Anterior Chamber Remodeling after Cataract Surgery in Eyes with Shallow Anterior Chamber: A Prospective Study

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Abstract

Objective: To evaluate morphological changes in the anterior chamber following cataract surgery in eyes with shallow anterior chambers using anterior segment optical coherence tomography (AS-OCT).

Material and Methods: This hospital-based prospective interventional study included 96 patients with cataract and shallow anterior chambers. Preoperative and postoperative AS-OCT was used to assess anterior chamber depth (ACD) and anterior chamber angle (ACA). Visual acuity, Biometric parameters, and clinical characteristics were recorded. Postoperative evaluation was performed at 1 week and 1 month.

Results: Mean preoperative ACD increased significantly from 2.10 ± 0.12 mm to 3.25 ± 0.17 mm at 1 week and 3.40 ± 0.17 mm at 1 month ($p < 0.001$). Mean ACA widened from $21.22 \pm 1.40°$ preoperatively to $36.07 \pm 1.85°$ at 1 month ($p < 0.001$). Visual acuity improved significantly from 1.45 ± 0.67 LogMAR preoperatively to 0.32 ± 0.12 LogMAR at 1 month ($p < 0.001$). No significant correlation was found between ACD changes and axial length, lens thickness, or visual improvement.

Conclusion: Cataract surgery with intraocular lens implantation induces significant and sustained anterior chamber remodeling in eyes with shallow anterior chambers, leading to increased anterior chamber depth, wider anterior chamber angles, and excellent visual rehabilitation. The absence of significant correlations between biometric parameters and postoperative anatomical changes suggests that cataract extraction provides consistent anterior segment expansion regardless of baseline ocular biometry. AS-OCT offers reliable, objective assessment of these morphological changes and may be valuable for preoperative planning and postoperative evaluation in patients with shallow anterior chambers.

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Introduction

One of the most widespread ophthalmic procedures that are performed on a global scale is cataract surgery and it has millions of cases that are performed every year. Conventionally, the main objective of cataract surgery has been to recover the visual acuity using a clear intraocular lens (IOL) to replace the non-transparent crystalline lens. [1] Nevertheless, as surgical procedures and imaging technologies have progressed, it has become quite clear that cataract surgery causes major structural changes in the anterior part of the eye as a whole; these include visual improvement, anterior chamber depth (ACD), angle configuration, and overall morphology of the anterior segment. These adjustments are particularly essential with patients who have shallow anterior chambers because in addition to restoring vision, "the surgery can also be therapeutic in terms of anatomical predisposition to angle crowding and angle-closure glaucoma. In such a manner, cataract surgery has been transformed into a dual-purpose intervention, which performs a visual rehabilitative and anatomical corrective task. [2]

Phacoemulsification and more recently femtosecond laser-assisted cataract surgery, have enabled the removal of the lens with such precision that the incisions are smaller, which results in minimal surgical trauma, and also enables refracting of the anterior chamber so that it can be controlled. These methods can not only offer safer surgery but also contribute to the stability of the anterior segment after surgery, and have led to further refinement of the spatial dynamics of the anterior chamber, crowding of the anterior chamber can be predicted and more physiological aqueous outflow patterns can be achieved. [3]

Pathophysiologic ally, the crystalline lens is a key component of the anterior chamber anatomy. As we get older, our lens continues to grow and thicken and this leads to progressive shallowing of the anterior chamber. This anterior movement of the iris-lens diaphragm decreases the amount of space available in the angle and predisposes angle closure. Cataract surgery is an effective way to do so, as it can reposition the anterior chamber to a more physiologically desirable position, by removing the thickened lens and replacing it with a much thinner IOL, which in small eyes, hyperopic eyes, or those prone to angle closure, even minor gains in anterior chamber depth have significant clinical effects. [4]

Morphological Changes After Cataract Surgery

Factors leading to crowding in the anterior segment is the crystalline lens that becomes thicker and moves forward with age. By removing it, it removes this bulk, consequently restoring a more physiologic balance in the ocular chamber. The implantation of a foldable IOL, which is much thinner, is more posteriorly located in the capsular bag, not only restores the visual transparency but also allows the extra space in the anterior chamber where the hypertrophic natural lens was located earlier. [18]

Furthermore, structural changes of the anterior chamber after phacoemulsification have direct relationships with the aqueous humor dynamics and long-term management of intraocular pressure (IOP). The outflow resistance in the trabecular meshwork is decreased by increasing the functional space of the anterior chamber, which leads to enhanced aqueous drainage. This means that most of the patients having glaucoma or ocular hypertension at the same time undergo postoperative stabilization of IOP and, in some instances, a decreased requirement of anti-glaucoma drugs. This effect of reducing pressure is usually more eminent in patients with constrained angles or high preoperative IOP, which indicates a therapeutic use of cataract surgery beyond just as a visual restoration. [18, 21]

Material and Methods

Study Design and Setting

This is an institutional based prospective observational study. The clinical setting comprised a Tertiary academic center with dedicated Department of Ophthalmology and the studied was carried from 2024-2026.

Study Population

Ninty-six newly diagnosed patients with age-related cataract who were scheduled to undergo phacoemulsification with posterior chamber intraocular lens (IOL) implantation. Patients underwent a comprehensive preoperative ophthalmic evaluation after obtaining written informed consent.

Ethical Considerations

Approval was obtained from the Institutional Ethics Committee prior to commencement of the study (IEC approval no. (SU/R/2024/1350 71). Written informed consent was taken from all patients. The study adhered to the principles of the Declaration of Helsinki.

Inclusion Criteria

- Patients with cataract and shallow anterior chamber
- Hypermetropic patients with cataract
- Patients willing to provide informed consent

Exclusion Criteria

- All Pseudophakic patients.
- Patients having cataract with deep anterior chamber.
- Myopic patients with cataract.
- Patients with active corneal disease or corneal opacity.
- Patients unwilling or unable to comply with the study protocol or follow-up visits.

Data Collection

After obtaining informed consent, all participants underwent detailed history and clinical examination with Best Corrected Visual Acuity assesment (Snellen, converted to logMAR), A detailed anterior segment examination was subsequently performed using a slit-lamp biomicroscope (Appasamy Associates, Chennai, Tamil Nadu, India). The anterior chamber was graded according to the Van Herick grading system, and cataract morphology and severity were evaluated by slit-lamp examination using a +20 Diopter Volk lens (Volk Optical Inc., Mentor, Ohio, USA).

Anterior segment imaging was performed using an Anterior Segment Optical Coherence Tomography (AS-OCT) system (Appasamy Associates, Chennai, Tamil Nadu, India). Quantitative measurements including anterior chamber depth (ACD), angle opening parameters, trabecular-iris angle (TIA), trabecular-iris space area (TISA), angle opening distance (AOD), lens vault (LV), and other anterior segment parameters were recorded under standardized lighting conditions by the same experienced examiner to minimize interobserver variability.

Ocular biometry was performed preoperatively for intraocular lens power calculation. Objective refraction and keratometry readings were obtained using an Auto-Refractometer/Keratometer (Model AARK-7000) Appasamy Associates, Chennai, Tamil Nadu, India). Axial length measurements and IOL power calculations were performed using an A-scan ultrasound biometer (Model AppaScan MAX-AP) Appasamy Associates, Chennai, Tamil Nadu, India), and the appropriate IOL power was selected using standard biometric formulas.

All cataract surgeries were performed under an operating

microscope (Leica Microsystems, Wetzlar, Germany). A standard phacoemulsification technique with in-the-bag IOL implantation was employed in all cases to ensure uniformity of the surgical procedure. All parameters analysis of Anterior chamber done using Optical Coherence Tomography Machine (APPA OCT 2019 AMBATTUR CHENNAI).
Follow-up were conducted at 1 week and 1 months using identical protocols.

Data Analysis
Data were entered in Microsoft Excel 2010 and analyzed using Stata MP-17. Descriptive statistics were used for demographic and clinical variables. Parametric and non-parametric tests were applied as appropriate. Correlation analysis assessed structure–function relationships. $p < 0.05$ was considered statistically significant.

Result
A total of 96 eyes of 96 patients with cataract and shallow anterior chambers were included in the final analysis. The demographic and baseline clinical characteristics are summarized in Table 1.

Baseline Characteristics
The majority of patients belonged to the 51–60-year age group (49/96, 51.0%), followed by the 61–70-year group (34/96, 35.4%). Patients aged <50 years constituted 6/96 (6.3%), while 7/96 (7.3%) were older than 70 years. There was a slight male predominance, with 53 males (55.2%) and 43 females (44.8%).

Table 1: Demographic Profile

Age Group	No. of Patients	%
<50	6	6.25
51–60	49	51.04167
61–70	34	35.41667
>70	7	7.291667
Total	96	100

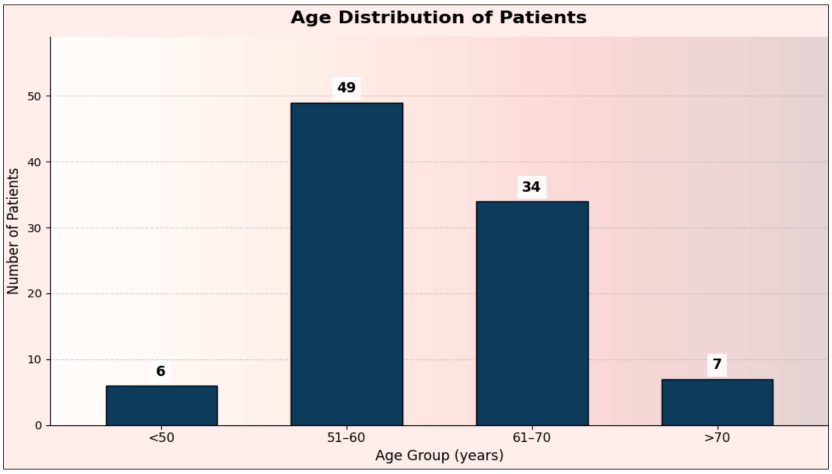

Fig 1: Demographic Profile

Regarding cataract morphology, Nuclear Grade II cataract was the most common subtype, observed in 26 patients (27.0%), followed by mature senile cataract in 20 patients (20.8%) and phacomorphic glaucoma in 15 patients (15.6%). Cortical cataract and posterior subcapsular cataract was each present in 12 patients (12.5%), whereas Nuclear Grade III cataract was observed in 11 patients (11.4%). The remaining cataract subtypes constituted a small proportion of the study population (Table 2).

Table 2: Cataract Grading

Grading of Cataract	No. of Patients	%
Nuclear Grade II	26	27.0
MSC	20	20.8
Phacomorphic Glaucoma	15	15.6
Cortical	12	12.5
Posterior Subcapsular	12	12.5
Nuclear Grade III	11	11.4
Total	96	100

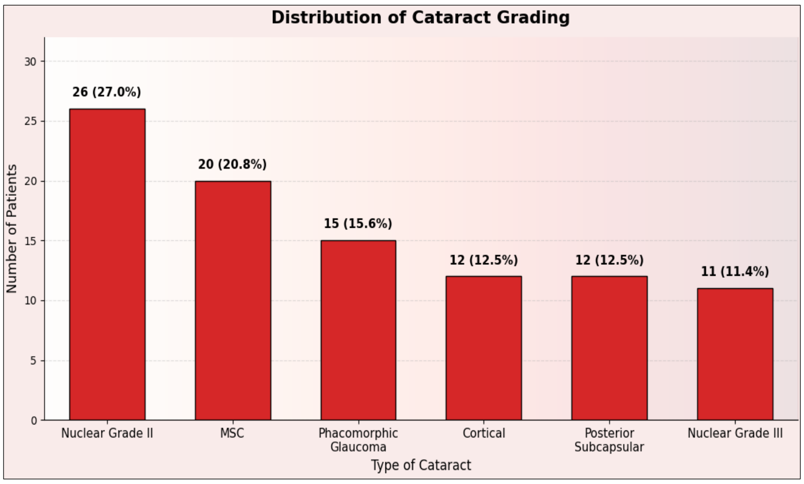

Fig 2: Distribution of Cataract Grading

Baseline Biometric Parameters and Surgical Techniques

Baseline ocular biometric measurements are presented in Table 3. The mean axial length was 22.02 ± 0.35 mm, the mean preoperative anterior chamber depth (ACD) was 2.10 ± 0.12 mm, the mean preoperative anterior chamber angle (ACA) was 21.22 ± 1.40°, and the mean anteroposterior lens thickness was 4.32 ± 0.21 mm.

Table 3: Preoperative Biometric Parameters

Parameter	Mean ± SD
Axial Length (mm)	22.02 ± 0.35
Preoperative ACD (mm)	2.10 ± 0.12
Preoperative ACA (°)	21.22 ± 1.40
AP Thickness of Lens (mm)	4.32 ± 0.21

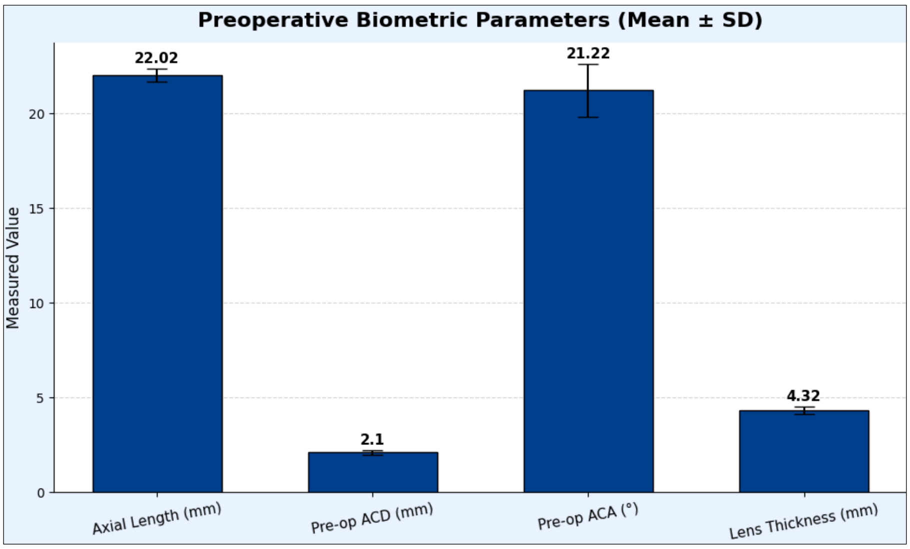

Fig 3: Baseline Ocular Biometric Measurement

Regarding surgical management, 70 patients (72.9%) underwent phacoemulsification with intraocular lens (IOL) implantation, while 26 patients (27.1%) underwent small-incision cataract surgery (SICS) with IOL implantation.

Postoperative Changes in Anterior Chamber Parameters

Changes in anterior chamber morphology following cataract surgery. Repeated postoperative measurements demonstrated a statistically significant increase in anterior chamber depth following cataract extraction (Repeated-measures ANOVA, $p < 0.001$).

The mean ACD increased from 2.10 ± 0.12 mm preoperatively to 3.25 ± 0.17 mm at 1 week, representing a mean increase of 1.15 mm, and further to 3.40 ± 0.17 mm at 1 month, corresponding to an overall mean increase of 1.30 mm from baseline ($p < 0.001$).

Similarly, the mean ACA widened significantly after surgery (Repeated-measures ANOVA, $p < 0.001$). The mean ACA increased from 21.22 ± 1.40° preoperatively to 34.46 ± 1.83° at 1 week and further to 36.07 ± 1.85° at 1 month, representing an overall mean increase of 14.85° from baseline.

Functional Outcomes

Postoperative visual outcomes are summarized in Table 4. Mean best-corrected visual acuity improved significantly following cataract surgery (Repeated-measures ANOVA, $p < 0.001$).

Table 4: Visual Acuity Changes

Time	Mean LogMAR VA ± SD	P-value
Preoperative LogMAR VA	1.45 ± 0.67	
Postoperative 1 Week LogMAR VA	0.42 ± 0.16	<0.001
Postoperative 1 Month LogMAR VA	0.32 ± 0.12	<0.001

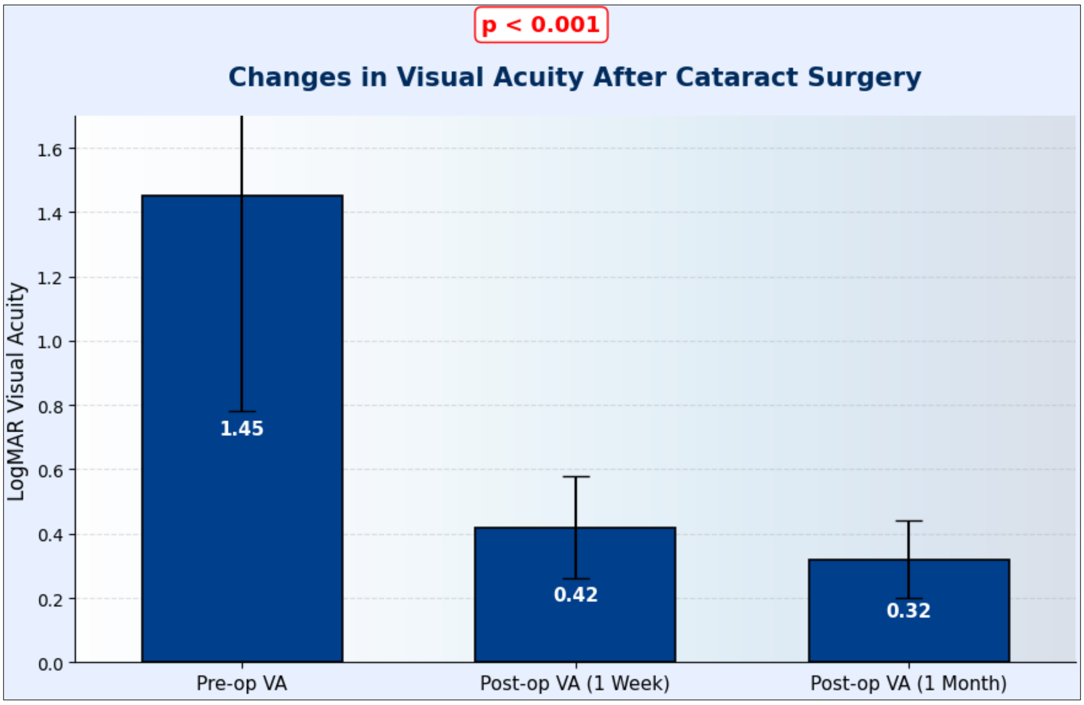

Fig 4: Postoperative Visual Outcomes

The mean visual acuity improved from 1.45 ± 0.67 LogMAR preoperatively to 0.42 ± 0.16 LogMAR at 1 week, corresponding to a mean improvement of 1.03 LogMAR units, and further improved to 0.32 ± 0.12 LogMAR at 1 month, representing an overall improvement of 1.13 LogMAR units from baseline ($p < 0.001$).

Association and Correlation Analyses

No statistically significant association was observed between cataract morphology and preoperative anterior chamber depth (one-way ANOVA, $p = 0.449$).

The mean postoperative increase in anterior chamber depth was comparable between surgical techniques. Patients undergoing phacoemulsification with IOL implantation demonstrated a mean ΔACD of 1.29 mm, whereas those undergoing SICS with IOL implantation showed a mean ΔACD of 1.33 mm. The difference between the two groups was not statistically significant (independent-samples t-test, $p = 0.170$).

Pearson correlation analysis demonstrated no significant correlation between preoperative ACD and preoperative ACA ($r = 0.03$, $p = 0.797$), lens thickness and preoperative ACD ($r = -0.06$, $p = 0.543$), or axial length and preoperative ACD ($r = -0.05$, $p = 0.607$). Likewise, no significant correlation was observed between the change in ACD and change in ACA ($r = 0.08$, $p = 0.467$) or between the change in ACD and postoperative improvement in visual acuity ($r = -0.01$, $p = 0.900$).

Overall, cataract surgery resulted in significant deepening of the anterior chamber, widening of the anterior chamber angle, and marked improvement in visual acuity, irrespective of cataract morphology or surgical technique.

Discussion

The present study evaluated morphological and functional changes in the anterior segment before and after cataract surgery using anterior segment optical coherence tomography (AS-OCT), with particular emphasis on anterior chamber depth (ACD), anterior chamber angle (ACA), and visual performance. The findings demonstrated significant improvement in visual acuity, accompanied by marked deepening of the anterior chamber and widening of the anterior chamber angle following surgery. These anatomical changes support the evolving concept that cataract surgery not only restores vision but also remodels anterior segment anatomy, offering particular benefit to eyes with shallow anterior chambers and narrow angles that are predisposed to angle-closure glaucoma.

Most participants (86.4%) were between 51 and 70 years of age, consistent with previous studies by Kasai *et al.*[1] and Dawczynski *et al.* [28], reflecting the age-related nature of cataract development due to progressive lens thickening and anterior displacement. Males constituted 55.2% of the study population, similar to reports by Kim *et al.* [29] and Lee *et al.* [31], although sex was not associated with significant differences in anterior segment morphology. Operated eyes were almost equally distributed between the left (51.0%) and right (48.9%), minimizing laterality bias and supporting the study's internal validity.

Nuclear Grade II cataract was the most common subtype (27.0%), followed by mature senile cataract (20.8%) and phacomorphic glaucoma (15.6%). The inclusion of phacomorphic glaucoma cases is clinically important because these eyes typically have shallow anterior chambers and derive substantial anatomical benefit from cataract extraction, consistent with the findings of Ghadamzadeh *et al*.[42].

Phacoemulsification with intraocular lens (IOL) implantation was performed in 72.9% of patients, while 27.0% underwent small-incision cataract surgery (SICS) with IOL implantation. Both techniques produced comparable increases in ACD (1.29 mm vs. 1.33 mm; $p = 0.1701$), indicating that anterior chamber deepening primarily results from crystalline lens removal rather than the surgical technique, in agreement with Dhanaseelan *et al*.[7]

Strength of study as it is clinically relevant as it comprehensively evaluates morphological changes in the anterior segment following cataract surgery using anterior segment optical coherence tomography (AS-OCT), a reliable and non-invasive imaging modality. By objectively assessing anterior chamber depth (ACD) and anterior chamber angle (ACA) before and after surgery, the study provides precise quantitative evidence of anterior segment remodeling associated with cataract extraction.

Despite limitations such as short follow-up duration and the prospective design, serial OCT evaluation, and strong structure–function correlation enhances the clinical relevance of this study.

Conclusion

The current research points out the tremendous anatomical and functional advantages associated with cataract surgery besides its well-being in terms of visual recovery. Remodeling of the anterior segment is significant following cataract removal with intraocular lens implantation as the anterior chamber is deepened and the anterior chamber angle is enlarged. Such structural variations lead to a more desirable anterior segment configuration and have significant ramifications on ocular physiology, especially in those eyes that are susceptible to angle crowding and angle-closure processes.

The research also shows that cataract surgery causes a significant gain in visual activity, confirming its effectiveness as a vision-sight restoration procedure, but also provides anatomical correction. The alterations in anterior chamber morphology were also similar among the various surgical methods, which may suggest that the removal of lenses is the main factor that causes anterior segment remodeling and not the type of surgery used.

Additionally, anterior segment optical coherence tomography was found to be a dependable, non-invasive, and reproducible technique of assessing the parameters of the anterior chamber pre- and post-operative. AS-OCT made it possible to document subtle changes in anatomy, thus improving the knowledge of the anterior segment dynamics after cataract surgery.

The lack of strong relationships between preoperative biometric variables and postoperative anatomical changes indicate that anterior chamber remodeling is a complicated, multifactorial process, which can be affected by multiple anatomical and physiological variables. The results highlight the importance of personalized evaluation and attentive preoperative examination, especially in patients with shallow anterior chambers or those who may have an angle-closure disease.

To sum up, cataract surgery cannot be merely seen as a visual clarity restoring procedure but rather as an effective anatomical intervention that can alter the anterior segment configuration in a meaningful clinical way. Incorporation of AS-OCT into the normal cataract assessment process can be helpful in surgical planning, risk assessment, and post-operative care, which enhances the patient outcome and makes ophthalmic care safer and more accurate.

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