

Lowering of intraocular pressure after phacoemulsification in primary open-angle and angle-closure glaucoma: Correlation with lens thickness

Mohideen Abdul Kader, Arkaprava Pradhan¹, Aakriti Garg Shukla², Devendra Maheswari¹, Ramakrishnan R¹, Debahuti Midya³

Purpose: To assess anterior chamber configuration changes during phacoemulsification in primary angle-closure suspect (PACS/PAC) and primary open-angle glaucoma (POAG). **Methods:** Prospective observational comparative study of anterior segment optical coherence tomography (AS-OCT) findings before and after phacoemulsification on three groups of patients (PACS/PAC, POAG, and controls). Data were collected over a period of 9 months. Main outcome measures included mean change in anterior chamber depth (ACD), angle opening distance (AOD), and trabecular iris space area (TISA). **Results:** 153 patients (51 PACS/PAC, 51 POAG, and 51 controls) were included in the study. Change in all parameters (ACD, AOD at 500 μ m, and AOD at 750 μ m) between the groups demonstrated a greater change in PACS/PAC as compared to POAG and controls. AOD at 750 μ m in the temporal quadrant, which has been considered to be having the highest correlation or best representation of the angle, increased in all groups after phacoemulsification (463.59 \pm 10.99 vs. 656.27 \pm 9.73 mm in PACS; 521.29 \pm 16.36 vs. 674.37 \pm 8.72 mm in POAG; 549.27 \pm 12.40 vs. 702.82 \pm 13.04 mm in controls, ($P < 0.001$). After phacoemulsification, intraocular pressure (IOP) decreased by 2.75 \pm 1.17 mm Hg in PACS/PAC ($P < 0.001$), 2.14 \pm 1.33 mm Hg in POAG and 1.90 \pm 1.25 mm Hg in controls and it was statistically significant in the PACS group compared to control ($P < 0.001$). **Conclusion:** Phacoemulsification with intraocular lens implantation is associated with increase in the ACD and angle parameters and a corresponding decrease in IOP. Findings were more pronounced in PACS/PAC suggesting early phacoemulsification may be a treatment option in this group.

Key words: Anterior chamber angle, intraocular pressure, lens thickness, phacoemulsification, primary angle-closure suspect, primary open-angle glaucoma

Primary angle-closure glaucoma (PACG) is less prevalent (0.5%–0.6%) than primary open-angle glaucoma (POAG) (2%–3%) worldwide.^[1,2] However, PACG is equally prevalent in the Indian population as is POAG.^[3] Approximately 86% of people with PACG are in Asia with approximately 48% in China, 23.9% in India, and 14.1% in South-East Asia.^[4] Prevalence of angle-closure disease in southern India is 1.58%, and it is three times higher in women than in men.^[5] Clinical experience has demonstrated that cataract extraction is associated with deepening of the central anterior chamber and widening of the angle. It is also a common clinical understanding that as lens thickness increases, there is an increase in angle crowding with predisposition to relative pupillary block.^[6] Although gonioscopy is the gold standard for anterior chamber angle assessment, limitations with regard to technique exist.^[7] These include the need for minimal illumination for angle visualization, uncertainty of the change in angle configuration when a gonio-lens is in direct contact with the cornea, and dependence on individual skill

and experience for interpretation of the angle configuration.^[7,8] Anterior segment-optical coherence tomography (AS-OCT) emerged in 1994 as a potentially more objective method to assess the angle.^[9] AS-OCT uses a longer wavelength (1310 nm) than conventional posterior segment OCT (830 nm), allowing high-resolution cross-sectional imaging of the anterior chamber and visualization of the angle. Its rapid image acquisition and noncontact method offer potential advantages.^[10] AS-OCT is not without limitations. As most ASOCT instruments measure only horizontal and vertical meridians, up to 80% of superior angles are not adequately visible,^[11] ASOCT can't image peripheral anterior synechiae properly and measurement can be different in different age group.^[12-14] In patients with coexisting PACG and cataract, cataract surgery alone has been suggested a consistent lowering of IOP by 1.88–5.5 mm Hg.^[15-18] Thomas *et al.*^[19] noted that IOP control after initial phacoemulsification in PAC is better than POAG. However, there is a paucity of information on the effect of cataract surgery in eyes with primary angle-closure

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Department of Glaucoma, Aravind Eye Hospital, Tirunelveli,
¹Department of Vitreo Retina, Sankara Nethralaya, Chennai,
²Department of Glaucoma, Wills Eye Hospital, Philadelphia, USA,
³Department of Paediatric Ophthalmology, Sankara Nethralaya, Chennai, India

Correspondence to: Dr. Arkaprava Pradhan, Medical Research Foundation, Sankara Nethralaya, College Road 18, Nungambakkam, Chennai - 600 006, Tamil Nadu, India. E-mail: kap@snmail.org

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suspect (PACS/PAC). Our study aims to examine whether phacoemulsification with intraocular lens implantation can cause a significant change in ACD, angle parameters, and final IOP in patients with PACS/PAC with cataract.

Methods

This was a prospective, observational, comparative study between PACS/PAC, POAG, and control patients with visually significant cataracts who were planning to undergo phacoemulsification. Approval was obtained from the Aravind Eye Hospital Institutional Review Ethics Committee (ECR 816/Inst/Tn/2016). All study procedures adhered to the recommendations of the Declaration of Helsinki. All study participants provided written informed consent. All patients seen at the glaucoma department and cataract department of Aravind Eye Hospital were considered for this study and the patients were selected randomly.

Inclusion criteria were as follows: age 40 years or older, presence of visually significant cataract scheduled for cataract surgery, and diagnosed as PACS/PAC and POAG. Patients having cataract without glaucoma were considered for the control group. Controls were age-matched. Diagnosis of PACS, PAC, and POAG has been done by preoperative gonioscopy.

Primary angle-closure suspect (PACS)

Irido trabecular contact in three or more quadrants, but normal IOP, optic disc, and visual field, without evidence of PAS.

Primary angle-closure (PAC)

Irido trabecular contact in three or more quadrants with either raised IOP and/or primary PAS. Glaucomatous changes of optic disc and visual field were not present.^[6]

Primary open-angle glaucoma (POAG)

Open, normal-appearing anterior chamber angle, raised IOP with optic disc and visual field changes but not associated with any other underlying disease.

Exclusion criteria were as follows: prior acute angle-closure glaucoma, previous filtration surgery, history of uveitis, on long-term corticosteroid instillation, ocular trauma, and degenerative changes of the cornea (edema, dystrophy). Those undergoing combined procedures and those with intraoperative complications during cataract surgery were also excluded.

Clinical assessment

All participants underwent a complete eye examination by a trained ophthalmologist. Visual acuity was measured with logMAR chart. IOP was measured with applanation tonometry. Lens thickness, anterior chamber depth, and angle opening distance were measured using ASOCT. Follow-up visits took place on the 3rd, 6th, 12th weeks postoperatively. Ocular examinations and AS-OCT were done in a semi-dark room. The Visante OCT (Carl Zeiss Meditec, Dublin, CA with an axial resolution of 18 microns and transverse resolution of 60 microns) was used. Slit-lamp examination, intraocular pressure (IOP), and AS-OCT had been done in each visit. In all patients, parameters such as axial length (AL), anterior chamber depth (ACD), lens thickness (LT), angle opening distance at 500 um from scleral spur (AOD 500: the distance

surface on a line perpendicular to the trabecular meshwork; 500 um from the scleral spur- AOD500) [Fig. 1], AOD at 750 um (AOD750), Trabeculo-iris space area at 500 um from scleral spur (TISA 500- the surface area of a trapezoid with the following boundaries: anteriorly- the angle opening distance at 500 um from scleral spur; posteriorly- a line drawn from the scleral spur perpendicular to the plane of the inner scleral wall to the iris; superiorly- the inner corneoscleral wall; and inferiorly- the iris surface)^[20,21] [Fig. 2] and TISA at 750 um (TISA 750) were taken from anterior segment OCT (AS-OCT) before and after phacoemulsification.

Main outcome measures

The main outcome measures were an increase in ACD, widening of angle, changes in AOD 500 and AOD 750, and changes in TISA 500 and TISA 750.

Secondary outcome measures included a decrease in the IOP by GAT (Goldmann applanation tonometry).

Surgical procedure

Patients received topical anesthesia of proparacaine hydrochloride 0.5% and intracameral preservative-free lidocaine 1% or sub-Tenon injection of 1.5 ml of lidocaine 1% mixed with epinephrine and hyaluronidase injection. Side port incision was made at the 10-o'clock position. A 2.8-mm clear corneal incision was made and continuous curvilinear capsulorhexis was done with cystitome. Hydrodissection was done. Phacoemulsification was performed using the direct chop technique in all the groups. Cortical cleaning was done using a uniaxial irrigation aspiration cannula. Viscoelastic material was injected in the bag and foldable hydrophobic IOL was implanted in the capsular bag. Intracameral 0.1 cc moxifloxacin was used at the end of the procedure. Postoperatively, all patients received topical antibiotics with dexamethasone sodium phosphate 0.1% on a tapered schedule over a 1-month period.

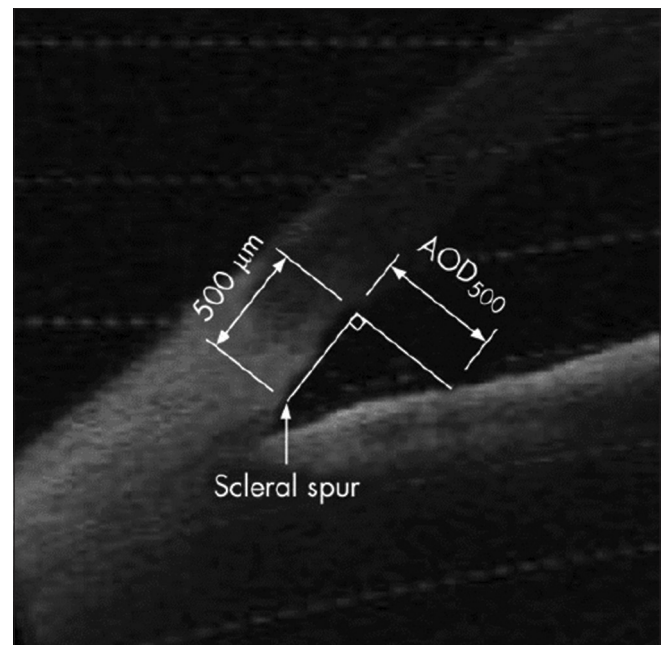


Figure 1: AS-OCT image showing the angle opening distance, 500 um from the scleral spur

Statistical analysis

STATA 11.1 statistical software was used for statistical analysis. Paired *t* tests and Wilcoxon sign test were used for continuous variables and for comparison between preoperative and final postoperative visit, respectively. Kruskal–Wallis test was used for comparing two or more independent samples of equal or different sample sizes, $P < 0.05$ was considered significant. A sample size calculation was performed, which found a sample size of 51 in each group has taken with the assumption of 90% power and 5% alpha error.

Results

A total of 153 eyes from 153 patients were included in this study: 51 PACS/PAC, 51 POAG, and 51 control eyes. Baseline characteristics are shown in Table 1. Age significantly differed among the three groups (66.2 years in PACS/PAC, 71.6 in OAG, and 69.0 in controls; $P < 0.001$). The proportions of men and women were similar in all groups ($P = 0.925$). Right eye was affected more than left eye in each group, but they are not statistically significant. The optic cup: disc ratio (CDR) differed between each group but was not statistically significant. CDR was more in the POAG group compared to that in the PACS/PAC and control groups. Differences in IOP and lens thickness between the groups were statistically significant. Lens thickness was significantly greater in the PACS/PAC group (4.48 ± 0.38 mm) than that in the POAG and control groups (4.14 ± 0.08 and 4.15 ± 0.11 mm, respectively; $P < 0.001$). Mean axial length in the PACS, POAG, and control groups were 22.78, 24.02, and 24.78 mm, respectively. Best-corrected visual acuity (BCVA) was recorded using logMAR chart. There was no significant difference of BCVA between the groups, but there was significant improvement in best corrected visual acuity (BCVA) after surgery in each group [Table 2].

ACD comparison between groups is shown in Table 1. The PACS/PAC group was significantly shallower than the other groups (2.08 ± 0.12 mm in PACS, 2.84 ± 0.13 mm in POAG, and 2.29 ± 0.14 mm in controls; $P < 0.001$). ACD significantly changed in all groups after surgery, with the greatest change

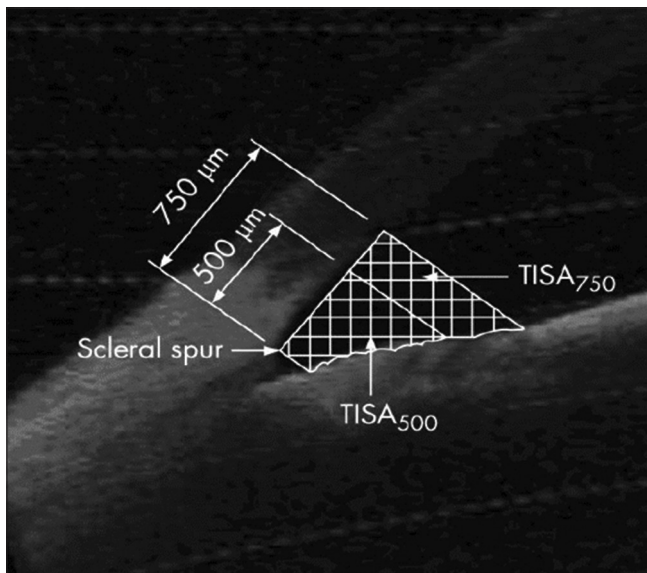


Figure 2: AS-OCT image showing the trabecular iris surface area, 500 um from the scleral spur

in PACS/PAC group (1.81 ± 0.11 mm in PACS, 1.19 ± 0.12 mm in POAG, and 1.12 ± 0.15 mm in controls; $P < 0.001$) [Table 2].

There were significant changes in IOP in the final postoperative visit (12 weeks). It decreased from 20.33 ± 2.6 mm Hg to 17.59 ± 1.8 mm Hg in the PACS/PAC

Table 1: Demographic and baseline clinical characteristics of the study participants

	PACS/PAC	POAG	Control	<i>P</i> ^a
Age, years	66.20 (6.0)	71.63 (4.6)	69.00 (5.3)	<0.001
Gender, <i>n</i> (%)				
Male	24 (47.1)	26 (51.0)	25 (49.0)	0.925 ^b
Female	27 (52.9)	25 (49.0)	26 (51.0)	
Eye, <i>n</i> (%)				
Right eye	30 (58.8)	31 (60.8)	26 (51.0)	-
Left eye	21 (41.2)	20 (39.2)	25 (49.0)	
CDR	0.55 (0.1)	0.62 (0.1)	0.54 (0.1)	0.005
IOP, mm Hg	20.33 (2.6)	22.12 (3.8)	16.47 (2.2)	<0.001
Lens thickness	4.48 (0.4)	4.14 (0.1)	4.15 (0.1)	<0.001
Axial length	22.78 (0.03)	24.02 (0.8)	24.78 (0.5)	<0.001
ACD	2.08 (0.1)	2.84 (0.1)	2.92 (0.1)	<0.001
BCVA, log MAR	1.32 (0.3)	1.35 (0.3)	1.29 (0.3)	0.611 ^c

Values were presented in mean (standard deviation); Gender and eye were reported in frequency and %. CDR-cup to disc ratio; IOP-intraocular pressure; ACD-anterior chamber depth; BCVA-best-corrected visual acuity (presented in log MAR); log MAR-logarithm of minimal angle of resolution. ^aANOVA test; ^bChi-square test; ^cKruskal-Wallis test

Table 2: Comparison of IOP, ACD, and BCVA between the study groups

	PACS/PAC	POAG	Control	<i>P</i> ^a
IOP				
Baseline	20.33 (2.6)	22.12 (3.8)	16.47 (2.2)	<0.001
Week 3	20.29 (2.6)	21.75 (3.8)	16.31 (2.3)	<0.001
Week 6	18.73 (2.1)	20.82 (3.6)	15.33 (2.0)	<0.001
Week 12	17.59 (1.8)	19.98 (3.6)	14.57 (1.9)	<0.001
<i>P</i> ^d	<0.001	<0.001	<0.001	-
ACD				
Baseline	2.08 (0.1)	2.84 (0.1)	2.92 (0.1)	<0.001
Week 3	3.88 (0.04)	4.02 (0.04)	4.01 (0.03)	<0.001
Week 6	3.89 (0.1)	4.03 (0.04)	4.02 (0.03)	<0.001
Week 12	3.89 (0.1)	4.03 (0.04)	4.04 (0.1)	<0.001
<i>P</i> ^d	<0.001	<0.001	<0.001	-
BCVA				
Baseline	1.29 (0.3)	1.35 (0.3)	1.32 (0.3)	0.611
Week 3	0.04 (0.1)	0.04 (0.1)	0.02 (0.1)	0.448
Week 6	0.03 (0.1)	0.03 (0.1)	0.02 (0.1)	0.863
Week 12	0.02 (0.1)	0.02 (0.1)	0.02 (0.1)	0.829
<i>P</i> ^e	<0.001	<0.001	<0.001	-

IOP-intraocular pressure; ACD-anterior chamber depth; BCVA - best-corrected visual acuity (presented in logMAR); mean (standard deviation) were reported in the tables. ^aANOVA test; ^cKruskal-Wallis test; ^dPaired *t* test (Postoperative at week12 compared with baseline); ^eWilcoxon sign rank test (Postoperative at week12 BCVA compared with baseline)

group, from 22.12 ± 3.8 mm Hg to 19.98 ± 3.6 mm Hg in the POAG group, and from 16.47 ± 2.2 mm Hg to 14.57 ± 1.9 mm Hg in the control group; it was statistically significant in all the groups ($P < 0.001$) [Table 2].

A positive correlation was found between preoperative and postoperative IOP difference and LT in the PACS/PAC group ($R^2 = 0.28$; $P = 0.048$). These associations were not found in the POAG or control groups ($P > 0.05$ for both). It is clear from Table 3 that IOP lowering was maximum in eyes with lens thickness of more than 4.15 mm. Requirement of anti-glaucoma medication decreased after cataract surgery in glaucoma patients. In the shallow angle group, it became preoperatively 13.72% to 3.9% postoperatively. In the POAG group it became preoperatively 15.68% to 11.76% postoperatively [Table 4].

Angle opening distance (AOD-500) of nasal quadrant [Table 5] changed significantly from 264.76 ± 13.08 to 476.65 ± mm in the PACS/PAC group, from 332.59 ± 16.50 to 491.08 ± 13.66 mm in the open angle group, and from 359.59 ± 12.86 to 514.86 ± 11.53 mm in the control group; these findings were statistically significant ($P < 0.001$) [Figs. 3 and 4]. Angle opening distance (AOD 750) of temporal quadrant [Table 5] changed significantly from 463.59 ± 10.99 to 656.27 ± 9.73 mm in the PACS/PAC group, from 521.29 ± 16.36 to 674.37 ± 8.72 mm in the open angle group, and from 549.27 ± 12.40 to 702.82 ± 13.04 mm in the control group; these findings were also statistically significant ($P < 0.001$). TISA 500 of nasal quadrant [Table 5]

Table 3: Correlation between IOP difference and lens thickness

IOP difference vs. Lens thickness	Correlation (rho)	P ^s
POAG	0.16	0.270
PACS/PAC	0.28	0.048
Control	0.02	0.888

S: Spearman rank-order correlation

Table 4: Requirement of antiglaucoma medication (AGM) after surgery

	Shallow angle	POAG
Preoperative	13.72%	15.68%
Postoperative	3.9%	11.76%
P	0.0253	0.1573

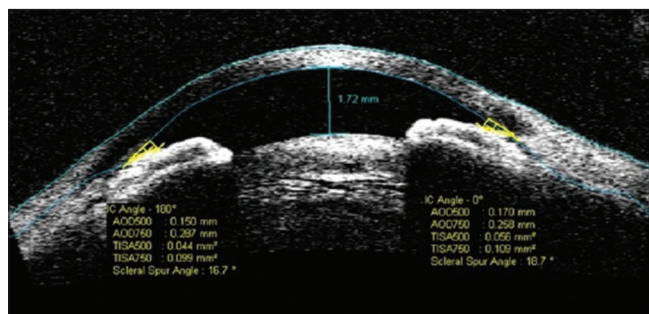


Figure 3: AS-OCT of right eye of a patient shows shallow anterior chamber with angle opening distance (AOD) and trabecular iris surface area (TISA)

changed significantly from 85.57 ± 9.95 to 211.12 ± 10.26 mm in the PACS/PAC group, from 131.74 ± 13.49 to 229.37 ± 12.45 mm in the open angle group, and from 161.96 ± 31.45 to 248.76 ± 9.57 mm in the control group. TISA750 of temporal quadrant [Table 5] changed significantly from 157.82 ± 8.78 to 264.63 ± 11.55 in the PACS/PAC group, from 199.73 ± 23.77 to 280.55 ± 14.19 mm in the open angle group, and from 227.23 ± 9.29 to 304.31 ± 10.92 mm in the control group. These two findings were also statistically significant ($P < 0.001$).

Discussion

Our study indicates an increase in ACD, widening of angle, change in AOD 500 and AOD 750, change in TISA 500 and TISA 750, and a decrease in IOP after cataract surgery. In a population-based study from South India, Thomas *et al.*^[19,20] reported that 22% of PACS progressed to PAC and 28.5% of PAC progressed to PACG over 5 years. They too found that bilateral PACS was a clinical risk factor for progression to PAC.^[21] Phacoemulsification causes deepening of the central anterior chamber and widening of the angle which can delay in progression of PACS to PAC and PACG. AS-OCT, which is a noncontact equipment, has better penetration through the sclera and can acquire real-time imaging at 8 frames/s, and was used in this study to document the changes in the anterior segment morphology before and after phacoemulsification.

The average change in the anterior chamber depth (ACD) was 1.81 ± 0.11 mm in the PACS/PAC group, 1.19 ± 0.12 mm in the POAG group, and 1.12 ± 0.15 mm in the control group. The difference was statistically significant ($P < 0.001$), and there was more anterior chamber deepening in patients with shallow angle than in other groups.

The changes in the IOP showed a statistically significant change in each group when compared between the preoperative and postoperative values. Studies by Shin *et al.*^[21] Tai *et al.*^[22] and Nolan *et al.*^[23] found a decrease in the IOP and significant changes in the angle configuration following phacoemulsification. IOP decreased by 2.74 ± 1.7 mm Hg in the PACS/PAC group, by 2.13 ± 0.12 mm Hg in the POAG group, and by 1.90 ± 1.25 mm Hg in the control group. Zhuo *et al.*^[24] in their study found a mean decrease by 1.6 ± 2.5 mm Hg in the IOP postoperatively and their results are comparable. Pandav *et al.*^[25] found overall 22.82% reduction in IOP and 38.61% reduction in medication on a mean follow-up of 2.68 ± 2.71 years (median: 1 year) in all subsets of ACD. Our study showed that requirement of anti-glaucoma medication was less after the cataract surgery.

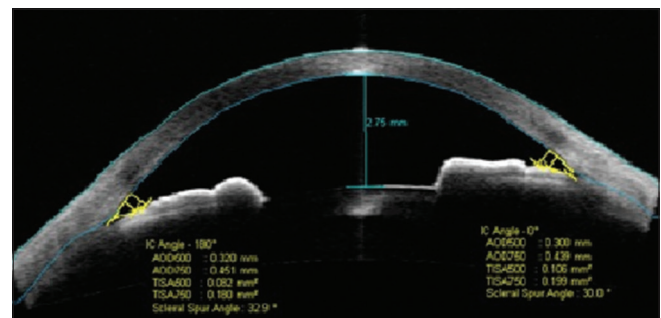


Figure 4: AS-OCT image showing increased anterior chamber depth with the widening of AOD and TISA after cataract surgery

Table 5: Comparison of baseline angle parameters between the study groups

	PACS/PAC	POAG	Control	P
AOD 500 (Nasal)	264.76 (13.1)	332.59 (16.5)	359.59 (12.9)	<0.001
AOD 750 (Temporal)	463.59 (11.0)	521.29 (16.4)	549.27 (12.4)	<0.001
TISA 500 (Nasal)	85.57 (9.9)	131.75 (13.5)	161.96 (31.5)	<0.001
TISA 750 (Temporal)	157.82 (8.8)	199.73 (23.8)	227.24 (9.3)	<0.001

^aANOVA test; mean (standard deviation) were reported in the tables. $P < 0.001$ is significant

The changes in the angle parameters in our studies showed statistically significant changes in parameters such as ACD, AOD 500, AOD 750, TISA 500, and TISA 750 in both nasal and temporal quadrant in all three groups when compared between the preoperative and postoperative values. Zhuo *et al.*^[24] also showed in their study that angles that were $<30^\circ$ preoperatively tend to open more postoperatively. Nolan *et al.*^[23] found a significant difference in the change of AOD 500 in the group >60 years of age. Similar changes were also noted with TISA 500. This could be attributed to the increase in lens thickness with age.

AOD 750 has been considered to be having the highest correlation or best representation of the angle when assessed by gonioscopy as studied by Pekmezci *et al.*^[26] Lin *et al.*^[27] also explained that the IOP reduction is correlated with the lens thickness. In our study, we checked for a correlation between the AOD 750 and preoperative lens parameters and found that there was a statistically significant positive correlation between the lens thickness and the change in AOD 750, suggesting that the more the lens thickness preoperatively, the more there is a change in the AOD 750 as on the 12th week postoperatively.

Thus, we can conclude the IOP lowering effect is more in those patients who had more lens thickness preoperatively. Lens thickness is more in PACS/PAC group and the decrease in IOP after cataract surgery is also more compared to the other two groups. Thomas *et al.*^[28] noted that IOP lowering was greater in PACG, but no study has shown the exact value of lens thickness that can lead to greater IOP lowering after phacoemulsification. Our study shows that any lens thickness of more than 4.15 mm has a greater IOP-lowering effect after phacoemulsification.

Limitations

This study has several limitations. Our study may not have been sufficiently powered to detect differences between the three study groups. Additionally, significant changes in age between the three groups may have been associated with the density of cataract and contributed to variation in angle morphology and IOP-lowering after surgery. Moreover, the current image processing software requires the operator to manually define the position of the scleral spur to calculate variables, including the AOD. Variability of manual measurement may lead to differing outcomes. Only the nasal and temporal locations were imaged; significant findings from superior and inferior quadrants may have been missed. Additionally, the exact same section may not have been imaged at the pre- and post-cataract surgery visits, leading to potential confounding of the results. Finally, the studied population was entirely South Indian. This may affect the results of this study.

Conclusion

Phacoemulsification and intraocular lens implantation causes a significant increase in the anterior chamber depth and angle parameters with a corresponding decrease in the intraocular pressure in all the groups but are more pronounced in the group with shallow angles. It was found that any lens thickness more than 4.15 mm has a greater IOP-lowering effect after phacoemulsification, which can also be a treatment option in the PACS/PAC subgroup of patients as it delays the progression of PACS to PAC or PACG.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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