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Original Article

Ophthalmology Section

Association of Posterior Capsular Opacification with Different Type of Intraocular Lenses: A Retrospective Study from Gujarat, India

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ABSTRACT

Introduction: Posterior Capsular Opacification (PCO) is the most common complication following cataract surgery, caused by the proliferation and migration of Lens Epithelial Cells (LECs). Though surgical techniques aim to minimise cortical remnants, the physical and chemical properties of Implanted Intraocular Lenses (IOLs), are increasingly recognised as the primary determinants of capsular clarity. Consequently, identifying specific lens configurations that actively inhibit the cellular mechanisms driving PCO is crucial for minimising secondary laser interventions.

Aim: To find the prevalence of PCO in patients coming to eye OPD at a tertiary care hospital and to compare and associate the prevalence of PCO with the type of IOL implanted and other ocular parameters.

Materials and Methods: A retrospective study was conducted at Shree Krishna Hospital, Pramukhswami Medical College, Karamsad, Gujarat, India analysing the records of 270 patients who underwent cataract surgery with IOL implantation followed by an Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) laser capsulotomy. Operative and clinical data such as type of cataract surgery, design and material of IOL and co-morbidities were retrieved from medical records. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 26.0, using descriptive statistics and the Chi-square test to evaluate associations between categorical variables.

Result: The overall prevalence of PCO in this study was 44.4% (n=120/270). The analysis revealed a statistically significant association between the occurrence of PCO and both the material composition and optic design of the implanted IOL. Patients implanted with hydrophilic IOLs exhibited a significantly higher likelihood of developing PCO compared to those receiving hydrophobic IOLs {71.4% (n=60/84) vs 32.3% (n=60/186)}. Similarly, the occurrence of PCO in eyes with round-edged IOLs was markedly greater than in those with square-edged designs {86.7% (n=104/120) vs 13.3% (n=16/120)}.

Conclusion: The study revealed a strong association between PCO, material, and IOL design. Specifically, hydrophilic IOLs and those with round-edged were more likely to result in PCO compared to hydrophobic and square-edged IOLs. On the other hand, factors such as patient age, presence of diabetes mellitus, and the type of cataract surgery (phacoemulsification versus manual small incision cataract surgery) showed no significant influence on PCO development.

Keywords: Biomaterials, Lens epithelial cells, Manual small incision cataract surgery, Phacoemulsification

INTRODUCTION

Cataracts remain the leading cause of blindness worldwide, with surgical extraction and intraocular lens implantation serving as the definitive treatment [1]. Despite significant advancements in surgical techniques, postoperative complications persist. Among these, PCO is the most frequent late-stage complication, characterised by a complex multifactorial aetiology [2]. PCO can develop after any type of extracapsular cataract surgery, progressively diminishing both visual acuity and the overall quality of vision [3]. In severe cases, PCO can induce capsular bag constriction, leading to the gradual decentration of the implanted IOL [4].

Extensive research has focused on identifying the determinants of PCO development. While some studies implicate specific aspects of the surgical technique [5,6], the consensus highlights the pivotal role of IOL design and biomaterial [7]. Specifically, a hydrophobic acrylic material combined with a continuous, square posterior edged design has been established as the two most critical features in preventing PCO [5]. However, despite the widespread commercial availability of these specifications, subtle variations in the incidence and severity of PCO persist, directly blocking the central visual axis. Peripheral capsular opacities can significantly impair peripheral vision and degrade optical quality manifesting as a reduced contrast sensitivity and debilitating glare or halo effects [8].

Epidemiological data indicate that despite modern surgical refinements, PCO occurs in approximately 11.8% of cases within the first postoperative year, rising to 20.7% at three years, and reaching 28.4% by five years [6]. Long-term cumulative incidence rates can reach up to 50% in adults and nearly 100% in paediatric populations between two months and five years post-surgery [6]. Furthermore, the optical haze from PCO impairs accurate fundus visualisation and interferes with advanced diagnostic modalities, such as Optical Coherence Tomography (OCT), ultimately reducing the patient's quality of life [6].

Pathophysiologically, PCO is driven by the migration, proliferation, and trans-differentiation of residual LECs into fibroblastic and lens fibre-like cells [9]. This process is notably more aggressive in younger individuals due to higher cell density and increased mitotic activity [10]. Consequently, ongoing research is heavily focused on developing safe, effective strategies to mitigate PCO alongside evolving surgical techniques. While previous research establishes that hydrophobic acrylic material and square-edged IOL designs are the most critical factors in preventing PCO, variations in its incidence and severity persists [5]. To address this clinical challenge, the present study was undertaken to evaluate the prevalence of PCO and analyse its association with specific IOL designs, biomaterials, and other relevant clinical parameters. Novelty of this study lies in its comprehensive dual cohort comparative approach which simultaneously evaluates biomaterials and optic edge configurations alongside systemic patient co-morbidities. By conducting this multiparameter analysis at a major tertiary teaching hospital, this study aimed to provide critical data to optimise IOL selection guidelines and minimise the clinical and economic burden of post-cataract complications.

MATERIALS AND METHODS

This retrospective, dual cohort comparative study was conducted over a duration of one year from May 2024 to April 2025 in the Department of Ophthalmology at a tertiary care teaching hospital, Shree Krishna Hospital, Pramukhswami Medical College, Karamsad, Gujarat, India utilising clinical records of patients who underwent cataract surgery at this centre between January 2018 to December 2023. Institutional Ethical Committee (IEC) approval was obtained prior to the commencement of the study (IEC/BU/145/Faculty/17/172/2023). Given the retrospective nature of the study and the utilisation of previous case records from the Medical Record Department (MRD) with assured patient confidentiality, the requirement for informed consent was waived by the committee.

Inclusion criteria: Subjects who had undergone both primary uncomplicated cataract surgery with IOL implantation and subsequent Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) laser capsulotomy for PCO at Shree Krishna Hospital and patients with complete medical records documenting demographics, co-morbidities and specific IOL properties were included in the study.

Exclusion criteria: Patients who had undergone primary cataract surgery or IOL implantation at an external facility and presented to this institute solely for the Nd:YAG laser capsulotomy and patients with intraoperative complications compromising capsular bag integrity, presented with confounding pre-existing ocular co-morbidities (active uveitis, severe corneal opacity, advanced glaucoma, or macular pathology) or had incomplete clinical and surgical records were excluded from the study.

Sample size calculation: The sample size was calculated using the standard single proportion formula: $n=Z^2 * p *(1-p)/d^2$. Based on a 95% confidence level (Z=1.96), an expected cumulative PCO prevalence (p) of 20.7% at three years derived from previous epidemiological literature [6], and an allowable margin of error (d) of 5%, the minimum required sample size was determined to be 253 patients. To account for potential incomplete records and ensure study robustness, a purposive sample of 270 patients meeting the strict eligibility criteria was ultimately selected.

Study Procedure

Data collection involved restoring and reviewing physical and electronic patient files from the MRD from May 2024 to April 2025 with a minimum 12 months follow-up after cataract surgery, to gather comprehensive operative and non-operative clinical data. Clinically significant PCO was defined as slit-lamp confirmed posterior capsule opacification accompanied by a ≥ 2-line decline in Snellen Best Corrected Visual Acuity (BCVA) requiring an Nd:YAG laser capsulotomy [11]. PCO severity was graded 1=no or slight PCO without reduced red reflex; 2=mild PCO reducing the red reflex, Elschnig pearls to the IOL edge; 3=moderate fibrosis or Elschnig pearls inside IOL edge but with a clear visual axis; 4=severe fibrosis or Elschnig pearls covering the visual axis and severely reducing the red reflex [12].

To analyse the determinants of capsular opacification, the study population was categorised into two primary cohorts: Group A, which included patients who developed clinically significant PCO requiring laser intervention, and Group B, using consecutive matching from the same institutional database which comprised patients who underwent uncomplicated cataract surgery during the same time period but did not develop PCO and maintained a completely clear posterior capsule (Grade 0) with no visual decline throughout their follow-up period. Both groups were systematically compared and correlated across various clinical and demographic parameters, including patient age, gender distribution, systemic co-morbidities (such as Diabetes Mellitus), the surgical technique employed (phacoemulsification versus manual small incision cataract surgery), and the specific biomaterial and optical design of the IOL.

STATISTICAL ANALYSIS

Data were collected retrospectively through case record forms and entered into MS excel 2016. Data analysis was done in SPSS Software version 26.0. Using descriptive statistics and the Chi-square test to evaluate associations between categorical variables. Binary logistic regression analysis was performed to identify factors associated with the development of PCO. The dependent variable was the presence of PCO (yes/no). Independent variables included age, diabetes mellitus, surgical technique, IOL material, and IOL design. Adjusted Odds Ratios (AORs) with 95% Confidence Intervals (CIs) were calculated. Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test and a p-value of <0.05 was considered statistically significant.

RESULTS

A total of 270 eyes from 270 patients were evaluated, with 120 patients stratified into the PCO cohort (Group A) and 150 patients tracked in the PCO-free control cohort (Group B) [Table/Fig-1]. Age distribution was comparable across both cohorts (p-value=0.623), with the majority of patients falling within the 41-70 years age (63.7%). The proportion of PCO was slightly higher among males (51.1%) than females (48.9%), this difference was not statistically significant (χ^2=1.307, p-value=0.253). Systemic diabetes mellitus was present in 27.4% of the study population, showing no statistically significant difference between Group A and Group B. Phacoemulsification constituted the majority of surgical procedures across the study population (90.0%, n=243/270), showing no significant difference in proportion between the PCO and control groups (91% vs 89.3%, p-value=0.682) [Table/Fig-2].

Bivariate analysis revealed a strong, statistically significant association between the specific characteristics of the IOL and the subsequent development of PCO requiring laser intervention.

	Group A (PCO Present)	Group B (PCO Absent)	Total
Number of patients	120	150	270
Percentage	44.4%	55.6%	100

[Table/Fig-1]: Distribution based on the presence or absence of PCO.

Parameters	Total	Group A (n=120)	Group B (n=150)	p-value
Age (years)				
≤ 40	9 (3.33%)	4 (3.33%)	5 (3.33%)	0.623
41-70	172 (63.7%)	78 (65%)	94 (62.66%)	
≥71	89 (33.00%)	38 (31.67%)	51 (34%)	
Gender				
Male	138 (51.11%)	66 (55%)	72 (48%)	0.253
Female	132 (48.89%)	54 (45%)	78 (52%)	
Diabetes				
Present	74 (27.40%)	31 (25.83%)	43 (28.67%)	0.692
Absent	196 (72.60%)	89 (74.17%)	107 (71.33%)	
Type of cataract surgery				
Phacoemulsification	243 (90%)	109 (91%)	134 (89.3%)	0.682
Manual Small Incision Cataract Surgery	27 (10%)	11 (9%)	16 (10.7%)	

[Table/Fig-2]: Demographic profile and types of cataract surgery done among study participants.

Patients implanted with hydrophilic IOLs exhibited a significantly higher likelihood of developing PCO compared to those receiving hydrophobic IOLs {71.4% (n=60/84) vs 32.3% (n=60/186)} [Table/Fig-3]. Similarly, the occurrence of PCO in eyes with round-edged IOLs was markedly greater than in those with square-edged designs {86.7% (n=104/120) vs 13.3% (n=16/120)} [Table/Fig-4]. This shows that IOL bio-material and geometric design profiles vary significantly between the PCO and control populations.

Type of material of IOL	Total	Group A (n=120)	Group B (n=150)	p-value
Hydrophilic	84 (31.1%)	60 (71.4%)	24 (28.6%)	0.0021
Hydrophobic	186 (68.9%)	60 (32.3%)	126 (67.7%)	
Total	270	120	150	

[Table/Fig-3]: Type of material of IOL.

Design of IOL	Total	Group A (n=120)	Group B (n=150)	p-value
Square edge	153	16 (13.3%)	137 (91.3%)	<0.001
Round edge	117	104 (86.7%)	13 (8.7%)	

[Table/Fig-4]: Distribution according to the design of IOL.

Multivariable binary logistic regression was performed to determine the independent predictors of PCO after adjusting for age, diabetes mellitus, surgical technique, IOL material, and IOL design. The regression model was statistically significant (Omnibus χ^2=226.29, df=8, p-value <0.001) and demonstrated good calibration (Hosmer-Lemeshow χ^2=4.34, df=8, p-value=0.825). The model explained 56.7% of the variation in PCO (Cox & Snell R^2) and 76.0% (Nagelkerke R^2), with an overall classification accuracy of 89.3%.

After adjustment for potential confounders, hydrophilic IOL implantation remained significantly associated with the development of PCO (aOR 18.69; 95% CI: 5.68-61.54; p-value <0.001). Similarly, implantation of a round-edged IOL was associated with substantially higher odds of developing PCO compared with a square-edged IOL (aOR 175.09; 95% CI: 53.93-568.44; p-value <0.001). Age, diabetes mellitus and surgical technique were not significantly associated with PCO after adjustment (all p-value>0.05) [Table/Fig-5].

Variable	Adjusted OR (95% CI)	p-value
Age	0.992 (0.959 - 1.026)	0.623
Diabetes mellitus	1.216 (0.463 - 3.192)	0.692
Surgical technique	0.698 (0.163 - 2.990)	0.628
IOL material (Hydrophilic vs Hydrophobic Acrylic)	18.691 (5.68 - 61.540)	<0.001
IOL design (Round Edge vs Square Edge)	175.091 (53.93 - 568.441)	<0.001

[Table/Fig-5]: Multivariable binary logistic regression analysis of predictors of posterior capsule opacification.

DISCUSSION

The PCO remains the most prevalent long-term complication limiting visual rehabilitation following cataract surgery, demonstrating a crude prevalence of 44.4% in the present study population. While bivariate analysis initially suggested potential trends across patient demographics and surgical approaches, multivariable logistic regression analysis demonstrated that when all clinical variables are mutually adjusted, patient-specific factors (age and diabetes) and surgical techniques (phacoemulsification versus small incision cataract surgery) do not serve as independent predictors of PCO. Instead, intraocular lens, biomaterial and geometric design emerge as the primary, independent determinants of postoperative capsular clarity. The relationship between patient age and PCO development remains highly debated in ophthalmic literature. While older age groups presented with a higher absolute volume of PCO in descriptive data- aligning with age-related risk trends highlighted by Konopińska J et al., this trend did not maintain independent statistical significance in this multivariable model [6]. This lack of independent association mirrors the findings of Placeres Dabán J et al., who noted that age per se does not govern capsular fibrosis when lens design variables are rigorously controlled [13]. Similarly, this study demonstrated that systemic co-morbidities, specifically diabetes mellitus and hypertension, were not independently associated with increased PCO risk (p-value>0.05). Although authors like Hasareen S and Manjula TR and Kiziltoprak H et al., suggest patients with diabetes accelerates PCO formation, results align more closely with Vasavada AR et al., indicating that underlying systemic vascular diseases do not significantly modify the long-term capsular micro-environment [14-16].

Regarding the surgical modality, absolute numbers initially showed a higher incidence of PCO in eyes undergoing phacoemulsification compared to small incision cataract surgery. However, this finding is a reflection of institutional procedural volume rather than true physiological risk. When subjected to multivariable adjustment, the surgical technique showed no independent association with PCO development. This aligns with the consensus established by Tassignon MJ which demonstrated that while phacoemulsification facilitates thorough cortical clean-up and leaves fewer cellular remnants, long-term success in preventing PCO is fundamentally dependent on the specifications of the co-implanted IOL rather than the extraction method itself [17].

The definitive findings of present study lie in the highly significant independent associations observed for IOL bio-material and edge geometry, confirming them as the key determinants of PCO. Hydrophilic acrylic lenses demonstrated a significantly higher risk profile for PCO development compared to hydrophobic acrylic lenses because hydrophobic materials feature low water content and high fibronectin binding affinities, allowing them to adhere tightly to the posterior capsule. This bio-adhesive “shrink-wrapping” effect creates an intense mechanical seal that physically arrests the migration of migrating LECs [18,19]. Conversely, hydrophilic IOL surfaces suppress postsurgical inflammation by minimising cell and protein adhesion, they simultaneously create a favourable environment for LECs to proliferate and migrate. To address this, extensive research has focused on applying hydrophilic anti-biofouling coatings to IOL surfaces, which help lower the incidence of PCO by hindering LEC attachment, growth, and movement [20,21]. This material liability is compounded by optic geometry as present study confirmed that traditional round-edged optics carry a vastly increased risk of PCO development compared to continuous square-edged designs. As established by work from Nibourg LM et al., and Haripriya A et al., a sharp, continuous 90° square posterior edge exerts concentrated mechanical pressure on the posterior capsule, inducing contact inhibition in migrating LECs and creating a structural roadblock that stops them from encroaching onto the central visual axis [22,23].

Limitation(s)

Several limitations should be considered when interpreting these findings. First, the study was conducted at a single centre with a relatively small sample size, limiting the generalisation of the results. Second, the vast majority of the cohort underwent phacoemulsification rather than manual small incision cataract surgery. While literature typically associates manual small incision cataract surgery with higher PCO rates, present study findings reflected a higher prevalence in the phacoemulsification group, indicating a potential selection bias.

CONCLUSION(S)

PCO remains a common late complication following cataract surgery, with an observed rate of 44.4% in this cohort. Higher PCO incidence was strongly associated with hydrophilic materials and round-edged optic designs, whereas hydrophobic and square-edged lenses carried a lower risk. Patient age, systemic diabetes mellitus, and surgical technique (phacoemulsification vs manual small incision cataract surgery) were not independently associated with PCO development. Overall, these observational findings suggest that selecting hydrophobic acrylic lenses with a continuous square-edged profile may help lower the risk of PCO and the subsequent need for Nd:YAG laser capsulotomy. Rather than subjective slit-lamp grading, future research should utilise automated digital image analysis systems to quantify PCO density and area more objectively.

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