[12], no significant association was found in some studies.[10,22,24] This difference may be due to differences in ACD. LV alone may not be effective in patients with larger ACDs. However, LV may show higher predictive properties, especially in narrow-angle patients.

Combinations of various parameters have been studied to predict IOP reduction after cataract surgery better. The studies in the literature aim best to predict postoperative IOP reduction with the simplest combinations. PDR is one of them, and in one study, the R2 value was 73% in predicting IOP two months after cataract surgery.[6] However, in other studies, this rate was found to be 31.4% and 45.1%.7,25 In our study, this rate was 56.7% and 42.3% for absolute change and percent change, respectively. Especially in study populations with a smaller preoperative IOP, the predictive value of the PDR may be lower. LP was also found to be predictive of IOP reduction.[7] In the study of Hsu et al., the R2 value was found to be 45.5%.[7] Since both ACD and LT are used in the calculation of LP, we thought it would be a suitable parameter and included LP in the study. However, since we think that considering the LT as a whole will affect the anterior chamber more, we also evaluated the ACD/LT ratio. As a result, although LP was significant in the IOP percentage change in univariate analysis, this significance was lost in multivariate analysis. However, ACD/LT showed significant results in absolute IOP change in multivariate analysis. Unlike LP, considering the entire LT in the ACD/LT ratio may better reflect the postoperative anterior segment parameters change. With preoperative IOP, the predictive value of ACD/LT on postoperative IOP reduction also reaches R2= 68.5%.

The most important limitation of the present study is its retrospective design. Postoperative short-term follow-up is another limitation. However, studies have reported that IOP stabilization is achieved in the second month after cataract surgery and continues for up to 24 months. A relatively small sample size is another limiting factor. In addition, the absence of postoperative Scheimpflug images of the patients prevented us from comparing anterior segment parameters in the postoperative period. However, we did not need postoperative anterior segment parameters to test the hypothesis of our study.

In conclusion, preoperative IOP and ACD/LT ratio are essential indicators of intraocular pressure change after cataract surgery in the non-glaucomatous patient group. ACD and LT measurement are more accessible methods and may provide clinical ease of use.

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