Clinical & Experimental Ophthalmology — RANZCO The Royal Australian and New Zealand College of Ophthalmologists

Clinical and Experimental Ophthalmology 2013; 41: 368–378 doi: 10.1111/j.1442-9071.2012.02871.x

Original Article

Effect of adjunctive viscogonioplasty on drainage angle status in cataract surgery: a randomized clinical trial

Yadollah Eslami MD,[1] Golshan Latifi MD,[1] Sasan Moghimi MD,[1] Reza Ghaffari MD,[1] Ghasem Fakhraie MD,[1] Reza Zarei MD,[1] Mahmood Jabbarvand MD,[1] Massood Mohammadi MD[1] and Shan Lin MD[2]

[1]Farabi Eye Research Center, Tehran University of Medical Science, Tehran, Iran; and [2]Department of Ophthalmology, San Francisco School of Medicine, University of California, San Francisco, California, USA

Abstract

Background: To compare the anatomic effects of phacoemulsification (Phaco) versus combined phacoemulsification and viscogonioplasty (Phaco-VGP) on drainage angle status in primary angle-closure glaucoma (PACG) using anterior segment optical coherence tomography (AS-OCT).

Design: Prospective, randomized clinical trial.

Participants: Sixty-seven eyes of 57 patients with the diagnosis of PACG.

Method: Patients were randomized to undergo Phaco alone (33 eyes) or Phaco-VGP (34 eyes). Patients were examined postoperatively on day 1, week 1 and week 6. Indentation gonioscopy and AS-OCT were performed preoperatively and at 6 weeks after surgery.

Main Outcome Measures: Angle and anterior segment parameters by AS-OCT and amount of peripheral anterior synechiae (PAS) by gonioscopy.

Results: Sixty-five eyes of 55 patients completed the trial. The mean extent of PAS was significantly reduced from 127.7 to 95.0 degrees ($P < 0.001$) by Phaco alone, and from 174.0 to 77.3 degrees ($P < 0.001$) by Phaco-VGP. Phaco-VGP resulted in significantly greater reduction in PAS extent ($P = 0.002$). Angle-opening distance and trabecular-iris space-area measured by AS-OCT increased significantly after Phaco alone and Phaco-VGP ($P < 0.001$ for both). Although the change was higher in the Phaco-VGP group, this did not reach statistical significance. Anterior chamber depth (ACD) increased, and lens vault (LV) decreased after both procedures. The amount of change in ACD and LV was not significant between the two groups.

Conclusion: Both Phaco alone and Phaco-VGP resulted in widening of the drainage angle, deepening of the anterior chamber and reduction of intraocular pressure (IOP) and PAS extent in PACG eyes. Phaco-VGP resulted in significantly more reduction of PAS. However, it seems that additional VGP has no significant effect on short-term IOP.

Key words: anterior chamber depth, anterior segment optical coherence tomography, phacoemulsification, primary angle closure glaucoma, viscogonioplasty.

Introduction

Primary angle closure glaucoma (PACG) occurs when the anterior chamber drainage angle progressively narrows with a subsequent rise in intraocular pressure (IOP) leading to glaucomatous optic neuropathy.[1] The crystalline lens has a key role in configuring the anterior chamber (AC) and determining its biometric parameters. In angle-closure glaucoma,

■ **Correspondence:** Dr. Sasan Moghimi, Farabi Eye Research Center, Tehran University of Medical Science, Tehran, Iran. Email: sasanimii@yahoo.com

Received 24 May 2012; accepted 12 August 2012.

Competing/conflicts of interest: No stated conflict of interest.

Funding sources: No stated funding sources.

lens thickness is greater, and the thicker lens occupies a more anterior position compared to normal eyes.[2–6]

Cataract removal has been reported to deepen the AC and open the iridocorneal angle.[7–9] these biometric changes after cataract surgery are well documented in normal eyes, and in eyes with either open-angle or angle-closure glaucoma.[7,8,10] Some have considered these changes to be the main mechanisms for IOP lowering after phacoemulsification alone in these eyes.[11–13]

Some investigators have demonstrated that phacoemulsification has similar effects in narrow angle eyes with or without glaucomatous optic neuropathy,[14] but it is not always the case, and lens extraction does not inevitably result in angle widening and decrease in IOP in every case, probably because of peripheral anterior synechiae (PAS) that do not open. However, in these eyes the trabecular meshwork can be exposed again if PAS is broken and adherent iris is separated from the meshwork. Theoretically, goniosynechialysis can restore trabecular function in eyes with PACG by stripping PAS from the angle and exposing the underlying trabecular meshwork[15–17]

Although viscogonioplasty (VGP) has been introduced for breaking PAS in PACG by using a heavy viscoelastic,[1,18–20] recurrence of PAS or permanent damage might cause the goniosynechialysis to fail to regain aqueous outflow in the long term.[21,22] In the literature combined phacoemulsification and viscogoniosynechialysis was an effective and safe treatment for management of angle-closure glaucoma.[1,18–20] However, few studies have assessed the additional effect of goniosynechialysis on drainage angle anatomy.

Anterior segment optical coherence tomography (AS-OCT) is a new instrument that uses low-coherence interferometry and allows imaging of the entire cross section of anterior segments with a resolution of 10 to 18 μm. This device provides a noncontact assessment of the anterior chamber and angle parameters, and allow users to quantify angle width and measure anterior chamber dimensions and parameters including novel factors such as lens vault (LV), thus helping researchers in further understanding the pathogenesis of anterior segment disease.[23–27] Furthermore, AS-OCT has been introduced as a diagnostic tool for angle-closure disease.[28,29] Previous AS-OCT studies showed that the angle changed significantly after cataract surgery.[9,30] Postoperative angle changes have been noted to be larger in narrow angles and older patients, which may be related to the increase in lens volume during the ageing process.[8]

The objective of this randomized clinical study is to compare the effects of phacoemulsification alone versus combined phacoemulsification and VGP on drainage angle-status and anterior-segment parameters in PACG eyes. This is the first randomized study that evaluates the effect of adjunctive VGP on the drainage angle as determined by indentation gonioscopy and AS-OCT. The results from this study may be helpful in understanding the mechanisms of IOP lowering by phacoemulsification with or without VGP in these eyes.

METHODS

This was a prospective randomized clinical trial conducted in Farabi Eye Hospital, Tehran, Iran. The study protocol followed the tenets of the Declaration of Helsinki and was approved by the Farabi Hospital Research Ethics Committee (REC). Patients visiting the glaucoma clinic, from Oct 2009 to Oct 2010 were prospectively enrolled in the study if they met the inclusion and exclusion criteria. Written informed consent was obtained from all patients prior to enrolment.

Inclusion criteria

Inclusion criteria included: (i) PACG defined by at least 270 degree of irido-trabecular contact [appositional or synechial on gonioscopy] and glaucomatous optic neuropathy determined by optic disc cupping and glaucomatous visual field loss; (ii) visually significant cataract with best-corrected visual acuity of worse than 20/30; and (iii) patent peripheral iridotomy (PI).

Exclusion criteria

Exclusion criteria were: (i) eyes with a history of an acute or subacute attack of angle closure glaucoma; (ii) presence of any cause of secondary glaucoma including uveitic glaucoma, neovascular glaucoma, exfoliative glaucoma and phacomorphic glaucoma; and (iii) history of any previous incisional eye surgery.

Examinations included visual acuity (VA) testing with manifest refraction, IOP measurement by Goldmann applanation tonometry, complete slit lamp and fundus examination and gonioscopy (described in detail in the next discussion). IOP measurement, optic disc evaluation and gonioscopy were performed by a single glaucoma specialist (GL). Additional preoperative data gathered included demographic information and anti-glaucoma medications. For all patients, axial length and lens thickness were measured using A-scan ultrasound (Echoscan, model U3300, Nidek Inc., Tokyo, Japan).

Gonioscopy

Subjects underwent gonioscopy by a single glaucoma specialist who was masked to the AS-OCT images and findings. Patients were examined in low light conditions with a Zeiss-style four-mirror goniolens (Model G-4, Volk Optical, Mentor, OH). A narrow 1-mm beam of light was utilized; a vertical beam was used to evaluate the superior and inferior angles, while a horizontal beam was used for the nasal and temporal angles. All four quadrants were assessed with the eye in the primary position of gaze; slight tilting of the lens was allowed if there was significant lens vault. The angle was graded using a modified Scheie classification system (according to the most posterior angle structure visible):[31] Grade 0, when no structure is visible; Grade 1, Schwalbe's line and anterior meshwork visible; Grade 2, posterior pigmented meshwork visible; Grade 3, scleral spur visible; and Grade 4, ciliary band visible. Average of gonioscopic grading in the four quadrants was defined as the gonioscopic grade for each eye. Indentation gonioscopy was used to establish the presence and extent of peripheral anterior synechiae (PAS). PAS were defined as abnormal adhesions of the iris to the angle to the level of the trabecular meshwork which are at least 15° in width, and could not be broken with indentation gonioscopy. The extent of PAS was noted in degrees.

Anterior segment optical coherence tomography (AS-OCT)

Anterior segment optical coherence tomography (Visante OCT; Carl Zeiss Meditec, Dublin, CA) was performed for all the patients preoperatively and 6 weeks postoperatively in dark ambient lighting. Scans were centred on the undilated pupil, and were obtained along horizontal and vertical axes using the enhanced anterior segment single protocol. The same examiner (RG), who was masked to clinical findings, obtained all images. Three consecutive images were captured, and the image with the best quality regarding centration and visibility of the scleral spurs was chosen for analysis. Measurements were performed by two observers who were masked to the patients' gonioscopy findings and type of intervention. Although images of all four-angle quadrants were captured, images of the inferior and superior quadrants were not included in the analysis because of suboptimal image quality and previously reported poor reproducibility of the measurements.[32]

Angle parameters measured were the angle opening distance (AOD) and trabecular-iris space area (TISA) at 500 μm and 750 μm from the scleral spur; anterior chamber angle (ACA); and scleral spur angle (SSA) in the temporal and nasal quadrants. The mean of the nasal and temporal AOD500, AOD750, TISA500, TISA750 and ACA were labelled as AOD500, AOD750, TISA500, TISA750 and ACA, respectively. Anterior chamber depth (ACD) was defined as the distance from the endothelium at the centre of the cornea to the anterior pole of the cataractous lens or intraocular lens (IOL). Lens vault (LV) was defined as the perpendicular distance between the anterior lens surface to the horizontal line connecting the two scleral spurs,[27] and was measured by the chamber tool of the machine.

Randomization of subjects and sample size

Patients were randomized into two groups using computer-generated random blocks to receive either cataract extraction alone (Phaco alone group) or cataract extraction with viscogonioplasty (Phaco-VGP group). An investigator with no clinical involvement in the trial consecutively assigned each patient enrolled by the clinical investigators to one of the two groups according to the random blocks. Patients, clinical investigators who performed gonioscopy, AS-OCT and IOP measurement were masked to the allocated arm. Main outcome measures were angle and anterior segment parameters by AS-OCT and amount of PAS by gonioscopy. For an SD = 100 μ, we needed 30 patients in each group in order to achieve an 80% power to detect a difference of 75 μ in AOD500 between the two groups with a *P*-value of 0.05.

Cataract surgical technique

Surgery was performed by a single surgeon (SM) in all subjects under topical anaesthesia. Surgery consisted of routine phacoemulsification (phaco chop technique) via a 3.2-mm temporal clear corneal incision, with an in-the-bag one-piece acrylic intraocular lens (AcrySof SA60AT, Alcon Laboratories, Inc., Fort Worth, TX) implantation. Cohesive viscoelastic (Amvisc, Bausch & Lomb, Inc., Rochester, NY) was used before capsulorhexis trying to deepen but not to 'overfill' AC. Fritz Ruck Pentasys 2 (Ophthalmologische Systeme GmbH, Eschweiler, Germany) was used in all cases, with a vacuum of 350 mmHg, maximum ultrasound power of 30% and an IOP set of 70 mmHg.

VGP technique

Following IOL implantation, a cohesive viscoelastic (Amvisc, Bausch & Lomb, Inc., Rochester, NY) was used to deepen the AC and was then injected near the angle for 360 degrees twice without touching the angle with the cannula. No surgical instruments were used to physically break the PAS. After completion of VGP, the viscoelastic was meticulously removed.

All patients received oral acetazolamide 250 mg three times a day for 24 h, topical antibiotics four times a day for 1 week, as well as topical 1% prednisolone acetate every 2 h which was tapered gradually over 1 month. Anti-glaucoma medications were discontinued postoperatively and restarted if needed.

One investigator, who was masked to the surgery performed, examined all patients postoperatively on the first day, and at weeks 1 and 6. IOP, number of IOP-lowering drugs needed, best-corrected visual acuity (BCVA), angle status by indentation gonioscopy and complications were recorded. The main outcome measures were AS-OCT angle parameters after surgery. Secondary outcome measures included BCVA, IOP, topical glaucoma drugs, LV, ACD and gonioscopic angle status. Data from week 6 were used for outcome analysis in this report.

Statistical analysis was performed using SPSS software, version 17 (SPSS, Inc., Chicago, IL). Student *t*-test and chi square test were used for comparing parametric quantitative and qualitative variables between groups, respectively. The paired *t*-test was used to compare differences between preoperative and postoperative parametric data in the same group. Correlations between continuous data sets were analysed with the Pearson correlation coefficient. For nonparametric variables Mann–Whitney U test and *t*-test were used, and Spearman correlation coefficient was calculated. General linear model was used to adjust the change in variables with preoperative values. *P*-value of less than 0.05 was considered statistically significant. The data from the patients who had major intraoperative or postoperative complications (e.g. vitreous loss or endophthalmitis) were not included for analysis.

Results

Sixty-seven eyes of 57 patients with chronic angle closure glaucoma (CACG) and coexisting cataract were included in this randomized clinical trial. One patient from each group was lost to follow-up. Thus, data from 65 eyes of 55 patients (31 female [56.4%] and 24 male [43.6%]), with a mean (± SD) age of 64.55 ± 9.13 (range 48–85) were available for analysis. Of these 65 eyes, 32 (49.2%) were randomized into the 'Phaco alone' treatment group, and 33 (50.8%) were randomized into the 'Phaco-VGP' treatment group (Fig. 1). The patient demographics and baseline clinical status are shown in Table 1.

There were no statistically significant differences between the two groups regarding age, gender, visual acuity, IOP, number of glaucoma medication and vertical cup-to-disc ratio. Visual acuity increased significantly in the 'Phaco alone' and 'Phaco-VGP' groups. Both groups had significantly reduced mean IOP and mean number of glaucoma medications at 6 weeks after surgery, compared with their preoperative status ($P < 0.001$). However, there were no

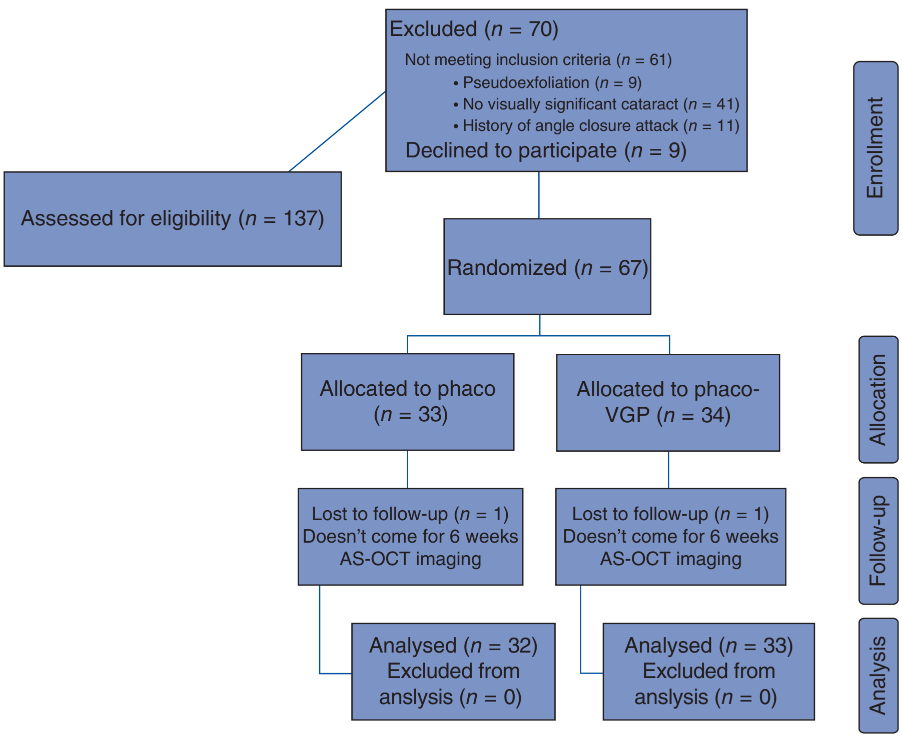

Figure 1. CONSORT flowchart demonstrated the number of patients enrolled, allocated and completed the follow-up in study population.

Table 1. Demographics and clinical status before and after surgery in the 'Phaco alone' group and 'Phaco-VGP' group

	Phaco alone	Phaco-VGP	*P*-value
Number of eyes	32	33	
Mean age ± SD (range) in years	65.4 ± 8.4 (52–85)	64.3 ± 9.8 (48–82)	0.66
Male to female ratio	11/16	13/15	0.67
Mean preoperative BCVA ± SD (range) as logMAR	0.55 ± 0.35 (0.2–1.6)	0.60 ± 0.32 (0.0–1.0)	0.53
Mean postoperative BCVA ± SD (range) as logMAR	0.27 ± 0.23 (0.2–1.6)	0.31 ± 0.21(0.0–1.0)	0.53
P-value	*P* < 0.001	*P* = 0.001	
Mean preoperative IOP ± SD (range) in mmHg	21.6 ± 6.0 (10–35)	24.5 ± 6.8 (10–34)	0.07
Mean postoperative IOP ± SD (range) in mmHg	15.6 ± 5.6 (6–30)	16.9 ± 4.9 (10–30)	0.31
P-value	<0.001	<0.001	
Mean preoperative number of glaucoma drugs ± SD (range)	1.0 ± 1.1 (0–3)	1.3 ± 1.2(0–3)	0.28
Mean postoperative number of glaucoma drugs ± SD (range)	0.0 ± 0.1(0–1)	0.1 ± 0.4(0–2)	0.26
P-value	<0.001	<0.001	
Mean vertical cup-to-disc ratio ± SD (range)	0.59 ± 0.21 (0.2–0.9)	0.62 ± 0.21 (0.2–0.9)	0.63

BCVA, best-corrected visual acuity; IOP, intraocular pressure; VGP, viscogonioplasty.

Table 2. Gonioscopic angle grading and extent of synechial angle closure before and after surgery in the 'Phaco alone' group and 'Phaco-VGP' group

	Phaco alone	Phaco-VGP	*P*-value
	Mean ± SD (range)	Mean ± SD (range)	
Preoperative extent of PAS in degrees	127.7 ± 131.2 (0–360)	174.0 ± 133.3 (0–360)	0.16
Postoperative PAS in degrees	95.0 ± 103.3 (0–330)	77.3 ± 92.9 (0–330)	0.46
P-value	<0.001	<0.001	
Change in extent of PAS in degrees	–32.7 ± 73.7 (–320–55)	–91.1 ± 75.7 (–225–0)	0.002
Preoperative angle grading	0.9 ± 0.8 (0–2)	0.9 ± 0.6 (0–2)	0.97
Postoperative angle grading	2.6 ± 1.0 (0–4)	2.9 ± 0.1 (0–4)	0.14
P-value	<0.001	<0.001	
Change of angle grading	1.6 ± 1.0 (–0.25–4)	2.0 ± 0.7 (0–3)	0.10

PAS, peripheral anterior synechiae; VGP, viscogonioplasty.

statistically significant differences between the two groups in BCVA, IOP and number of medications at week 6 ($P > 0.07$ for all) (Table 1).

Table 2 shows the gonioscopic findings of the patients. There was no statistically significant difference between the two groups in extent of synechial angle closure before surgery or 6 weeks postoperatively ($P = 0.16$ and 0.46, respectively). However, within both treatment groups, there was a statistically significant reduction in the mean extent of synechial angle closure at week 6, compared with the preoperative extent ($P < 0.001$ for both groups). Moreover the amount of change in PAS in the 'Phaco-VGP' group was significantly greater than in the control group ($P = 0.02$). This difference was also significance after adjusting with preoperative synechial extent ($P = 0.01$) There was no statistically significant difference between the two groups in angle grading in all four quadrants before and after surgery ($P = 0.97$ and 0.14, respectively). The angles opened in all four quadrants of both groups postoperatively, though. Gonioscopic measurements indicated an improvement in angle width in both groups ($P < 0.001$ for both).

Table 3 summarizes the pre- and postoperative AS-OCT angle findings in the two treatment groups. All angle indicators of angle width (AOD 500, TISA500, AOD 750, TISA 750 ACA and SSA) increased significantly in both groups after surgery. The amount of the increase was higher in the 'Phaco-VGP' group in absolute terms, however the differences were not statistically significant and only the ACA reached borderline statistical significance ($P = 0.051$). ACD and LV increased significantly in both groups after surgery; but the difference was also not significant between the two groups (Table 4).

Subgroup analysis in eyes with extensive PAS (PAS > 180 degree) and eyes with limited PAS (PAS ≤ 180) revealed no significant difference in change in IOP, number of medications and AC and angle parameters between the two groups. The only exception was change in PAS in the group with PAS ≤ 180 in which the 'Phaco-VGP' cases showed more reduction in PAS postoperatively ($P = 0.004$).

The amount of increase in ACD correlated negatively with preoperative ACD ($r = -0.71$ and $r = -0.62$, for 'Phaco-VGP' and 'Phaco alone', respectively [$P < 0.001$ for both groups]), and positively

Table 3. AS-OCT angle parameters before and after surgery in the 'Phaco alone' group and 'Phaco-VGP' group

	Phaco alone	Phaco-VGP	*P*-value
	Mean ± SD	Mean ± SD	
Preoperative AOD500 (mm)	0.121 ± 0.081	0.107 ± 0.077	0.49
Postoperative AOD500 (mm)	0.293 ± 0.143	0.312 ± 0.138	0.60
P-value	<0.001	<0.001	
Preoperative AOD750 (mm)	0.187 ± 0.121	0.166 ± 0.116	0.48
Postoperative AOD750 (mm)	0.483 ± 0.190	0.491 ± 0.174	0.85
P-value	<0.001	<0.001	
Preoperative TISA500 (mm)	0.040 ± 0.030	0.038 ± 0.026	0.82
Postoperative TISA500 (mm)	0.094 ± 0.054	0.101 ± 0.048	0.62
P-value	<0.001	<0.001	
Preoperative TISA750 (mm)	0.076 ± 0.052	0.075 ± 0.055	0.92
Postoperative TISA750 (mm)	0.191 ± 0.093	0.20 ± 0.09	0.67
P-value	<0.001	<0.001	
Change in AOD500 (mm)	0.173 ± 0.112	0.205 ± 0.104	0.24
Change in AOD750 (mm)	0.296 ± 0.169	0.325 ± 0.127	0.43
Change in TISA500 (mm)	0.055 ± 0.042	0.063 ± 0.033	0.40
Change in TISA750 (mm)	0.115 ± 0.074	0.126 ± 0.063	0.53
Change in ACA (mm)	13.09 ± 8.40	16.91 ± 7.23	0.05
Change in SSA (mm)	15.50 ± 9.28	18.33 ± 8.02	0.19

ACA, anterior chamber angle; AOD, angle opening distance; SSA, sclera spur angle; TISA, trabecular-iris space area; VGP, viscogonioplasty.

Table 4. AS-OCT anterior chamber parameters before and after surgery in the 'Phaco alone' group and 'Phaco-VGP' group

	Phaco alone	Phaco-VGP	*P*-value
	Mean ± SD	Mean ± SD	
Preoperative ACD (mm)	2.00 ± 0.31	2.00 ± 0.28	0.97
Postoperative ACD (mm)	3.60 ± 0.28	3.62 ± 0.25	0.89
P-value	<0.001	<0.001	
Preoperative LV ± SD (μ)	918.1 ± 167.8	942.2 ± 212.1	0.61
Postoperative LV ± SD (μ)	–650.9 ± 273.1	–707.6 ± 276.0	0.40
P-value	<0.001	<0.001	
Change in ACD (mm)	1.60 ± 0.33	1.61 ± 0.35	0.89
Change in LV (μ)	–1569.1 ± 316.0	–1650.0 ± 292.1	0.29

ACD, anterior chamber depth; LV, lens vault; VGP, viscogonioplasty.

with preoperative lens vault in both groups ($r = 0.47$, $P = 0.006$, and $r = 0.52$, $P = 0.002$ for the 'Phaco-VGP' and 'Phaco alone' groups, respectively) (Figs 2 and 3). The extent of IOP reduction postoperatively was directly related to the preoperative IOP in the 'Phaco alone' and 'Phaco-VGP' groups ($r = 0.54$, $P < 0.001$, and $r = 0.64$, $P < 0.001$, respectively) but not to the preoperative ACD, LV and angle parameters ($P > 0.12$ for all). In the 'Phaco alone' group, the only anterior chamber parameter that correlated with AOD500 change was LV change ($r = -0.43$, $P = 0.01$). However, this correlation was not found in the 'Phaco-VGP' group ($P = 0.46$).

Three patients in the 'Phaco-VGP' and one in the 'Phaco alone' group developed fibrin reaction postoperatively that resolved after a few days. Also, two patients in the 'Phaco-VGP' group developed hyphema intraoperatively that subsided within seconds by visco-tamponade.

Discussion

In this study, which is the first randomized study to evaluate the effect of adjunctive VGP on drainage angle as determined by indentation gonioscopy and AS-OCT, we showed a 167.1% and 230.1% increase in AOD500 and 83.32% and 83.55% in ACD in "Phaco alone' and 'Phaco-VGP' group, respectively. This is in agreement with the[33] study by Nolan *et al.* which showed a dramatic increase in angle width (88.2% increase in AOD500) after phacoemulsification in 21 eyes with cataract, seven of which had gonioscopic evidence of PAC. They also showed a significant 1.31 mm increase in ACD. Similarly,

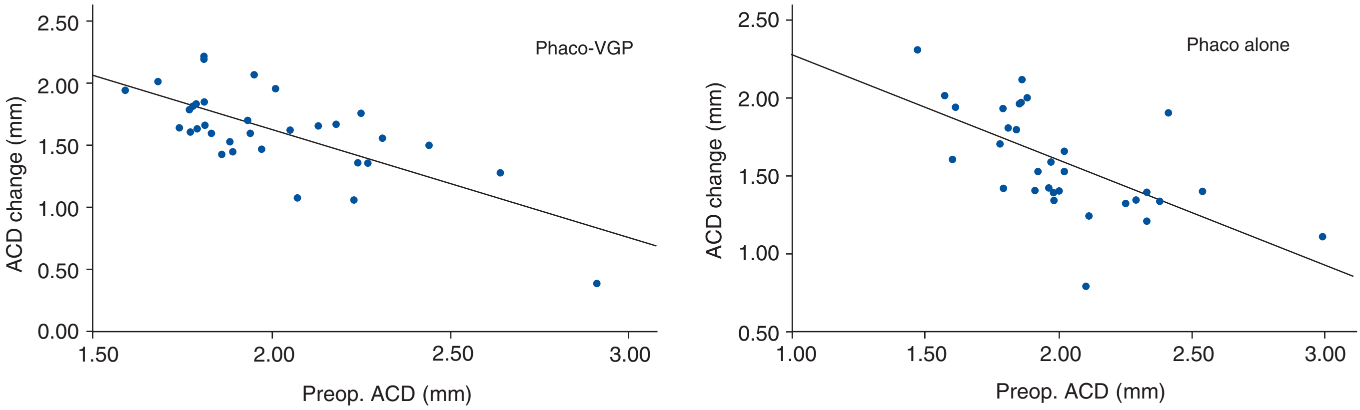

Figure 2. Scatter plot showing negative correlation between change in anterior chamber depth (ACD) and preoperative ACD in the 'Phaco alone' (r = –0.62, $P < 0.001$) and 'Phaco-VGP' groups (r = –0.71, $P < 0.001$).

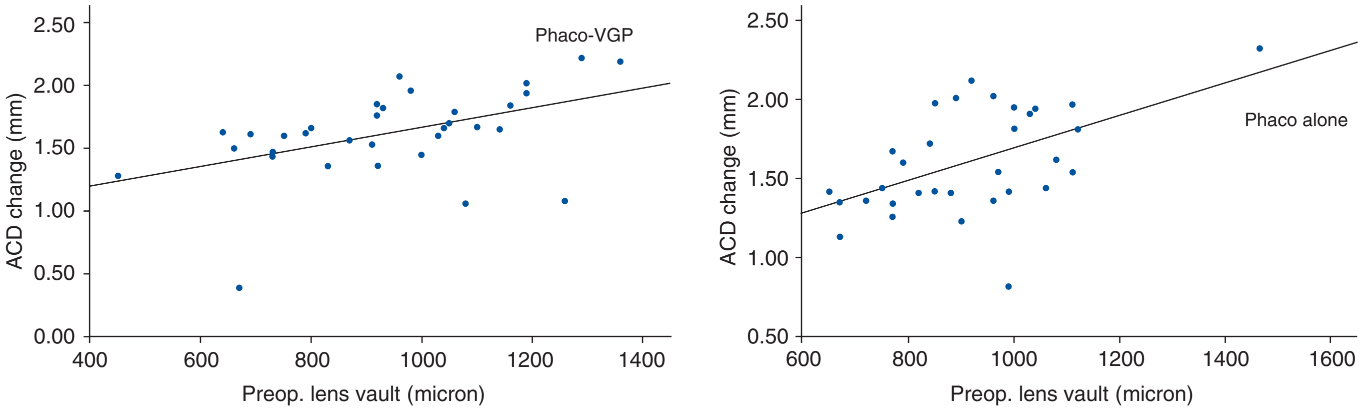

Figure 3. Scatter plot showing positive correlation between change in anterior chamber depth (ACD) and preoperative lens vault (LV) in the 'Phaco alone' (r = 0.52, $P = 0.002$) and 'Phaco-VGP' groups (r = 0.47, $P = 0.006$).

other investigators demonstrated a significant increase in AOD500 (from 0.09 to 0.25 mm),[34] ACD (from 2.03 to 3.39 mm),[34] and ACA (from 16.0 to 32.3 degree)[35] after phacoemulsification in patients with PACG or PAC.

In our study, changes in angle parameters were greater in the 'Phaco-VGP' group, although the difference did not reach statistical significance. The amount of change in ACD was similar in both groups, and may be explained by the concept that VGP is supposed to have its effect on the angle and peripheral iris rather than central structures. We also found that the extent of synechial angle closure was significantly reduced after the phacoemulsification alone and phacoemulsification plus VGP. However, the change in the 'Phaco-VGP' group was significantly more pronounced than in the 'Phaco alone' group.

In the past, the preferred practice was to perform cataract extraction combined with trabeculectomy in PACG patients who have a visually significant cataract in association with uncontrolled IOP.[36,37] However this combined procedure carries a significant risk of developing postoperative complications like flat anterior chamber, bleb leak, malignant glaucoma and choroidal effusion.[38] Based on two recent related randomized clinical trials (RCT), it appears that phacoemulsification alone is a reasonable surgical alternative to combined phacotrabeculectomy in CACG eyes, whether the preoperative IOP is medically controlled or not.[38,39]

The exact mechanism underlying this IOP reduction is not well understood. Phacoemulsification eliminates the pupillary block component and lessens angle crowding caused by a thick and anteriorly placed lens.[36] The deepening of the anterior chamber, the widening of the drainage angle and the improved access of aqueous to the trabecular meshwork may all contribute to this IOP reduction.[13] However, in patients with CACG and PAS, the trabecular meshwork may remain occluded by PAS despite the anterior chamber deepening after phacoemulsification alone. Potentially, the trabecular meshwork can be exposed by breaking PAS with goniosynechialysis.[15–17] Breaking PAS with goniosynechialysis and possible restoration of trabecular function before further irreversible structural changes, progress seems to be a logical approach to the treatment of CACG.[1,15]

Some investigators have evaluated the efficacy of VGP combined with cataract extraction in eyes with acute angle closure glaucoma (AACG).[1] They reported a significant reduction in IOP from 52.1 to 14.1 mmHg with no residual synechiae across 360 degrees of the angle.

A few studies reported the effectiveness of this procedure in management of patients with CACG, as well. Razeghinejad and Rahat showed a significant reduction of IOP from 16.7 to 14.4 mmHg and from 27.95 to 15.5 mmHg in medically controlled and uncontrolled patients, respectively. A significant number of their patients didn't have PAS, and they did not report the change in PAS or amount of open angle postoperatively.[40] Varma *et al.* in an RCT showed a greater reduction in IOP in patients who had undergone phacoemulsification and VGP than patients who had phacoemulsification alone. However, they did not mention the amount of PAS before and after surgery and didn't report the details of gonioscopic findings. They also stated that a study with AS-OCT was needed to document the difference instead of just subjective gonioscopic findings.[19] Although our study was not powered to detect a difference in IOP between the two surgical groups, the similarities in their effects suggest that IOP is not significantly improved by adding VGP when doing phacoemulsification. Although some investigators reported a reduction of PAS extent after performing phacoemulsification and goniosynechialysis in patients with AACG[15] or CACG,[40] mechanical deepening of the anterior chamber with viscoelastic and saline infusion during phacoemulsification alone may also open some PAS.[37] In the present study, which is the first study to assess the effect of additional VGP in cataract surgery on the drainage angle, PAS extent decreased significantly after both procedures. However, the change in PAS extent in the 'Phaco-VGP' group was significantly higher than in the 'Phaco alone' group. Injection of high molecular weight viscoelastics near the angle seems to have additional effect in the reduction of PAS extent.

In our study, the differences in the change in angle parameters did not reach statistical significance between the two groups. It has been suggested that gonioscopic appearance and AS-OCT readings are not exactly equivalent, because the two examinations evaluate different anatomic parameters. Gonioscopy can document the extent of synechial angle closure in degrees, whereas OCT measures a variety of anatomic parameters from a single cross-sectional scan.[41] A cross-section taken close to but not including a narrow area of PAS may result in narrow measurements of angle parameters, which would result in narrower angle readings in eyes with PAS.[28] These could in part explain the findings of the present study. In a clinical trial of Asian patients with PACG, there was only a weak correlation between the number of clock hours of PAS and AS-OCT parameters.[28]

Although some investigators showed reduction of IOP correlated with the extent of recurrent PAS after an attack of ACG,[15,42] there was no significant difference in change in IOP, number of medications and AC and angle parameters between the two groups in our cases with either PAS $\leq$ 180 or $>$ 180 degrees. The only exception was change in PAS in the group with PAS $\leq$ 180 in which the 'Phaco-VGP' cases showed more reduction in PAS postoperatively. Other studies also found little correlation between the preoperative PAS extent and IOP control after phacoemulsification in PACG[14,21,43,44] A possible explanation may be that it is difficult to evaluate the extent of PAS in eyes with extremely shallow anterior chambers[22,44] Gonioscopic appearance may not truly reflect the extent of damage in the trabecular meshwork, the loss of trabecular cells and the irregular architecture of the trabeculum that might exist in areas away from visible PAS.[45]

It has been shown that preoperative ACD is one of the prominent factors predicting post-cataract surgery IOP in PACG.[14,44–47] In eyes with a shallower ACD a large lens may prevent the access of aqueous to the angle and play a more predominant role in causing elevation of IOP.[14] Some studies have shown a negative correlation between preoperative ACD and postoperative widening of the drainage angle.[10,48,49] In our cases, the amount of increase in ACD correlated negatively with preoperative ACD. This finding was supported by Shin *et al.* in which AC deepening was reported to be inversely correlated to preoperative ACD in occludable angles.[7]

Lens vault is a recent novel structure that is being measured from the AS-OCT images. It quantifies the extent of the lens that is located anterior to the anterior chamber angles and has been shown to be an independent ocular parameter associated with PACG. Nongpiur *et al.* recently found that increased lens vault increases the risk of having angle closure by 48 times.[50] LV is a good indicator of the amount of narrowing of the preoperative anterior chamber, and has been shown to have a negative correlation with preoperative ACD.[51] We found that the amount of increase in ACD highly correlated with preoperative LV in both groups. Thus, LV might be a determinant for long-term IOP control after phacoemulsification.

The reported complications with VGP include mild to severe haemorrhage from the iris or trabecular meshwork, fibrin exudation, iridodialysis, shallow anterior chamber and transient elevation of IOP in the immediate postoperative period. Although Razeghinejad *et al*. didn't find any serious complications in their series of patients who underwent VGP, we encountered more fibrin reaction in the 'Phaco-VGP' group compared to the 'Phaco alone' group. However, VGP seems to be a much safer procedure than synechialysis done by knife or blunt spatula.

The results of our study should be interpreted with its limitations in mind. Our cases were not homogenous and had variable amount of PAS of varying duration. Thus, our sample size might not possess sufficient power to perform a subgroup analysis of those with different PAS extent. In addition, all the patients enrolled in our study were Iranian, and it is not known whether these findings could be generalized to patients of other ethnicities, particularly those in Asia where ACG is prevalent. Another limitation was the short duration of postoperative follow-up for IOP evaluation. That might have been a contributory reason for the non-significant correlation between change in IOP and anterior segment and angle parameters. One limitation of the AS-OCT is it obtains a cross-section of the anterior segment along one meridian and is unable to adequately assess for the extent of PAS. Lastly, although a glaucoma specialist measured PAS extent in degrees based on indentation gonioscopy, subjective evaluation of PAS might be an estimate and has some variability.

In summary, our randomized clinical trial showed that both phacoemulsification VGP and phacoemulsification alone resulted in opening of the drainage angle, deepening of the anterior chamber and reduction of PAS extent in PACG eyes. VGP results in greater reduction of PAS. Both procedures lead to significant reductions in medications and IOP, though there was no statistically significant difference between the two. Longer follow-up time points and larger number of subjects are needed to determine the effect of adjunctive VGP on IOP.

Acknowledgements

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported. The study and data accumulation were carried out with prospective approval from the Institutional Review Board of Tehran University of Medical Science (Trial Number: IRCT201012015288N1). Informed consent was obtained from all patients. The study adheres to the tenets of the Declaration of Helsinki.

References

1. Varma D, Adams W, Phelan P, Fraser S. Viscogonioplasty in patients with chronic narrow angle glaucoma. *Br J Ophthalmol* 2006; **90**: 648–9.
2. Lowe RF. Aetiology of the anatomical basis for primary angle-closure glaucoma. Biometrical comparisons between normal eyes and eyes with primary angle-closure glaucoma. *Br J Ophthalmol* 1970; **54**: 161–9.
3. Lowe R. Causes of shallow anterior chamber in primary angle-closure glaucoma. Ultrasonic biometry of normal and angle-closure glaucoma eyes. *Am J Ophthalmol* 1969; **67**: 87–93.
4. Foster PJ. The epidemiology of primary angle closure and associated glaucomatous optic neuropathy. Informa UK Ltd UK, 2002:50–8.
5. Friedman DS, Gazzard G, Foster P *et al*. Ultrasonographic biomicroscopy, Scheimpflug photography, and novel provocative tests in contralateral eyes of Chinese patients initially seen with acute angle closure. *Arch Ophthalmol* 2003; **121**: 633–42.
6. Wojciechowski R, Congdon N, Anninger W, Teo Broman A. Age, gender, biometry, refractive error, and the anterior chamber angle among Alaskan Eskimos. *Ophthalmology* 2003; **110**: 365–75.
7. Shin HC, Subrayan V, Tajunisah I. Changes in anterior chamber depth and intraocular pressure after phacoemulsification in eyes with occludable angles. *J Cataract Refract Surg* 2010; **36**: 1289–95.
8. Tai MC, Chien KH, Lu DW, Chen JT. Angle changes before and after cataract surgery assessed by Fourier-domain anterior segment optical coherence tomography. *J Cataract Refract Surg* 2010; **36**: 1758–62.
9. Huang G, Gonzalez E, Lee R, Chen YC, He M, Lin SC. Association of biometric factors with anterior chamber angle widening and intraocular pressure reduction after uneventful phacoemulsification for cataract. *J Cataract Refract Surg* 2012; **38**: 108–16.
10. Hayashi K, Hayashi H, Nakao F, Hayashi F. Changes in anterior chamber angle width and depth after intraocular lens implantation in eyes with glaucoma. *Ophthalmology* 2000; **107**: 698–703.
11. Viet Tran H, Liebmann JM, Ritch R. Iridociliary apposition in plateau iris syndrome persists after cataract extraction. *Am J Ophthalmol* 2003; **135**: 40–3.
12. Yang CH, Hung PT. Intraocular lens position and anterior chamber angle changes after cataract extraction in eyes with primary angle-closure glaucoma. *J Cataract Refract Surg* 1997; **23**: 1109–13.
13. Tham CCY, Leung DYL, Kwong YYY, Li FCH, Lai JSM, Lam DSC. Effects of phacoemulsification versus combined phaco-trabeculectomy on drainage angle status in primary angle closure glaucoma (PACG). *J Glaucoma* 2010; **19**: 119–23.
14. Liu CJ, Cheng CY, Wu CW, Lau LI, Chou JC, Hsu WM. Factors predicting intraocular pressure control after

phacoemulsification in angle-closure glaucoma. *Arch Ophthalmol* 2006; **124**: 1390–4.
15. Teekhasaenee C, Ritch R. Combined phacoemulsification and goniosynechialysis for uncontrolled chronic angle-closure glaucoma after acute angle-closure glaucoma. *Ophthalmology* 1999; **106**: 669–75.
16. Lai JSM, Tham CCY, Lam DSC. The efficacy and safety of combined phacoemulsification, intraocular lens implantation, and limited goniosynechialysis, followed by diode laser peripheral iridoplasty, in the treatment of cataract and chronic angle-closure glaucoma. *J Glaucoma* 2001; **10**: 309–15.
17. Senn P, Kopp B. Nd: [YAG laser synechiolysis in glaucoma due to iridocorneal angle synechiae]. *Klin Monatsbl Augenheilkd* 1990; **196**: 210–3.
18. Varma D, Baylis O, Wride N, Phelan P, Fraser S. Viscogonioplasty: an effective procedure for lowering intraocular pressure in primary angle closure glaucoma. *Eye* 2006; **21**: 472–5.
19. Varma D, Adams W, Bunce C, Phelan P, Fraser S. Viscogonioplasty in narrow angle glaucoma: a randomized controlled trial. *Clin Ophthalmol (Auckland, NZ)* 2010; **4**: 1475–9.
20. Razeghinejad MR. Combined phacoemulsification and viscogoniosynechialysis in patients with refractory acute angle-closure glaucoma. *J Cataract Refract Surg* 2008; **34**: 827–30.
21. Wishart P, Atkinson P. Extracapsular cataract extraction and posterior chamber lens implantation in patients with primary chronic angle-closure glaucoma: effect on intraocular pressure control. *Eye* 1989; **3**: 706–12.
22. Gunning FP, Greve EL. Lens extraction for uncontrolled angle-closure glaucoma: long-term follow-up. *J Cataract Refract Surg* 1998; **24**: 1347–56.
23. Gazzard G, Foster P, Friedman D, Khaw P, Seah S. Light to dark physiological variation in irido-trabecular angle width. *Br J Ophthalmol* 2004; **88**: 1357–482.
24. Nolan W. Anterior segment imaging: ultrasound biomicroscopy and anterior segment optical coherence tomography. *Curr Opin Ophthalmol* 2008; **19**: 115–21.
25. Dada T, Sihota R, Gadia R, Aggarwal A, Mandal S, Gupta V. Comparison of anterior segment optical coherence tomography and ultrasound biomicroscopy for assessment of the anterior segment. *J Cataract Refract Surg* 2007; **33**: 837–40.
26. Nolan W. Anterior segment imaging: identifying the landmarks. *Br J Ophthalmol* 2008; **92**: 1575–6.
27. Nongpiur ME, He M, Amerasinghe N *et al*. Lens vault, thickness, and position in Chinese subjects with angle closure. *Ophthalmology* 2011; **118**: 474–9.
28. Su DHW, Friedman DS, See JLS *et al*. Degree of angle closure and extent of peripheral anterior synechiae: an anterior segment OCT study. *Br J Ophthalmol* 2008; **92**: 103–7.
29. Nolan WP, See JL, Chew PTK *et al*. Detection of primary angle closure using anterior segment optical coherence tomography in Asian eyes. *Ophthalmology* 2007; **114**: 33–9.
30. Huang G, Gonzalez E, Peng PH *et al*. Anterior chamber depth, iridocorneal angle width, and intraocular pressure changes after phacoemulsification: narrow vs open iridocorneal angles. *Arch Ophthalmol* 2011; **129**: 1283–90.
31. Casson RJ, Newland HS, Muecke J *et al*. Gonioscopy findings and prevalence of occludable angles in a Burmese population: the Meiktila Eye Study. *Br J Ophthalmol* 2007; **91**: 856–9.
32. Radhakrishnan S, See J, Smith SD *et al*. Reproducibility of anterior chamber angle measurements obtained with anterior segment optical coherence tomography. *Invest Ophthalmol Vis Sci* 2007; **48**: 3683–8.
33. Nolan WP, See JL, Aung T *et al*. Changes in angle configuration after phacoemulsification measured by anterior segment optical coherence tomography. *J Glaucoma* 2008; **17**: 455–9.
34. Nonaka A, Kondo T, Kikuchi M *et al*. Angle widening and alteration of ciliary process configuration after cataract surgery for primary angle closure. *Ophthalmology* 2006; **113**: 437–41.
35. Dawczynski J, Koenigsdoerffer E, Augsten R, Strobel J. Anterior segment optical coherence tomography for evaluation of changes in anterior chamber angle and depth after intraocular lens implantation in eyes with glaucoma. *Eur J Ophthalmol* 2007; **17**: 363–7.
36. Ho CL, Walton DS, Pasquale LR. Lens extraction for angle-closure glaucoma. *Int Ophthalmol Clin* 2004; **44**: 213–28.
37. Lai JSM, Tham CCY, Chan JCH. The clinical outcomes of cataract extraction by phacoemulsification in eyes with primary angle-closure glaucoma (PACG) and co-existing cataract: a prospective case series. *J Glaucoma* 2006; **15**: 47–52.
38. Tham CCY, Kwong YYY, Leung DYL *et al*. Phacoemulsification versus combined phacotrabeculectomy in medically controlled chronic angle closure glaucoma with cataract. *Ophthalmology* 2008; **115**: 2167–73. e2.
39. Tham CCY, Kwong YYY, Leung DYL *et al*. Phacoemulsification versus combined phacotrabeculectomy in medically uncontrolled chronic angle closure glaucoma with cataracts. *Ophthalmology* 2009; **116**: 725–31. e3.
40. Razeghinejad MR, Rahat F. Combined phacoemulsification and viscogoniosynechialysis in the management of patients with chronic angle closure glaucoma. *Int Ophthalmol* 2010; **30**: 353–9.
41. Hong Y, Zhang C, Wang W. Comment on effects of phacoemulsification versus combined phacotrabeculectomy on drainage angle status in primary angle closure glaucoma. *J Glaucoma* 2010; **19**: 224–5.
42. Thomas R, Walland MJ, Parikh RS. Clear lens extraction in angle closure glaucoma. *Curr Opin Ophthalmol* 2011; **22**: 110–4.
43. Harasymowycz PJ, Papamatheakis DG, Ahmed I *et al*. Phacoemulsification and goniosynechialysis in the management of unresponsive primary angle closure. *J Glaucoma* 2005; **14**: 186–9.

44. Fakhraie G, Vahedian Z, Moghimi S, Eslami Y, Zarei R, Faraji Oskouee J. Phacoemulsification and goniosynechialysis for the management of refractory acute angle closure. *Eur J Ophthalmol* 2012; **22**: 714–8.
45. Liu CJ, Cheng CY, Ko YC, Lau LI. Determinants of long-term intraocular pressure after phacoemulsification in primary angle-closure glaucoma. *J Glaucoma* 2011; **20**: 566–70.
46. Latifi G, Moghimi S, Eslami Y, Fakhraie G, Zarei R, Lin S. Effect of phacoemulsification on drainage angle status in angle closure eyes with or without extensive peripheral anterior synechiae. *Eur J Ophthalmol* 2012; **3**: 0. doi: 10.5301/ejo.5000191. [Epub ahead of print].
47. Moghimi S, Lin S. Role of phacoemulsification in angle closure glaucoma. *Yan Ke Xue Bao* 2011; **26**: 121–31.
48. Marchini G, Pagliarusco A, Toscano A, Tosi R, Brunelli C, Bonomi L. Ultrasound biomicroscopic and conventional ultrasonographic study of ocular dimensions in primary angle-closure glaucoma. *Ophthalmology* 1998; **105**: 2091–8.
49. Kurimoto Y, Park M, Sakaue H, Kondo T. Changes in the anterior chamber configuration after small-incision cataract surgery with posterior chamber intraocular lens implantation. *Am J Ophthalmol* 1997; **124**: 775–80.
50. Nongpiur ME, Ku JYF, Aung T. Angle closure glaucoma: a mechanistic review. *Curr Opin Ophthalmol* 2011; **22**: 96–101.
51. Kucumen RB, Yenerel NM, Gorgun E, Kulacoglu DN, Dinc UA, Alimgil ML. Anterior segment optical coherence tomography measurement of anterior chamber depth and angle changes after phacoemulsification and intraocular lens implantation. *J Cataract Refract Surg* 2008; **34**: 1694–8.