Original Article

# Changes in anterior chamber biometry and intraocular pressure after uneventful phacoemulsification in non-glaucomatous eyes

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## ABSTRACT

**Background:** In non-glaucomatous eyes, many factors impact intraocular pressure (IOP) reduction following phacoemulsification. This study aimed to determine the relationship between changes in IOP and alterations in anterior chamber biometric measurements using the Pentacam Scheimpflug anterior segment imaging system before and after uneventful phacoemulsification in non-glaucomatous eyes.

**Methods:** This prospective interventional study included patients with ages of 20 – 80 years, no known systemic diseases, and visually significant cataracts necessitating phacoemulsification with posterior chamber intraocular lens implantation. The preoperative and two-month postoperative IOPs were measured using a Goldmann applanation tonometer, and the iridocorneal angle (ICA) in four quadrants (superior, inferior, nasal, and temporal), anterior chamber depth (ACD), and anterior chamber volume (ACV) were measured using the Pentacam.

**Results:** Forty-two eyes of 42 patients with a mean (standard deviation [SD]) age of 56.8 (10.7) years were included; 22 (52%) were men and 20 (48%) were women. The eyes demonstrated statistically significant changes in postoperative IOP, ACD, ACV, and in widening of the ICA (all $P < 0.05$), with a mean (SD) IOP reduction of 4.5 (2.7) mmHg, ACD deepening of 0.7 (0.6) mm, ACV increase of 33.2 (21.1) $mm^3$, and ICA widening of 7.5° (6.4°), 12.4° (7.7°), 9.1° (7.1°), and 11.5° (6.1°) in the superior, inferior, temporal, and nasal quadrants, respectively. A significant positive correlation was detected between pre- and postoperative IOP ($r = +0.58$; $P < 0.001$) and between pre- and postoperative ACD ($r = +0.50$; $P < 0.001$). Significant negative correlations were detected between preoperative ACV and changes in ACV ($r = -0.42$; $P < 0.001$) and between preoperative ICA and changes in ICA ($r = -0.02$; $P = 0.001$). However, no significant correlations were observed between the changes in IOP and patient age ($r = +0.001$; $P = 0.957$) and axial length of the eye ($r = +0.13$; $P = 0.221$), or changes in ICA ($r = -0.01$; $P = 0.945$), ACD ($r = +0.01$; $P = 0.945$), and ACV ($r = -0.12$; $P = 0.599$).

**Conclusions:** We observed a significant reduction in IOP, widening of the ICA, and increases in ACD and ACV after phacoemulsification; however, there was no significant correlation between changes in IOP and other biometric variables. Further studies are required to determine the exact mechanisms underlying these effects.

## KEYWORDS

phacoemulsifications, intraocular lens implantation, intraocular pressures, anterior chambers, biometric analysis, data correlation

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## INTRODUCTION

Cataracts and glaucoma are among the main causes of visual impairment worldwide [1]. Although not typically severe enough to cause blindness, these two conditions are comorbid in many patients [2]. Numerous studies have reported changes in intraocular pressure (IOP) after cataract surgery [3-7], with significantly reduced postoperative IOP compared to preoperative values [4-7]. Differences in effects according to surgical technique are controversial, as IOP changes in the three refractive categories were reportedly the same whether using phacoemulsification or extracapsular cataract extraction [7]. However, some have held that IOP reduction is greater after phacoemulsification than after extracapsular cataract extraction [2].

Aging increases volume of the human crystalline lens. Changes in the anterior and posterior chamber anatomy may follow, eventually resulting in an increased IOP [8]. As the lens ages, the anterior capsule is directed anteriorly, causing forward advancement of the zonules and anterior traction on the ciliary body. This, in turn, leads to compression of both the trabecular meshwork and Schlemm's canal. Considering the contribution of the anterior tendons of the ciliary muscles to the trabecular meshwork, the muscles of the ciliary body advance anteriorly by enlarging the crystalline lens, the tendons relax, and the distance between trabecular structures narrows [9]. Cataract extraction deepens the anterior chamber, lowers IOP, and increases the iridocorneal angle (ICA) width [10].

In non-glaucomatous eyes, several anatomic and physiological factors affect IOP reduction following phacoemulsification [11]. One of the most important is the preoperative anterior chamber angle configuration [11-13]. Greater IOP reductions occur in eyes with partially or completely closed angles. The *pressure to angle ratio* was defined as the ratio of the preoperative corrected IOP to the preoperative anterior chamber angle. An investigation in non-glaucomatous eyes revealed a sensitivity and specificity of 52.9% and 80.6%, respectively, of a pressure to angle ratio ≥ 5.6 mmHg per degree for a postoperative IOP reduction of ≥ 2 mmHg [12]. In addition to angle anatomy, other factors independently affect postoperative IOP reduction, such as aqueous humor dynamics, preoperative IOP, and ocular comorbidities [14, 15].

Clinical assessment of the anterior segment is usually achieved using slit-lamp biomicroscopy [16]; however, objective assessment of the angle is limited, and direct anterior chamber angle examination can also be achieved using diagnostic contact lenses such as the Goldmann 3-mirror lens [17]. Recently, numerous tools for anterior segment evaluation have been invented, such as ultrasonic biomicroscopy [18], optic coherence tomography [19, 20], Orbscan slit topography [20], and Pentacam Scheimpflug imaging [19, 20]. Each of these tools provides quantitative assessment and qualitative imaging of the anterior segment structures. The Pentacam Scheimpflug is a rapid, non-invasive, easy-to-utilize, reproducible, user-independent imaging tool with high patient comfort. In addition, it rapidly assesses nearly all parameters of the anterior segment and requires no topical anesthesia [21-23].

This study aimed to determine the relationship between IOP and biometric changes in the anterior chamber using Pentacam Scheimpflug imaging (Oculus GmbH, Wetzlar, Germany) after uneventful phacoemulsification in non-glaucomatous eyes.

## METHODS

This prospective interventional study was conducted at Ibn Al Haitham Teaching Eye Hospital, Baghdad, Iraq, between July 2020 and July 2021. Ethical approval was obtained from the Ministry of Higher Education and Scientific Research, University of Anbar Ethical Approval Committee (Anbar, Iraq). The study complied with the tenets of the Declaration of Helsinki, and all participants provided written informed consent before recruitment.

We included patients with ages between 20 and 80 years, no known systemic diseases such as diabetes mellitus and hypertension, and visually significant cataracts requiring phacoemulsification with posterior chamber intraocular lens implantation. We excluded patients with (1) ICA < 20° according to Pentacam measurements, (2) previous eye trauma or surgery, (3) uveitis, (4) glaucoma, (5) use of topical or systemic drugs that might affect IOP readings, such as ocular or systemic steroids, (6) pseudo-exfoliation syndrome, or (7) intraoperative complications such as capsulorhexis complications, iris trauma, posterior capsule tear, zonular dialysis, and vitreous loss, or postoperative complications such as bullous keratopathy and glaucoma.

A full ophthalmic examination was performed one day before cataract surgery. Best-corrected distance visual acuity (BCDVA) was measured using a Snellen chart (Elite Medical Instruments EMI, Orange County, CA, USA). IOP was measured using a Goldmann applanation tonometer (Model AT 900; Haag-Streit, Switzerland) after the application of a single drop of topical tetracaine hydrochloride 0.5% (Cooper Pharmaceuticals SA, Athens, Greece) and a fluorescein sodium ophthalmic strip (Medical Equipment India) to the patient's eye. The anterior segment was examined under a slit-lamp microscope (BM 900; Haag-Streit). Fundus examination was performed using a + 90.0 diopter non-contact lens (Volk Optical, Inc., OH, USA) under a slit lamp for eyes in which cataract density permitted. When the fundus was not visible, the posterior segment was assessed using B-scan ultrasonography (NIDEK Echoscan US-4000; Gamagori, Japan). Axial length and intraocular lens (IOL) power were measured using IOLMaster (Carl-Zeiss Meditec, Jena, Germany).

The ICA in four quadrants (superior, inferior, nasal, and temporal), anterior chamber depth (ACD), and anterior chamber volume (ACV) were measured using the Pentacam in a standard dimly illuminated room by an expert technician. The patient sat comfortably with the aid of a chinrest and forehead strap and was asked to fixate on a black target with blue background lighting. A rotating Scheimpflug camera and slit monochromatic light are included in the Pentacam system [24], both of which rotate 360° around the optical axis to quantify the anterior and posterior corneal elevation data, corneal thickness, ACV, ACD, and ICA in automatic mode. The BCDVA, IOP, and Pentacam images of the anterior segment were repeated two months postoperatively by the same examiner or technician.

Surgery was performed under topical or retrobulbar anesthesia. A corneal incision was made using a 2.8-mm keratome. A capsulorrhexis of approximately 5.0 mm in diameter was performed using Utrata capsulorhexis forceps under viscoelastic protection. Uneventful phacoemulsification was performed as previously described [25]. A foldable acrylic IOL with a 6.0-mm optic and 12.5-mm overall diameter (Rohto neo eye IOL foldable acrylic hydrophilic; Rohto Laboratories, Indonesia) (18 eyes) or a hydrophilic Auroflex (Aurolab, Tamil Nadu, India) (24 eyes) was implanted in the capsular bag. The incisions were not sutured. Postoperatively, the patients were administered topical 0.5% moxifloxacin (Vigamox; Alcon Laboratories, Inc., Fort Worth, TX, USA) and prednisolone acetate 1% (Pred Forte®; Allergan, Inc., Irvine, CA, USA) four times per day, with tapering over one month.

Statistical analyses were performed using Statistical Package for the Social Sciences version 23 (SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA). The Kolmogorov – Smirnov test was used to test the normality of data distribution. Pearson's correlation test was used to assess the correlations between variables. Qualitative variables were compared using the chi-square test and are displayed as frequencies and percentages. Quantitative variables were compared using the Student's *t*-test and are displayed as mean and standard deviation (SD). A *P*-value < 0.05 was regarded as significant.

## RESULTS

We included 42 eyes of 42 patients with a mean (SD) age of 56.8 (10.7) years, all having uneventful phacoemulsification. Twenty-two (52%) patients were men and 20 (48%) were women, with a right-to-left eye ratio of 1:1. The mean (SD) axial length was 23.2 (1.2) mm. Twenty-five eyes (60%) had nuclear sclerotic cataracts, 10 eyes (24%) had posterior subcapsular cataracts, three eyes (7%) had cortical cataracts, and four eyes (9%) had mixed cataracts.

The eyes demonstrated statistically significant changes in postoperative IOP ($P < 0.001$), with a mean (SD) reduction of 4.5 (2.7) mmHg (Table 1). A significant moderate and positive correlation was detected between pre- and postoperative IOP values ($r = +0.58$; $P < 0.001$) (Figure 1A), but not between changes in IOP and

**Table 1. Preoperative and postoperative parameters and their changes in all included eyes**

| Parameter | Preoperative values | Postoperative values | Change* | *P*-value |
|---|---|---|---|---|
| **IOP (mmHg), Mean ± SD** | 18.5 ± 2.9 | 14.0 ± 2.9 | - 4.5 ± 2.7 | **< 0.001** |
| **ACD (mm), Mean ± SD** | 2.7 ± 0.4 | 3.4 ± 0.7 | 0.7 ± 0.6 | **0.001** |
| **Superior angle (degree), Mean ± SD** | 31.9 ± 7.7 | 39.4 ± 6.7 | 7.5 ± 6.4 | **< 0.001** |
| **Inferior angle (degree), Mean ± SD** | 31.3 ± 7.2 | 43.7 ± 6.1 | 12.4 ± 7.7 | **0.034** |
| **Temporal angle (degree), Mean ± SD** | 35.6 ± 7.9 | 44.7 ± 6.4 | 9.1 ± 7.1 | **< 0.001** |
| **Nasal angle (degree), Mean ± SD** | 34.8 ± 6.5 | 46.3 ± 5.1 | 11.5 ± 6.1 | **0.002** |
| **Total ICA (degree), Mean ± SD** | 33.4 ± 5.2 | 43.5 ± 4.2 | 10.1 ± 4.9 | **< 0.001** |
| **ACV($mm^3$), Mean ± SD** | 145.6 ± 39.2 | 178.8 ± 35.9 | 33.2 ± 21.1 | **< 0.001** |

**Abbreviations: IOP, intraocular pressure; mmHg, millimeter of mercury; SD, standard deviation; ACD, anterior chamber depth; mm, millimeters; ICA, iridocorneal angle; ACV, anterior chamber volume; $mm^3$, cubic millimeters. Note: *P*-values < 0.05 are shown in bold;*Change represents postoperative – preoperative mean values.**

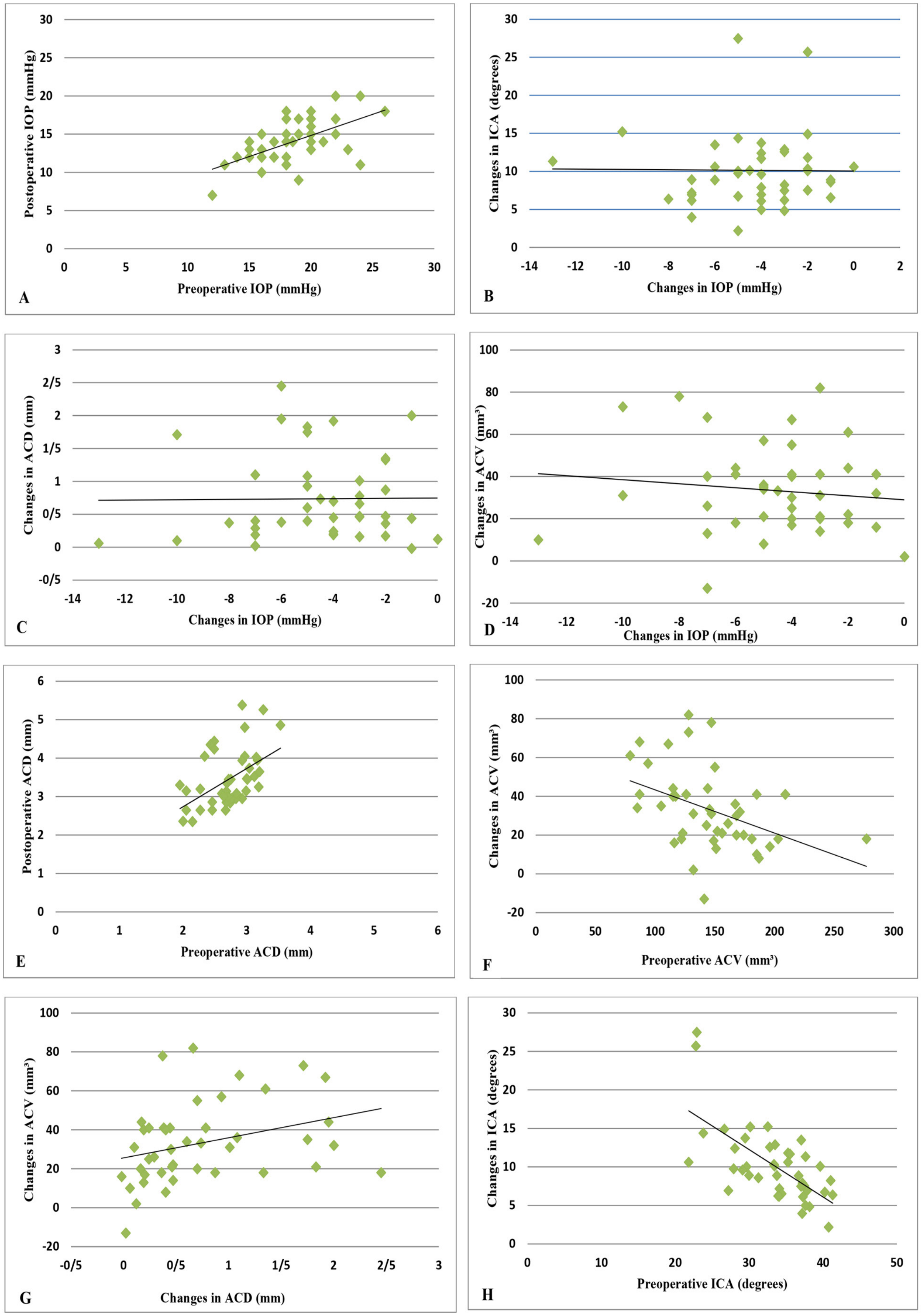


**Figure 1. Scatterplots for Pearson correlation between (A) preoperative and postoperative IOP, (B) changes in IOP and ICA, (C) changes in IOP and ACD, (D) changes in IOP and ACV, (E) preoperative and postoperative ACD, (F) preoperative ACV and changes in ACV, (G) changes in ACD and ACV, and (H) preoperative ICA and changes in ICA. Abbreviations: IOP, intraocular pressure; mmHg, millimeter of mercury; ICA, iridocorneal angle; ACD, anterior chamber depth; mm, millimeters; ACV, anterior chamber volume; mm$^3$, cubic millimeters**

changes in ICA (r = - 0.01; $P$ = 0.945) (Figure 1B), ACD (r = + 0.01; $P$ = 0. 945) (Figure 1C), or ACV (r = - 0.12; $P$ = 0.599) (Figure 1D). There was no significant correlation between changes in IOP and patient age (r = + 0.001; $P$ = 0.957) or axial length of the eye (r = + 0.13; $P$ = 0.221).

The eyes demonstrated statistically significant changes in postoperative ACD ($P$ = 0.001) and ACV ($P$ < 0.001) (Table 1), with a mean (SD) deepening of 0.7 (0.6) mm in ACD and an increase of 33.2 (21.1) $mm^3$ in ACV. A significant moderate and positive correlation was detected between preoperative and postoperative ACD (r = + 0.50; $P$ < 0.001) (Figure 1E), but not between changes in ACD and ICA (r = - 0.009; $P$ = 0.075). A significant low and negative correlation was detected between preoperative ACV and changes in ACV (r = - 0.42; $P$ < 0.001) (Figure 1F), but not between changes in ACD and changes in ACV (r = + 0.32; $P$ = 0.075) (Figure 1G).

The eyes demonstrated statistically significant widening of the ICA, with mean (SD) values of 7.5° (6.4°), 12.4° (7.7°), 9.1° (7.1°), and 11.5° (6.1°) in the superior, inferior, temporal, and nasal quadrants, respectively (all $P$ < 0.05) (Table 1). A significant change in the total ICA was detected postoperatively ($P$ < 0.001), with a mean (SD) deepening of 10.1° (4.9°) (Table 1). A significant negligible and negative correlation was found between preoperative ICA and changes in ICA (r = - 0.02; $P$ = 0.001) (Figure 1H), indicating that the narrower the preoperative ICA, the more widening of the postoperative ICA.

## DISCUSSION

The current study employed the advantages of the Pentacam imaging tool and found statistically significant changes in all parameters, including a reduction in IOP, increases in ACD and ACV, and a widening in the total and four quadrants of the ICA two months after uneventful phacoemulsification in non-glaucomatous eyes. A significant direct correlation was detected between preoperative and postoperative IOP and between preoperative and postoperative ACD. A significant inverse correlation was detected between preoperative ACV and changes in ACV and between preoperative ICA and changes in ICA.

The Pentacam is a noncontact optical appliance that uses a simple anterior segment analyzer, and the data are captured rapidly and operator-independently. Currently, the Pentacam system calculates ACD with a standard deviation of 20 μm in normal eyes [21]. The previous EAS-1000 model of the Scheimpflug videophotography system acquired only a single anterior segment image, while the Pentacam acquires up to 50 images in each scan [26]. Many studies have used different devices to evaluate changes in ICA after cataract surgery [27, 28]. The old method was gonioscopic examination; however, this method is difficult to perform, user-dependent, and non-quantitative [29-31]. We employed the Pentacam to measure anterior segment parameters and found results comparable with those of studies conducted on non-glaucomatous eyes using other measurement devices [27, 28].

Despite the difference in instruments used, as in the current study, Liu et al. [27] found a significant difference between preoperative and postoperative IOP using a Canon TX-10 tonometer in non-glaucomatous eyes with senile cataracts and in eyes with primary angle closure and cataracts; both groups demonstrated a significant decreasing trend. Likewise, they found a significant difference between the preoperative and postoperative ACDs using an Alcon Ultrascan A/B in non-glaucomatous eyes with senile cataracts and in eyes with primary angle closure and cataracts, both of which demonstrated significant deepening [27]. Similarly, Issa et al. [28], at 8 – 9 weeks after uneventful phacoemulsification in non-glaucomatous eyes, observed a significant deepening in ACD with a mean (SD) of 1.10 (0.44) mm using a contact ultrasound A-scanner (Sonomed Model 100A), also detecting a significant inverse correlation between this deepening and preoperative ACD. Moreover, they found a significant decrease in postoperative IOP with a mean of 2.55 (1.78) mmHg, and they detected a significant direct correlation between this reduction and preoperative IOP using a Goldmann applanation tonometer, as well as preoperative ACD [28]. We found a significant direct correlation between pre- and postoperative IOP, but not between changes in IOP and ACD.

Also using the Pentacam Scheimpflug camera, as in the current study, Ucakhan et al. [32] observed a significant increase in mean ACV (164.7 $mm^3$ to 200.9 $mm^3$), ACD (3.0 mm to 3.9 mm), and ICA (35.7° to 41.5°) in four quadrants and a decrease in IOP (15.8 mmHg to 13.2 mmHg) using Goldmann applanation tonometry at three months after uneventful phacoemulsification in non-glaucomatous eyes [32]. Altan et al. [33] followed open-angle non-glaucomatous eyes after uneventful phacoemulsification up to the sixth month and found a significantly lower IOP at all postoperative examinations compared to the preoperative value using a Goldmann applanation tonometer. Using a Goldmann 3-mirror lens, widening of the ICA was revealed at 1-week and 1-month postoperative examinations, compared to the preoperative value, based on the Shaffer classification. Likewise, the ACD significantly deepened at all postoperative measurements compared to the preoperative values using A-scan ultrasonography. However, postoperative reduction in IOP was not dependent on changes in ACD or ICA width; the only statistically significant predictor was the preoperative IOP [33]. Similarly, we observed a significant decrease in IOP with a mean (SD) of - 4.5 (2.7) mmHg two months after cataract surgery, with a significant positive correlation between the pre- and postoperative IOP, but not with changes in ACD, ICA, or ACV.

Hayashi et al. [34] used the EAS-1000 Scheimpflug videophotography system and demonstrated a significant increase in ACD and widening of the ICA three months after phacoemulsification in both glaucomatous and non-glaucomatous eyes, and these changes were more prominent in eyes with angle-closure glaucoma. They attributed the decrease in IOP to an increase in ICA width and concluded that cataract removal may improve IOP more consistently in eyes with crowded angles. In contrast, in eyes with open-angle glaucoma, in which the aqueous drainage system is compromised, the IOP-lowering effect may be temporary [34]. Doganay et al. measured IOP using a Goldmann applanation tonometer and the ACD, ACV, and ICA using a Pentacam at 1, 3, and 6 months postoperatively. All postoperative measurements were significantly different from preoperative values. Likewise, they found no significant correlation between IOP reduction and changes in ACD, ACV, or ICA [35]. We followed non-glaucomatous eyes with open ICA for up to two months postoperatively and found no significant correlation between IOP reduction and ACD deepening or ICA widening.

All these studies demonstrated a significant reduction in IOP in both non- glaucomatous [27, 28, 32-34] and glaucomatous eyes [34], which was not correlated with ACD and ICA width [33, 35]. They attributed the anterior chamber alterations to a backward iris shift with about 10º angular motion post-cataract extraction, in addition to the release of a probable accompanying relative papillary block in eyes with a crowded anterior chamber [13, 27, 32]. Our results were comparable with those of the aforementioned studies, and similarly, all found considerable postoperative changes such as deepening of the ACD or widening of the ICA in all four quadrants.

Several studies have discussed the possible mechanisms of IOP reduction after phacoemulsification. In general, they emphasized three potential mechanisms: increased aqueous humor drainage through the uveoscleral pathway, enhanced conventional pathway by decreasing aqueous humor outflow resistance, and aqueous humor hyposecretion due to traction on the ciliary body via the zonule or other biomechanical alterations [36-42]. Dooley et al. introduced two additional novel indices of preoperative parameters, preoperative IOP / preoperative ACV and preoperative IOP / preoperative ICA, as measures predictive of IOP reduction after uneventful phacoemulsification in non-glaucomatous eyes [12]. The cause of IOP reduction in normal eyes after phacoemulsification may be due to increased uveoscleral outflow or aqueous humor hyposecretion [33, 35]. Regardless of the mechanism, we noticed a significant reduction in IOP, and the postoperative IOP was directly correlated with the preoperative IOP.

In line with previous studies, our findings revealed a significant reduction in IOP and improvement in anterior segment parameters two months after uneventful phacoemulsification in non-glaucomatous eyes. Using a Scheimpflug rotating camera to evaluate the anterior chamber could be associated with reduced visualization of angle structures owing to light scattering in the angle region, which might increase measurement errors [32]. This was avoided by excluding eyes with limited visualization of the angular structures. However, our study was limited by a lack of comparison groups featuring eyes with open- or closed-angle glaucoma, which should be addressed in further studies of the same population. Another limitation is the short follow-up period. The durability of IOP reduction after cataract extraction procedures should be confirmed over a longer follow-up period. Further studies using both tonography and fluorometry are required to elucidate the exact mechanisms of IOP reduction observed after uneventful cataract extraction procedures.

## CONCLUSIONS

In short-term follow-up, a significant reduction in IOP with a deepening of ACD, an increase in ACV, and a widening of the total and four quadrants of the ICA were observed after uneventful phacoemulsification in non-glaucomatous eyes. This reduced postoperative IOP was significantly correlated with preoperative IOP, yet not with ACD, ICA, or ACV changes. Long-term IOP reduction should be confirmed over a longer follow-up period. Further studies are required to determine the exact mechanisms underlying these effects.

## ETHICAL DECLARATIONS

**Ethical approval:** Ethical approval was obtained from the Ministry of Higher Education and Scientific Research, University of Anbar Ethical Approval Committee (Anbar, Iraq). The study complied with the tenets of the Declaration of Helsinki, and all participants provided written informed consent before recruitment.
**Conflict of interest:** None.

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