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Original Research Article

A Comparison of Changes in Anterior Chamber Angle, Anterior Chamber Depth and Iop after Phacoemulsification in Normotensive Cataract Patients

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ABSTRACT
Background: Phacoemulsification induces anatomical changes in the anterior segment that may influence intraocular pressure (IOP) even in eyes without glaucoma.
Aims: To evaluate changes in anterior chamber depth (ACD), anterior chamber angle (ACA), and IOP following phacoemulsification in normotensive senile cataract patients and to assess correlations between anatomical changes and IOP reduction.
Methods: A Prospective Observational Study of Fifty eyes with senile cataract undergoing uncomplicated phacoemulsification were included. IOP was measured using Goldmann applanation tonometry. ACA was assessed in four quadrants using Goldmann four-mirror gonioscopy, and ACD was measured using A-scan ultrasonography. Measurements were recorded preoperatively and at 1, 2, and 6 months postoperatively.
Results: Mean IOP decreased significantly from 18.6 ± 3.1 mmHg preoperatively to 14.2 ± 2.6 mmHg at 6 months ($p<0.001$). Mean ACD increased from 2.73 ± 0.32 mm to 3.43 ± 0.36 mm ($p<0.001$). ACA widened significantly in all quadrants postoperatively ($p<0.001$). IOP reduction correlated significantly with higher preoperative IOP but not with changes in ACD or ACA.
Conclusions: Phacoemulsification in normotensive eyes significantly deepens the anterior chamber, widens the anterior chamber angle, and reduces IOP, providing benefits beyond visual rehabilitation.

Keywords: Phacoemulsification, Intraocular Pressure, Anterior Chamber Depth, Anterior Chamber Angle, Senile Cataract.

INTRODUCTION

Cataract remains the leading cause of avoidable blindness worldwide and continues to pose a major public health challenge, particularly in developing and low-income countries where access to surgical care remains limited. Global estimates indicate that cataract accounts for a substantial proportion of moderate to severe visual impairment and blindness, disproportionately affecting the elderly population and placing a significant burden on healthcare systems and individual quality of life. [1] Among the various subtypes, age-related or senile cataract is by far the most prevalent, and its progressive nature significantly impairs visual acuity, contrast sensitivity, and overall functional vision. The consequent deterioration in daily activities, independence, and psychosocial well-being makes timely surgical intervention not merely a clinical necessity but a public health imperative. [2]

Phacoemulsification with posterior chamber intraocular lens (IOL) implantation has emerged as the gold standard technique for cataract extraction and is widely adopted across ophthalmic centers globally. Its widespread acceptance is attributable to its excellent safety profile, rapid postoperative visual recovery, minimal surgically induced astigmatism, small incision size, and highly predictable refractive outcomes. [2] However, the clinical significance of phacoemulsification extends well beyond the restoration of visual function. Cataract surgery induces a series of significant anatomical and physiological alterations within the anterior segment of the eye that have important implications for ocular health. Removal of the crystalline lens leads to deepening of the anterior chamber, widening of the anterior chamber angle (ACA), and a measurable reduction in intraocular pressure (IOP), even in eyes without pre-existing glaucoma or elevated baseline pressure. [3,4] These structural changes reflect a fundamental reorganization of anterior segment geometry following the elimination of the space-occupying crystalline lens.

Multiple studies have demonstrated statistically significant and sustained IOP reduction following phacoemulsification in both glaucomatous and nonglaucomatous eyes, establishing that this pressure-lowering effect is a consistent and reproducible consequence of lens extraction rather than an incidental observation. [3–6] The underlying mechanism is believed to involve posterior displacement of the iris–lens diaphragm following removal of the crystalline lens, which in turn increases anterior chamber depth (ACD) and reduces crowding of the trabecular meshwork. This decompression of the outflow pathway facilitates improved aqueous humor drainage and consequently lowers IOP. [7–9] Understanding these mechanisms is of considerable relevance not only to cataract surgeons but also to clinicians managing patients with glaucoma or borderline ocular hypertension.

The crystalline lens undergoes progressive thickening with advancing age as a result of the continuous addition of lens fibers throughout life. This age-related increase in lens volume contributes to gradual shallowing of the anterior chamber and narrowing of the anterior chamber angle, thereby reducing the available space for aqueous humor outflow. [10] The landmark EAGLE study provided robust clinical evidence that lens extraction significantly lowers IOP and widens the anterior chamber angle in eyes with angle-closure disease, establishing early lens extraction as a superior intervention compared with laser peripheral iridotomy in this context. [5,11] Although the anatomical and pressure-related effects of phacoemulsification are most pronounced in eyes with angle-closure glaucoma, where the mechanical contribution of the lens to outflow obstruction is most direct, similar and clinically meaningful pressure-lowering trends have also been documented in normotensive eyes and those with open-angle configurations. [4,12] This suggests that the anterior segment benefits of lens extraction are not restricted to pathological states but represent a broader physiological consequence of removing the crystalline lens.

Baseline IOP has been consistently identified as an important determinant of the magnitude of postoperative pressure reduction, with eyes demonstrating higher preoperative IOP generally showing greater absolute reductions following surgery. [4,13] This relationship implies that the pressure-lowering effect of phacoemulsification may be of particular clinical value in patients with elevated baseline pressures, even in the absence of a formal diagnosis of glaucoma. Mansberger et al. further corroborated these observations, confirming sustained and clinically significant IOP reduction following cataract extraction in patients with ocular hypertension, thereby supporting the therapeutic potential of lens extraction as a pressure-modulating intervention. [14]

Advances in anterior segment imaging technology, particularly anterior segment optical coherence tomography (AS-OCT), have greatly enhanced the ability to precisely quantify changes in anterior chamber depth and angle parameters in the postoperative period. These high-resolution, non-contact imaging modalities have enabled objective and reproducible measurement of anterior segment structures, facilitating a more nuanced understanding of the anatomical remodeling that accompanies phacoemulsification. Imaging studies have consistently demonstrated postoperative widening of the ACA and reduction in lens vault following lens extraction, providing morphometric confirmation of the clinically observed improvements in anterior chamber geometry. [7–9,15,16] However, a notable observation emerging from several of these studies is that the degree of anatomical widening does not consistently correlate with the magnitude of IOP reduction, suggesting that the pressure-lowering mechanisms following phacoemulsification are multifactorial and cannot be explained by angle widening alone. [13,17] Functional changes at the trabecular meshwork level, alterations in aqueous humor dynamics, and biomechanical modifications of the corneoscleral tissues have all been proposed as contributing factors.

Despite the growing body of global evidence supporting the anterior segment benefits of phacoemulsification, data specifically evaluating these changes in normotensive

Indian populations remain relatively limited. This represents a meaningful gap in the literature, particularly given the well-documented anatomical predisposition of Asian eyes toward shallower anterior chambers and narrower angles compared with their Western counterparts. [18,19] These population-specific anatomical differences may influence both the baseline characteristics of the anterior segment and the magnitude of structural changes following lens extraction, making it important to evaluate these outcomes in ethnically relevant cohorts. Studies conducted in predominantly Caucasian or East Asian populations may not fully reflect the anterior segment morphology and surgical outcomes in the Indian population. The present study was therefore designed to systematically assess changes in anterior chamber depth, anterior chamber angle, and intraocular pressure following uneventful phacoemulsification in normotensive senile cataract patients drawn from an Indian tertiary care setting, and to analyze the relationship between the anatomical alterations induced by lens extraction and the degree of postoperative IOP reduction. The findings are intended to contribute population-specific data to the existing literature and to enhance the understanding of the physiological consequences of cataract surgery in normotensive eyes.

Subjects

This prospective observational study included normotensive patients with senile cataract who underwent uneventful phacoemulsification with posterior chamber intraocular lens implantation.

Inclusion Criteria

- Patients aged 45 – 75 years
- Diagnosis of senile cataract
- Normotensive eyes with preoperative intraocular pressure within the normal physiological range (10–21 mmHg)
- Patients undergoing uneventful phacoemulsification with posterior chamber intraocular lens implantation
- Willingness to participate and comply with follow-up protocol

Exclusion Criteria

- History or presence of glaucoma, ocular hypertension, or angle-closure disease
- History of uveitis or pseudoexfoliation syndrome
- Presence of corneal pathology affecting anterior segment assessment
- Retinal or posterior segment disease that could influence visual or pressure outcomes
- Previous ocular surgery
- Eyes with intraoperative complications
- Eyes developing significant postoperative complications during follow-up that could affect anterior chamber parameters or intraocular pressure

MATERIALS AND METHODS

This prospective observational study evaluated 50 eyes of 50 patients undergoing uneventful phacoemulsification for senile cataract at a tertiary care center between June 2025 and December 2025. All procedures adhered to the tenets of the Declaration of Helsinki. Institutional Ethics Committee approval was obtained prior to commencement of the study, and written informed consent was obtained from all participants.

All participants underwent a comprehensive preoperative ophthalmic evaluation. Preoperative assessment included best-corrected visual acuity using Snellen's chart, slit-lamp Biomicroscopy for anterior segment evaluation, and dilated fundus examination with direct and indirect Ophthalmoscopy to rule out posterior segment pathology.

Intraocular pressure was measured using Goldmann applanation tonometry, the reference standard for IOP assessment. Anterior chamber angle evaluation was performed using Goldmann four-mirror gonioscope under standardized illumination conditions, and grading was recorded in all four quadrants according to Shaffer's classification. Measurement of anterior chamber depth was performed using A-scan ultrasonography along the visual axis.

Surgical Technique

All surgeries were performed by a single experienced surgeon under strict aseptic precautions using topical anesthesia and a standardized clear corneal phacoemulsification technique. After instillation of topical anesthetic drops, the periocular skin was cleaned with 10% povidone–iodine solution and the conjunctival sac was irrigated with 5% povidone–iodine. The operative eye was draped in a sterile fashion, and a sterile eyelid speculum was inserted to maintain adequate exposure.

Following adequate pupillary dilation, a 2.8-mm temporal clear corneal main incision and a side-port incision were created using a keratome and microblade, respectively. A viscoelastic agent was injected into the anterior chamber to maintain chamber stability and protect the corneal endothelium. Continuous curvilinear capsulorhexis of approximately 5.0–5.5 mm was performed using a cystotome and capsulorhexis forceps. This was followed by gentle hydrodissection and hydrodelineation to achieve free rotation of the nucleus.

Phacoemulsification of the nucleus was carried out using the divide-and-conquer technique. Nuclear fragments were emulsified and aspirated, followed by thorough cortical cleanup using bimanual irrigation–aspiration. The capsular bag was then inflated with viscoelastic, and a foldable posterior chamber intraocular lens was implanted within the capsular bag.

After intraocular lens implantation, residual viscoelastic material was meticulously aspirated from both the anterior chamber and capsular bag. The main incision and side-port wounds were hydrated with balanced salt solution to ensure watertight closure. The incisions were self-sealing and did not require sutures.

At the completion of surgery, a topical antibiotic was instilled according to institutional protocol, and a sterile eye pad or shield was applied. All patients received standard postoperative topical antibiotic and steroid therapy.

Postoperative regimen included topical antibiotics and steroids.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (IBM SPSS 21) software. Continuous variables such as intraocular pressure (IOP), anterior chamber depth (ACD), and other ocular biometric parameters were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

Normality of data distribution was assessed using the Shapiro–Wilk test. Preoperative and postoperative values of IOP and ACD at different follow-up intervals were compared using paired t-test for normally distributed data. Changes in anterior chamber angle (ACA) grades before and after surgery were analyzed using the Chi-square test or Fisher's exact test, as appropriate.

A p-value of less than 0.05 was considered statistically significant.

RESULTS

Fifty eyes of 50 patients were analyzed. The demographic characteristics of the study population are summarized in Table 1.

Intraocular Pressure

A statistically significant reduction in intraocular pressure was observed following phacoemulsification at all postoperative visits. ($p < 0.001$) The decline in IOP was evident as early as the first postoperative month and remained stable through six months, indicating sustained pressure control. (Table 2) The reduction was more pronounced in eyes with higher baseline IOP. These findings are consistent with previously reported pressure-lowering effects of cataract surgery. [3–6,14,20,21]

Anterior Chamber Depth

A significant increase in anterior chamber depth was observed postoperatively ($p < 0.001$), with maximal deepening noted during early follow-up and maintained throughout the study period. (Table 2) The expansion of the anterior chamber was uniform across the cohort, reflecting effective posterior displacement of the iris–lens diaphragm. [7–9,15,22]

Anterior Chamber Angle

Postoperative gonioscopy demonstrated significant widening of the anterior chamber angle ($p < 0.001$). Eyes with narrower preoperative angles showed greater improvement in Shaffer grading, with a shift toward higher angle grades at follow-up (Table 3). This confirms substantial anterior segment remodeling following lens extraction. [7,8,16,23]

Correlation Analysis

A significant positive association was observed between baseline IOP and the magnitude of postoperative IOP reduction. However, no statistically significant correlation was found between the degree of anterior chamber deepening or angle widening and the extent of IOP reduction, suggesting that pressure lowering may not be solely dependent on anatomical expansion. [4,13,14,17,21,24]

DISCUSSION

The present study demonstrates that phacoemulsification in normotensive senile cataract patients results in significant anterior chamber deepening, widening of the anterior chamber angle, and sustained IOP reduction over six months. These findings collectively underscore the broader physiological impact of lens extraction beyond its primary role in visual rehabilitation, and contribute to the growing body of evidence supporting the biomechanical significance of cataract surgery in anterior segment remodeling.

The magnitude and durability of IOP reduction observed in our cohort are consistent with contemporary literature. Mansberger et al. [14] and Chen et al. [3] demonstrated sustained postoperative IOP lowering following cataract extraction across diverse patient populations. Similar conclusions were reported by Shingleton et al. [20], who emphasized the role of lens extraction in long-term pressure modulation, noting that the pressure-lowering effect persisted well beyond the early postoperative period. The consistency of IOP reduction across these studies, as well as in our cohort, suggests that the pressure-lowering effect of phacoemulsification is a reliable and reproducible outcome rather than an incidental finding. In our study, mean IOP declined from 18.6 ± 3.1 mmHg preoperatively to 14.2 ± 2.6 mmHg at six months, representing a clinically meaningful reduction that was sustained at all follow-up intervals.

Anterior segment imaging studies have quantitatively confirmed structural remodeling after lens extraction. Lee et al. [7] and Huang et al. [8] demonstrated significant increases in anterior chamber depth and angle width using anterior segment optical coherence tomography (AS-OCT), providing objective morphometric evidence of the anatomical changes that follow phacoemulsification. More recent OCT-based analyses by Kim et al. [9] and Lai and Tham [25] further validated sustained anterior segment expansion after surgery, confirming that these structural changes are not transient but persist over time. Nongpiur et al. [23] highlighted the importance of modern imaging modalities in understanding postoperative anatomical changes, emphasizing that high-resolution anterior segment imaging has transformed our ability to quantify and interpret the structural consequences of lens removal. In the present study, anterior chamber depth increased from 2.73 ± 0.32 mm preoperatively to 3.43 ± 0.36 mm postoperatively, consistent with the posterior displacement of the iris–lens diaphragm following lens extraction.

The EAGLE trial established that early lens extraction provides superior pressure control and anatomical widening compared with laser peripheral iridotomy in angle-closure disease. [5,11] This landmark study shifted clinical thinking toward lens extraction as a primary intervention in angle-closure management, demonstrating not only greater IOP reduction but also improved quality of life outcomes. Subsequent reviews and updates by Day et al. [26] and Aung et al. [27] reinforced this evolving paradigm, emphasizing that lens extraction plays a central role in angle-closure management by addressing the underlying anatomical substrate rather than merely providing a bypass for aqueous drainage. He et al. [16] further emphasized the biomechanical influence of the crystalline lens on anterior segment configuration, demonstrating that progressive age-related lens growth contributes to anterior chamber crowding and that its removal fundamentally alters the spatial relationships within the anterior segment.

Although our cohort consisted of normotensive eyes without angle-closure disease, the anatomical principles described in that context remain relevant and applicable. The crystalline lens exerts a mechanical influence on anterior chamber geometry regardless of the clinical diagnosis, and its removal predictably deepens the anterior chamber and widens the angle irrespective of the preoperative pressure status. Francis et al. [27] and Shrivastava and Singh [17] have described cataract surgery as an important adjunct in glaucoma management, highlighting mechanisms that extend beyond simple angle widening. These include improvements in trabecular meshwork function, changes in aqueous humor dynamics, and alterations in the biomechanical properties of the anterior segment tissues following decompression of the anterior chamber.

Interestingly, while significant anterior segment expansion was documented in our cohort, the absence of a strong correlation between the degree of structural enlargement and the magnitude of IOP reduction supports the hypothesis that postoperative pressure control is multifactorial in nature. [13,17] This dissociation between anatomical widening and pressure reduction suggests that the mere mechanical expansion of the anterior chamber angle does not fully account for the observed IOP changes. Ang and Whyte [24] similarly reported that anatomical widening alone does not fully account for IOP reduction following lens extraction, and proposed that functional changes at the level of the trabecular meshwork may play an equally important role. Recent reviews by Tham and Leung [29] further suggest that improved trabecular function, altered aqueous dynamics, and biomechanical changes in the corneoscleral and uveal tissues may all contribute to the pressure-lowering effect. The release of mechanical stress on the trabecular meshwork following removal of a large, crowding lens may restore or enhance its filtering capacity, independent of the degree of angle widening observed gonioscopically.

Our findings therefore align with global evidence demonstrating that phacoemulsification induces durable anatomical remodeling and clinically meaningful IOP reduction, even in normotensive eyes. The results of the present study further support the concept that the anterior segment benefits of cataract surgery are not confined to eyes with pre-existing pressure elevation or angle pathology, but extend to the broader population of patients undergoing routine lens extraction.

The sustained IOP reduction observed at six months strongly suggests that postoperative pressure modulation is not merely transient or inflammation-related, but reflects durable biomechanical remodeling of the anterior segment. Early postoperative IOP changes could theoretically be attributed to residual viscoelastic effects, postoperative inflammation, or transient alterations in aqueous dynamics. However, the persistence of significant IOP reduction through six months of follow-up in our cohort argues against such transient explanations and supports the conclusion that lens extraction induces lasting structural and functional changes in the aqueous outflow pathway. These findings have important implications for the perioperative counseling of cataract patients, particularly those with borderline IOP or early glaucomatous changes, in whom the additional pressure-lowering benefit of phacoemulsification may represent a clinically valuable outcome.

CONCLUSION

Phacoemulsification results in significant anterior chamber angle widening, increased anterior chamber depth, and sustained intraocular pressure reduction in normotensive senile cataract patients. The greater postoperative IOP reduction observed in eyes with higher baseline IOP suggests that pressure modulation following lens extraction is multifactorial and not solely dependent on anatomical widening. These findings support the concept that phacoemulsification confers meaningful biomechanical and physiological benefits beyond visual rehabilitation.

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LIMITATIONS

Limitations of the present study include the relatively small sample size, single-center study design, absence of a control group, and limited duration of follow-up. In addition, gonioscopic assessment of the anterior chamber angle may be observer-dependent.

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Table 1. Demographic and Baseline Characteristics of the Study Population (n = 50)

Parameter	Value
Number of patients (eyes)	50 (50)
Age (years), mean ± SD	57.2 ± 9.4
Age range (years)	45–75

Gender (Male : Female)	22 : 28
Preoperative IOP (mmHg), mean ± SD	18.6 ± 3.1
Preoperative Anterior Chamber Depth (ACD) (mm), mean ± SD	2.73 ± 0.32
Preoperative Anterior Chamber Angle (ACA), mean Shaffer grade ± SD	2.0 ± 0.5
Most common preoperative Shaffer grade	Grade 2

Table 2. Changes in Intraocular Pressure (IOP) and Anterior Chamber Depth (ACD) Following Phacoemulsification (n = 50)

Time Point	Mean IOP (mmHg) ± SD	Mean Change (IOP)	p-value*	Mean ACD (mm) ± SD	Mean Change (ACD)	p-value*
Preoperative	18.6 ± 3.1	—	—	2.73 ± 0.32	—	—
1st Month Postoperative	15.8 ± 2.8	−2.8	<0.001	3.30 ± 0.35	+0.57	<0.001
2nd Month Postoperative	14.9 ± 2.7	−3.7	<0.001	3.38 ± 0.36	+0.65	<0.001
6th Month Postoperative	14.2 ± 2.6	−4.4	<0.001	3.43 ± 0.36	+0.70	<0.001

*Paired t-test compared with preoperative values.

Table 3. Changes in Anterior Chamber Angle (ACA) Following Phacoemulsification (n = 50)

A. Mean Shaffer Grade Changes

Time Point	Mean Shaffer Grade ± SD	Mean Change from Baseline	p-value*
Preoperative	2.0 ± 0.5	—	—
1st Month Postoperative	3.0 ± 0.5	+1.0 grade	<0.001
2nd Month Postoperative	3.2 ± 0.5	+1.2 grades	<0.001
6th Month Postoperative	3.5 ± 0.5	+1.5 grades	<0.001

B. Distribution of Shaffer Grades Preoperatively and at 6 Months

Shaffer Grade	Preoperative (n)	6-Month Postoperative (n)
Grade 1	10	0
Grade 2	25	5
Grade 3	12	20
Grade 4	3	25
Total	**50**	**50**
Chi-square (χ^2)	**32.9**	
p-value*	**<0.001**	

*Chi-square test compared with preoperative distribution.