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Anterior Chamber Morphometry before and after Cataract Surgery

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Abstract

Purpose: To quantify the effects of cataract surgery on the anterior chamber topography in patients with angle-closure glaucoma (PACG), open-angle glaucoma (POAG) and patients with no evidence of glaucoma or ocular hypertension.

Materials and methods: 170 eyes of 119 patients undergoing phacoemulsification, followed by posterior chamber intraocular lens implantations (PC IOL), were divided into three groups as follows: PACG (50 eyes, 28 patients), POAG (40 eyes, 29 patients) and a control group (80 eyes, 62 patients). The Pentacam rotating Scheimpflug camera measured the following changes that occurred in the anterior chamber: depth (ACD), volume (ACV), angle (ACA) and central corneal thickness (CCT). Additionally, Goldmann applanation tonometry was used to evaluate intraocular pressure (IOP). All measurements were first taken preoperatively and subsequently at 3 weeks and 3 months postoperatively.

Results: When measured at 3 weeks and 3 months postoperatively, the mean ACD, ACV and ACA increased in all groups ($p<0.0001$), though mostly in group PACG. However, the PACG parameters, at the third week postoperatively, were still smaller than the POAG and control groups by approximately 0.4 mm, 38.5 mm^3, 3.7° ($p<0.05$).

The ACD, ACV and ACA differences between the third week and month postoperatively were statistically insignificant ($p>0.05$).

We also found insignificant postoperative pachymetric changes when compared to the preoperative period ($p>0.05$). The IOP decreased throughout all postoperative periods in all groups, though mostly in PACG eyes ($p<0.05$).

Conclusions: Cataract surgery significantly increased ACD, ACV and ACA in all study groups. The surgery respectively decreased IOP and induced insignificant changes of CCT.

Keywords: Anterior chamber; Cataract surgery; Glaucoma

Introduction

It is well known that the risk of glaucoma and cataract increases with age, and worsens the visual acuity prognosis and, respectively, the quality of life in the elderly community [1,2,4].

When managing coexistent cataract and glaucoma, especially in open-angle glaucoma (POAG), it remains undecided whether to choose a surgical procedure as a separate cataract surgery or combined with filtering surgery in order to achieve optimal values of intraocular pressure (IOP) [5-8].

Several previews of clinical trials proved that cataract surgery improves visual acuity, changes the architectonic of the anterior chamber and reduces IOP both in glaucomatous and non-glaucomatous eyes [2,3,8-29,33]. The surgery can be considered as a primary treatment for the management of angle-closure glaucoma (PACG) [3,8,13,16,20]. However, it has a modest contribution to IOP reduction in POAG cases [12,21,30,31]. On the other hand, the benefits of clear lens extraction, as a primary treatment of IOP elevation in eyes with narrow and occludable angles, are still debated [32].

Evaluating the anterior chamber morphometry may help to better understand the effect of cataract surgery on the lowering of IOP and on the dynamics of aqueous humor [33].

New visualization technologies, such as Pentacam rotating Scheimpflug camera (Oculus Inc., Wetzlar, Germany) help us to perform a reliable quantitative analysis of the anterior segments parameters and any changes following cataract surgery [34]. The rotating Scheimpflug camera offers fast, noncontact and noninvasive measurements of the anterior chamber [35].

The aim of this prospective study was to evaluate early postoperative changes in the anterior chamber configuration (anterior chamber depth (ACD), anterior chamber volume (ACV), anterior chamber angle (ACA) and central corneal thickness (CCT)) at 3 weeks and 3 months after cataract surgery in patients with PACG, compared to

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POAG, and with eyes without glaucoma history. Additionally, we also evaluated the cataract surgery's influence on IOP values in all groups of patients in the pre and post-operative period.

Materials and Methods

In this study, we investigated 170 eyes (93 right eyes (OD) and 77 left eyes (OL)) of 119 patients (83 females (F) and 36 males (M)) who underwent cataract surgery and PC IOL implantation.

We enrolled 90 glaucomatous eyes of 57 patients from the Glaucoma Department of Královské Vinohrady Teaching Hospital, 3rd Faculty of Medicine, Charles University in Prague. We compared them with a reference group of 80 non-glaucomatous eyes of 62 subjects who underwent cataract surgery between January 2012 and December 2013. The case series design was developed as a prospective and non-randomized research study. All the procedures of the study followed the tenets of the Declaration of Helsinki. The content and the purpose of the study were explained in detail to the enrolled patients and a written informed consent was obtained from each participant.

The glaucomatous eyes were divided into 2 groups as follows: group PACG composed of 50 eyes of 28 patients and group POAG composed of 40 eyes of 29 patients.

The non-glaucomatous eyes: the control group represented 80 eyes of 62 patients with senile cataract and no glaucoma evidence.

The exclusion criteria prior to surgery were the following: acute glaucoma attack, previous filtration surgery or other surgical eye intervention, degenerative changes of the cornea (edema, dystrophy, marginal degeneration, pterygium), history of uveitis, long-term corticosteroid instillation, anterior or posterior synechia and ocular trauma.

The exclusion criteria postoperatively were posterior capsule rupture, vitreous herniation, uveitis and other complications following phacoemulsification.

Preoperatively, on the operation day, all patients underwent a visual acuity examination of the Snellen optotypes, followed by a complete slit lamp examination. Afterwards, in order to evaluate the ACD, ACA, ACV and CCT, each patient had measurements done with a Pentacam Scheimpflug rotating camera without a previous instillation of anesthesia or mydriatics.

After the Pentacam assessments, we additionally evaluated the IOP with the Goldmann applanation tonometer and the noted value was an average of the three measurements. In the POAG and PACG groups, IOP measurements were performed with the presence of chronic glaucoma medication. Therefore, in the PACG group 85% of the patients used prostaglandin analogues prior to cataract surgery as monotherapy, while 15% of the patients used a fixed combination of prostaglandin analogues and beta-blockers as bi-therapy. In the POAG group 72.4% of the patients used prostaglandin analogues preoperatively as monotherapy, while 20.7% of the patients used a fixed combination of either prostaglandin analogues and beta-blockers or carboanhydrase inhibitors and beta-blockers as bi-therapy.

Only 6.9% of the POAG patients used tri-therapy prior to the cataract surgery as a combination of prostaglandin analogues, carboanhydrase inhibitors and beta-blockers.

The main purpose of this study was not to detect the effect of cataract surgery on the reduction of the glaucoma therapy. That's why the recommended glaucoma medication has not changed during all follow-up periods.

The cataract surgery was performed by 4 experienced surgeons from the Departments of Ophthalmology of Královské Vinohrady Teaching Hospital, 3rd Faculty of Medicine, Charles University in Prague under topical anesthesia and through a clear corneal incision. In all cases, an acrylic posterior chamber lens was implanted and all surgeries were uneventful. Postoperatively, all patients were prescribed five times daily: topical antibiotics (5 mg/ml Levofloxacinum gtt.-Oftaquix; Santen, Oy, Finland) for one week and steroids (0.1% Dexamethasonum gtt. - Dexamethasone; WZF Polfa S.A., Warsaw, Poland) for three weeks. All measurements were taken by the same examiner as follows: preoperatively on the day of the lens extraction, and three weeks and three months following cataract surgery. The order of the examination was strictly respected during all sessions.

Statistical analysis

A statistical analysis was performed, using Statistical software version 9.0 (Statsoft Inc., Tulsa, OK, USA). To assess the efficacy of cataract surgery, the observed variables (ACD, ACV, ACA, CCT and IOP) in three time intervals (pre-operative, three weeks and three months after cataract surgery) were compared, using an analysis of variance (ANOVA) with repeated measurements in each group separately. To compare all three groups with each other, an analysis of variance (with Bonferroni multiple comparisons tests) were evaluated for each time interval of the follow-up. A value of $p<0.05$ was considered statistically significant.

Results

The mean age of the patients was 71.53 ± 8.98 years, with a range between 47 and 91 years: the control group (mean age 70.54 ± 9.69; Male (eyes)/Female (eyes) ratio: M/F 21(28)/41(52); 44 right eyes, 36 left eyes; n=80), POAG (mean age 73.03 ± 8.81; M/F 8(9)/21(31); 23 right eyes, 17 left eyes; n=40) and PACG (mean age 71.94 ± 7.65; M/F 7(13)/21(37); 26 right eyes, 24 left eyes; n=50).

Both, in the third week and in the third month after cataract surgery, ACD, ACV and ACA increased significantly in all groups of patients and mostly in the PACG group ($p<0.05$). The differences in all values of ACD, ACV and ACA between the third week and the third month, following lens extraction, were statistically insignificant in all groups (Table 1).

In the third week post-surgery, ACD significantly deepened in all study groups ($p<0.0001$). Although the mean ACD doubled in the third week post-surgery compared to the measurement prior surgery, it still remains shallower in the PACG group than in the POAG, and, respectively, in the control group ($p=0.0028$; $p=0.0004$).

Furthermore, in each group we found statistically insignificant differences in ACD values or changes between the three-week and three-month follow-up period (Table1 and Figure 1).

Means ± SD				p-values of multiple Bonferroni test		
Parameters	**Preoperatively**	**3 weeks postoperatively**	**3 months postoperatively**	**Preoperatively vs 3 weeks postoperatively**	**Preoperatively vs 3 months postoperatively**	**3 weeks vs 3 months postoperatively**
Control Group (n = 80, Φ age: 70.54 ± 9.69 years)						
ACD [mm]	2.45 ± 0.44	4.20 ± 0.69	4.29 ± 0.72	<0.0001*†	<0.0001*†	0.3852
ACV [mm^3]	121.87 ± 37.95	175.90 ± 30.25	179.23 ± 31.35	<0.0001†	<0.0001†	0.5276
ACA [°]	28.77 ± 7.22	42.01 ± 4.9	42.32 ± 5.79	<0.0001†	<0.0001†	0.7441
CCT [μm]	557.76 ± 36.16	568.50 ± 40.52	553.55 ± 32.57	0.0764	0.4875	0.0139
POAG (n=40, Φ age: 73.03 ± 8.81 years)						
ACD [mm]	2.36 ± 0.39	4.19 ± 0.59	4.04 ± 0.71	<0.0001*†	<0.0001*†	0.2628
ACV [mm^3]	114.85 ± 32.57	165.67 ± 21.13	166.27 ± 21.41	<0.0001†	<0.0001†	0.9167
ACA [°]	28.96 ± 6.42	42.54 ± 6.20	40.97 ± 5.30	<0.0001†	<0.0001†	0.2426
CCT [μm]	550.42 ± 30.86	563.17 ± 33.72	548.82 ± 27.07	0.0826	0.8265	0.0511
PACG (n=50, Φ age:71.94 ± 7.65 years)						
ACD [mm]	1.80 ± 0.36	3.79 ± 0.66	3.81 ± 0.77	<0.0001*†	<0.0001*†	0.7236
ACV [mm^3]	76.82 ± 24.86	132.24 ± 22.31	134.86 ± 22.45	<0.0001†	<0.0001†	0.5738
ACA [°]	20.74 ± 6.96	38.58 ± 6.34	38.11 ± 5.75	<0.0001†	<0.0001†	0.7117
CCT [μm]	554.38 ± 35.70	569.02 ± 40.57	556.34 ± 36.00	0.0528	0.7942	0.093

Table 1: Clinical data of the study groups as calculated by ANOVA with repeated measurements: p-values of multiple comparisons Bonferroni test. ACD=anterior chamber depth, ACV=anterior chamber volume, ACA=anterior chamber angle, CCT=central corneal thickness, POAG=open-angle glaucoma, PACG=angle-closure glaucoma, *=statistically significant values, p<0.05, †=highly statistically significant values, p<0.0001, vs=versus.

The mean ACV recorded a similar trend of changes as ACD following cataract surgery.

In the first 3 weeks follow-up period, the mean ACV increased significantly in all three groups (p<0.0001), and mostly in the PACG group (Table 1 and Figure 2). However, the mean ACV in the PACG group was, at 3 weeks postoperatively, significantly smaller than in the other two groups (p<0.0001). Furthermore, we found that the mean ACV was significantly smaller in the POAG group at the third week post-surgery than in the control group (p=0.0450).

We did not notice any significant changes in ACV values, in any of the studied groups, between the third week and the third month after cataract surgery (Table 1).

The correlations between ACV values preoperatively and the postoperative changes were statistically significant in each group of patients (p<0.0001). The shallower the anterior chamber prior to cataract surgery, the greater the postoperative change of ACV (Table 1 and Figure 2).

After cataract surgery, the mean ACA widened significantly in all groups by almost 14.6° (p<0.0001). The mean postoperative widening of ACA was greatest in the PACG group (by approximately 17.6°). Compared to the preoperative period, it almost doubled (p<0.0001). In the POAG and control groups, the mean ACA widening was very similar and no significant differences in values were observed between them throughout the whole postoperative period (p>0.05). The correlations between ACA values prior to cataract surgery and postoperative changes were statistically significant in each group of patients (p<0.0001). The narrower the iridocorneal angle prior to cataract surgery, the greater the widening post cataract surgery (Table 1 and Figure 3).

In the third week after cataract surgery, the mean CCT increased insignificantly in all groups (p>0.05), though mostly in the PACG group, followed by the POAG group and by the control group (Table 1 and Figure 4).

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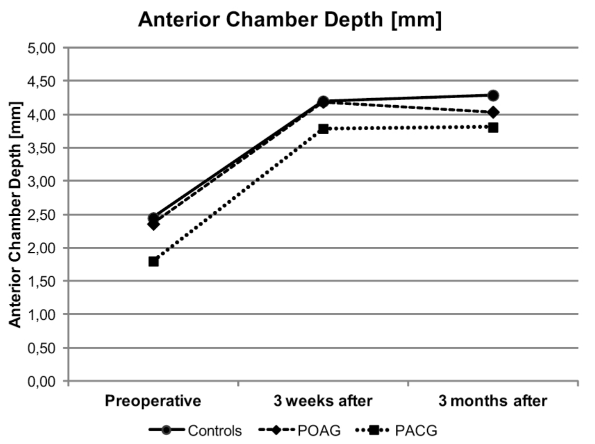

Figure 1: Anterior chamber depth (preoperatively, three weeks and three months after cataract surgery) in three groups of patients: Controls (n=80), POAG (n=40) and PACG (n=50). Controls: Control group; POAG: Open-Angle Glaucoma; PACG: Angle-Closure Glaucoma; 3 weeks after: 3 weeks after cataract surgery; 3 months after: 3 months after cataract surgery.

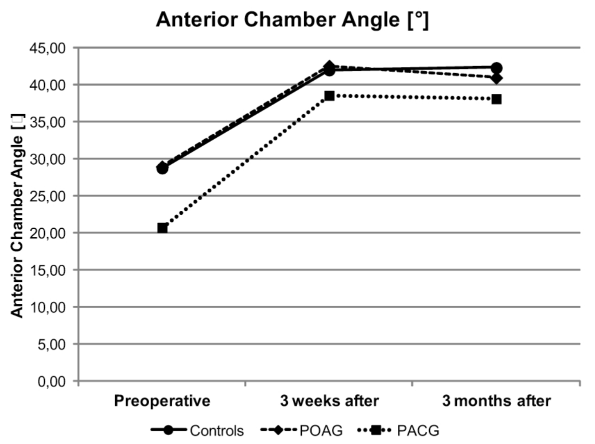

Figure 3: Anterior chamber angle (preoperatively, 3 weeks and 3 months after cataract surgery) in three groups of patients: Controls (n=80), POAG (n=40) and PACG (n=50). Controls: control group; POAG: Open-Angle Glaucoma; PACG: Angle-Closure Glaucoma; 3 weeks after: 3 weeks after cataract surgery; 3 months after: 3 months after cataract surgery.

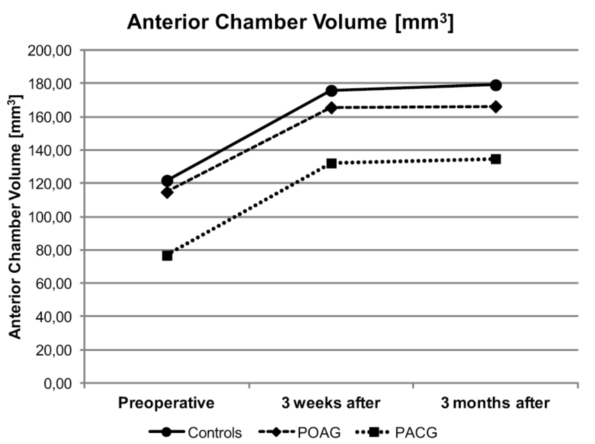

Figure 2: Anterior chamber volume (preoperatively, 3 weeks and 3 months after cataract surgery) in three groups of patients: Controls (n=80), POAG (n=40) and PACG (n=50) Controls: Control group, POAG: Open-Angle Glaucoma, PACG: Angle-Closure Glaucoma; 3 weeks after: 3 weeks after cataract surgery; 3 months after: 3 months after cataract surgery.

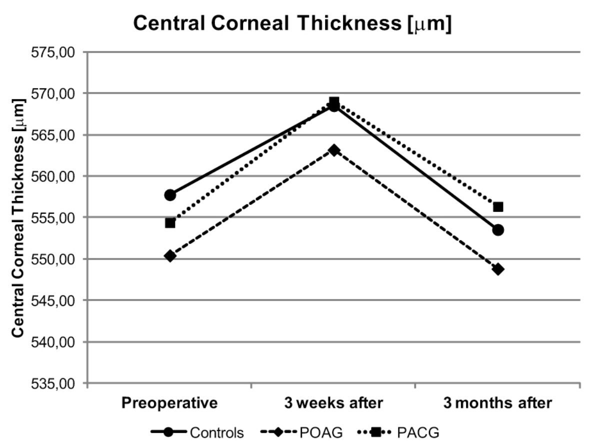

Figure 4: Central corneal thickness (preoperatively, 3 weeks and 3 months after cataract surgery) in three groups of patients: Controls (n=80), POAG (n=40) and PACG (n=50). Controls: Control Group; POAG: Open-Angle Glaucoma; PACG: Angle-Closure Glaucoma; 3 weeks after: 3 weeks after cataract surgery; 3 months after: 3 months after cataract surgery.

Compared to the preoperative period the third month following cataract surgery shows in each group of patients statistically insignificant CCT changes (p>0.05).

Moreover, we also documented that the difference in the values of CCT between the third month and the third week follow-up periods was statistically significant in the control group (p=0.0139; Table 1).

Prior to surgery, the mean IOP in all patients was 17.74 ± 3.48 mmHg. It, then, decreased in the third week following cataract surgery to 15.79 ± 3.59 mmHg and in the third month to 14.34 ± 2.93 mm Hg (p<0.05). The mean IOP in all patients decreased in the third week after cataract surgery by 1.95 ± 3.57 mmHg and in the third month after cataract surgery by 3.4 ± 2.93 mmHg. Differences between the third week and the third month (1.44 ± 2.79 mmHg) were statistically insignificant.

The IOP decreased significantly in all groups during the entire postoperative period, though mostly in the PACG eyes (Figure 5). Thus, the mean postoperative IOP reduction in PACG subjects in the first and second follow-up sessions (3.26 ± 0.12/4.74 ± 0.89 mmHg) was significantly higher (p<0.05) than in the POAG (0.85 ± 0.10/2.85 ± 0.52 mmHg) and control groups (1.68 ± 0.60/2.84 ± 0.08 mm Hg). Furthermore, both in the third week and third month postoperatively no statistically significant differences of the IOP decrease between the Control and POAG groups (p>0.05) were reported.

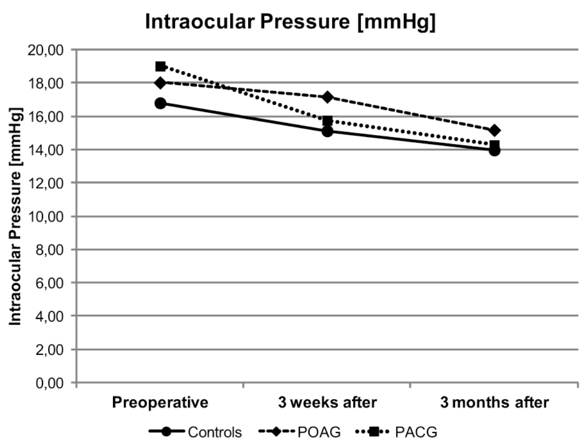

Figure 5: Intraocular pressure (preoperatively, 3 weeks and 3 months after cataract surgery) in three groups of patients: Controls (n=80), POAG (n=40) and PACG (n=50). Controls: Control group; POAG: Open-Angle Glaucoma; PACG: Angle-Closure Glaucoma; 3 Weeks After: 3 weeks after cataract surgery; 3 months after: 3 months after cataract surgery.

Discussion

A few recent clinical studies, based on the use of the Pentacam Scheimpflug rotating camera, demonstrated that cataract surgery induces a significant deepening of the anterior chamber, opening of the iridocorneal angle and a reduction of IOP. This is apparent in both glaucomatous and non-glaucomatous eyes.

Thus, in 2000 Hayashi et al. [23] investigated the changes in ACA and ACD, using a Scheimpflug system one week postoperatively. They continued to investigate during the 1st, 3rd, 6th, 9th and 12th months following cataract surgery in eyes with PACG, POAG and in eyes with no evidence of glaucoma or ocular hypertension. Similarly to us, Hayashi shows that ACD, and ACA respectively, increased significantly postoperatively in all studied groups and mostly in the PACG group. Also, no further significant changes in ACA and ACD occurred in the studied eyes from the first month post-surgery to the end of the study.

We assume that our study is consistent with Hayashi's. It reveals that the changes in anterior chamber morphology and IOP reduction, induced by cataract surgery, were more accentuated in eyes with a shallow anterior chamber. The explanation for these alterations is the postoperative backward shift of the iris, caused by the lens extraction with PC IOL implantation, a phenomenon that is greater in eyes with a shallow anterior chamber [10].

Even if our data showed a globally greater ACD deepening and ACA widening than Hayashi's results (by almost 0.2 mm and 2.04°), the IOP reduction in their subjects was relatively higher than in our patients. The explanation for the greater morphologic changes that occurred in our subjects is the shallower axial length of the anterior chamber of all our patients prior to cataract surgery (2.24 mm), compared to Hayashi's (2.51 mm). On the other hand, the higher IOP reduction, documented by Hayashi, can be explained by the fact that some of the patients enrolled in his study had a history of glaucoma filtration surgery before their cataract surgery.

The effects of cataract surgery on the anterior chamber parameters and IOP levels in eyes without glaucoma history were evaluated in 2009 by Uçakhan et al. [24] at 3 months postoperatively. Similar evaluations have been carried out in 2010 by Doganay et al. [9] at 1,3 and 6 months post-surgery and by Dooley et al. [25] at 6 weeks following cataract extraction.

Our control group results are in agreement with Uçakhan [24], Doganay [9] and Dooley et al. [25] respectively, and show that cataract surgery significantly increased the anterior chamber parameters and induced IOP reduction in non-glaucomatous eyes. Also, as with Doganay [9] and Dooley [25], we proved that our subjects had no significant postoperative pachymetric changes compared to the period prior to cataract surgery.

Consistent with Doganay's [9] findings, we also documented no statistically significant differences in values of ACD, ACV and ACA throughout the postoperative periods. This implies that anterior chamber postoperative morphometry may tend to remain stable.

Although our results are similar to the ones listed above [9,24,25], the anterior chamber morphometric changes and IOP reduction were slightly greater in our control group. Those changes can be explained by the inclusion of younger patients in previous studies (Doganay et al. [9] 65.37 ± 7.73 years, Uçakhan et al. [24] 65.8 ± 8.3 years, Dooley et al. [25] 69.2 ± 10.9 years versus 71.53 ± 8.98 years in the current study) with a deeper preoperative anterior chamber and, possibly, a thinner crystalline lens [25] and lower IOP (in mean by approximately 1.7 mmHg) prior to cataract surgery.

Liu et al. [27] in patients with PACG, Dooley et al. [25] and Issa et al. [26] in non-glaucomatous subjects described a novel ratio based on preoperative ACD and IOP as a strong predictor of postoperative IOP reduction.

Our results reveal a significant correlation between preoperative parameters and the postoperative changes: the shallower the preoperative anterior chamber and the higher preoperative IOP, the greater the postoperative changes. This suggests that the decrease in IOP is a result of aqueous outflow improvement by decompression or mechanical stretch of the trabecular meshwork and Schelmm's [22,23,36], resulted from an increased postoperative ACD.

In eyes with POAG, Slabaugh et al. [31] demonstrated a negative correlation between preoperative chamber depth and IOP postoperative reduction on year after phacoemulsification. This study found that a deeper chamber, with higher preoperative IOP, was associated with a greater IOP reduction post-operatively.

An explanation for this report was that the lens extraction in patients, with widely open angles, preoperatively, has only a partial mechanical influence on lowering IOP. The most important role in IOP reduction was considered to be the phacoemulsification ultrasound energy, which produces a stress response of the trabecular meshwork cell and, thus, potentially increases outflow [37].

Some other authors explain that the IOP reduction in POAG eyes is attributed to the stress response of trabecular meshwork cells, determined by phacoemulsification ultrasound energy [37].

Despite all the studies done so far, the exact IOP reduction mechanism induced by cataract surgery still remains unknown.

Our outcomes showed a significant IOP reduction in all patients, both in the third week after phacoemulsification (by 1.9 mmHg) and in the third month (by 3.4 mmHg).

The postoperative IOP decrease was significantly greater ($p<0.05$) and for a longer term in eyes with shorter ACD (PACG: in the 3rd week by 3.2 mmHg and in the 3rd month by 4.7 mmHg) than in eyes with larger ACD (Control/POAG group: in the 3rd week by 1.7/0.8 mmHg and in the 3rd month by 2.8/2.8 mmHg).

The present study has certain limitations regarding the accuracy of the Scheimpflug rotating camera visualization of the anterior chamber angle. The light from the Scheimpflug system cannot pass the corneo-scleral limbus. Therefore, it cannot visualize and exactly measure the real configuration and structures of the iridocorneal angle [38]. Another disadvantage of our research was that it was short-term, with only 3 months follow-up of measurements, after cataract surgery.

Our results demonstrate that uneventful phacoemulsification has a positive influence on ACD deepening, ACV increasing, ACA widening and IOP reduction both in glaucomatous and non-glaucomatous eyes. Therefore, at the end of the study, we found, in the control and in POAG patients, that: ACD became 1.7 X deeper, ACV 1.4 X greater and ACA 1.4 X wider than before surgery. While in patients with PACG, the anterior chamber parameters almost doubled: ACD 2.1 X, ACV 1.7 X, ACA 1.8 X compared to the period before surgery. Those changes were more prominent in patients with a low aqueous outflow facility, determined by a shallower anterior chamber. Thus, at the last follow-up session, the anterior chamber morphology became very similar in all studied subjects.

The postoperative deepening of the anterior chamber, explained by the posterior shift of the ciliary processes, may increase the aqueous humor outflow and cause the IOP to lower, mainly in eyes with PACG. The restoration of the anterior chamber anatomy, induced by cataract surgery, may prevent the risk of pupillary block and acute angle-closure attack in patients with occludable angles. On the other hand, the postoperative IOP decrease may determine a reduction of glaucoma medication in the postoperative period in both patients with PACG and POAG [28,29]. It also may delay, for a period, more complicated glaucoma filtration surgeries, such as trabeculectomy and tube shunt surgery.

To summarize, cataract surgery causes major changes in the anterior chamber biometrics and determines IOP reduction in all our patients, especially in those with shallower anterior chambers. It can be an effective treatment for patients with PACG and it may also help in the IOP management of subjects with POAG.

Conflict of Interest

The authors report no conflicts of interests. This research received no specific grant or any research funding.

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