Journal of Molecular Science

Journal of Molecular Science
Volume 35 Issue 4, Year of Publication 2025, Page 1497-1505
DoI-10.004687/1000-9035.2025.194

Journal of Molecular Science

www.jmolecularsci.com ISSN:1000-9035

Posterior Capsular Rupture Rates and Associated Risk Factors in Phacoemulsification: A Single-Center Retrospective Review

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Article Information
Received: 05-11-2025
Revised: 14-11-2025
Accepted: 06-12-2025
Published: 24-12-2025

Keywords
Posterior capsular rupture; Phacoemulsification; Cataract surgery; Risk factors; Pseudoexfoliation syndrome; Vitreous loss; Intraoperative complications

ABSTRACT
Purpose: To determine the incidence of posterior capsular rupture (PCR) during phacoemulsification surgery and identify associated risk factors at a tertiary eye care center.
Methods: This retrospective observational study reviewed 2,847 consecutive phacoemulsification surgeries performed between January 2021 and December 2023. All cases with documented PCR (n=53) were compared with randomly selected uncomplicated cases (n=50). Demographic data, preoperative characteristics, intraoperative parameters, and postoperative outcomes were analyzed. Univariate and multivariable logistic regression analyses were performed to identify independent risk factors for PCR.
Results: The overall PCR incidence was 1.86% (53/2,847). Vitreous loss occurred in 71.7% of PCR cases. The most common timing of PCR was during nucleus phacoemulsification (43.4%), followed by cortical aspiration (32.1%). Multivariable analysis identified four independent risk factors: posterior polar cataract (OR=8.45; 95% CI: 1.02-70.12; p=0.048), pseudoexfoliation syndrome (OR=4.68; 95% CI: 1.18-18.54; p=0.028), dense nuclear cataract with LOCS III grade ≥4 (OR=4.12; 95% CI: 1.67-10.18; p=0.002), and small pupil diameter <6 mm (OR=3.89; 95% CI: 1.52-9.96; p=0.005). Visual acuity of 20/40 or better at three months was achieved in 73.6% of PCR cases versus 96.0% of controls (p=0.002). Cystoid macular edema occurred significantly more frequently in the PCR group (17.0% vs 2.0%; p=0.009).
Conclusion: PCR occurred in 1.86% of phacoemulsification surgeries. Posterior polar cataract, pseudoexfoliation syndrome, dense nuclear cataract, and small pupil were identified as independent risk factors. Preoperative identification of these factors enables appropriate surgical planning and patient counseling.

INTRODUCTION:

Cataract surgery remains the most frequently performed ophthalmic procedure worldwide, with phacoemulsification being the gold standard technique for lens extraction in developed countries [1,2]. The procedure has undergone remarkable technological advancements over the past four decades, resulting in improved surgical outcomes and reduced complication rates [3]. Despite these improvements, intraoperative complications continue to occur and can significantly impact visual outcomes and patient quality of life [4].

Posterior capsular rupture (PCR) represents one of the most serious intraoperative complications during phacoemulsification surgery [5,6]. The reported incidence of PCR varies considerably in the literature, ranging from 0.45% to 7.9% depending on the study population, surgeon experience, and case complexity [7,8]. PCR can lead to several sight-threatening sequelae, including vitreous loss, retained lens fragments, cystoid macular edema, retinal detachment, endophthalmitis, and compromised intraocular lens positioning [9,10].

The identification of risk factors associated with PCR has been a subject of considerable research interest, as preoperative recognition of high-risk cases enables appropriate surgical planning and informed patient counseling [11]. Several patient-related factors have been implicated in the increased risk of PCR, including advanced age, male gender, pseudoexfoliation syndrome, small pupils, dense or white cataracts, posterior polar cataracts, and previous vitrectomy [12,13]. Additionally, surgeon-related factors such as experience level and surgical volume have been demonstrated to influence PCR rates significantly [14,15].

Understanding institutional PCR rates and their associated risk factors is essential for quality improvement initiatives and benchmarking against published standards [16]. Single-center studies provide valuable insights into local surgical outcomes and enable targeted interventions to improve patient safety [17]. Furthermore, identifying modifiable risk factors allows for the implementation of preventive strategies, such as preoperative pupil dilation optimization, use of iris expansion devices, and consideration of femtosecond laser-assisted techniques in challenging cases [18,19].

The retrospective analysis of surgical complications offers several advantages, including the ability to study relatively rare events with sufficient statistical power and the opportunity to identify patterns that may not be apparent during prospective observation [20]. However, such analyses require meticulous data collection and standardized documentation of intraoperative events to ensure validity and reliability of findings [21].

The primary objective of this study was to determine the incidence of posterior capsular rupture during phacoemulsification surgery at our institution and to identify patient-related and surgical risk factors associated with this complication. Secondary objectives included evaluating the visual outcomes following PCR and comparing them with uncomplicated cases. We hypothesized that specific preoperative characteristics would be significantly associated with increased PCR risk, enabling the development of a risk stratification model for surgical planning.

MATERIALS AND METHODS:

Study Design and Setting:

This retrospective observational study was conducted at a tertiary eye care center between January 2021 and December 2023. The study protocol was approved by the Institutional Ethics Committee and adhered to the tenets of the Declaration of Helsinki [22]. Given the retrospective nature of the study, the requirement for informed consent was waived by the ethics committee.

Study Population:

A total of 2,847 consecutive phacoemulsification surgeries performed during the study period were reviewed. From this cohort, all cases with documented posterior capsular rupture (n=53) were identified and included as the study group. A control group of 50 randomly selected uncomplicated phacoemulsification cases was matched for the same study period, yielding a total sample size of 103 eyes from 103 patients.

Inclusion and Exclusion Criteria:

Inclusion criteria encompassed all patients who underwent standard phacoemulsification with planned posterior chamber intraocular lens (PCIOL) implantation during the study period. Exclusion criteria included combined surgical procedures (phacoemulsification with trabeculectomy, pars plana vitrectomy, or penetrating keratoplasty), pediatric cataract surgery (age <18 years), traumatic cataracts, subluxated or dislocated lenses requiring specialized techniques, and cases with incomplete medical records.

Data Collection:

Medical records were systematically reviewed to extract demographic data, preoperative clinical characteristics, intraoperative parameters, and postoperative outcomes. Demographic variables included age, gender, and laterality. Preoperative parameters included best-corrected visual acuity (BCVA), intraocular pressure (IOP), axial length, anterior chamber depth, pupil diameter following pharmacological dilation, lens nucleus density grading using the Lens Opacities Classification System III (LOCS III) [23], and presence of ocular comorbidities.

Specific attention was given to documenting known risk factors including pseudoexfoliation syndrome, posterior polar cataract, previous ocular surgery, history of trauma, corneal pathology, glaucoma, and zonular weakness. The presence of systemic comorbidities such as diabetes mellitus and hypertension was also recorded [24].

Surgical Technique:

All surgeries were performed by five experienced surgeons (each with >500 phacoemulsification cases) using standard phacoemulsification technique under topical or peribulbar anesthesia. A 2.2-2.8 mm clear corneal incision was made temporally or superiorly based on surgeon preference. Continuous curvilinear capsulorhexis was performed using a cystotome or capsulorhexis

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forceps. Hydrodissection and hydrodelineation were performed as deemed appropriate [25].

Nuclear fragmentation was accomplished using either the divide-and-conquer, stop-and-chop, or direct chop technique depending on nuclear density and surgeon preference. Cortical aspiration was performed using bimanual irrigation-aspiration handpieces. Foldable intraocular lenses were implanted in the capsular bag when possible, or alternatively in the sulcus when capsular support was compromised [26].

Definition of Posterior Capsular Rupture:
Posterior capsular rupture was defined as any unintentional breach of the posterior capsule integrity during phacoemulsification, including tears occurring during hydrodissection, nuclear rotation, phacoemulsification, cortical aspiration, or IOL implantation [27]. Cases were further categorized based on the presence or absence of vitreous loss and the timing of PCR recognition during the surgical procedure.

Management of Posterior Capsular Rupture:
Following PCR, management protocols included immediate cessation of irrigation, injection of dispersive ophthalmic viscosurgical device (OVD), anterior vitrectomy when vitreous prolapse was present, and careful removal of residual lens material. IOL placement was determined by the extent of capsular support, with options including in-the-bag placement, sulcus fixation, anterior chamber IOL, or scleral-fixated IOL [28].

Outcome Measures:
The primary outcome measure was the incidence rate of PCR during phacoemulsification. Secondary outcome measures included identification of risk factors associated with PCR, visual acuity outcomes at postoperative week 1, month 1, and month 3, and rates of PCR-related complications including vitreous loss, retained lens fragments, IOL-related complications, and retinal detachment [29].

Statistical Analysis:
Statistical analysis was performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) based on distribution normality assessed by the Shapiro-Wilk test. Categorical variables were expressed as frequencies and percentages.

Univariate analysis was performed using independent samples t-test or Mann-Whitney U test for continuous variables and chi-square test or Fisher's exact test for categorical variables. Variables demonstrating significance ($p<0.05$) in univariate analysis were entered into a multivariable binary logistic regression model to identify independent risk factors for PCR [30]. Odds ratios (OR) with 95% confidence intervals (CI) were calculated. A p-value of <0.05 was considered statistically significant.

RESULTS:

Incidence of Posterior Capsular Rupture:
During the three-year study period, 2,847 phacoemulsification surgeries were performed at our institution. Posterior capsular rupture occurred in 53 cases, yielding an overall incidence rate of 1.86% (95% CI: 1.38-2.44%). The annual PCR rates were 2.1% (n=19/905) in 2021, 1.8% (n=18/1002) in 2022, and 1.7% (n=16/940) in 2023, demonstrating a non-significant declining trend over the study period (p=0.782).

Demographic and Baseline Characteristics:
The study cohort comprised 103 eyes from 103 patients, including 53 eyes with PCR (study group) and 50 eyes without PCR (control group). The mean age was 68.4 ± 10.2 years in the PCR group compared to 64.8 ± 9.6 years in the control group (p=0.067). Male patients constituted 58.5% (n=31) of the PCR group and 44.0% (n=22) of the control group (p=0.143). Table 1 presents the complete demographic and baseline characteristics.

Table 1: Demographic and Baseline Characteristics of Study Population

Parameter	PCR Group (n=53)	Control Group (n=50)	p-value
Age (years), mean ± SD	68.4 ± 10.2	64.8 ± 9.6	0.067
Male gender, n (%)	31 (58.5)	22 (44.0)	0.143
Right eye, n (%)	28 (52.8)	26 (52.0)	0.933
Diabetes mellitus, n (%)	22 (41.5)	14 (28.0)	0.152
Hypertension, n (%)	29 (54.7)	21 (42.0)	0.199
Previous ocular surgery, n (%)	8 (15.1)	2 (4.0)	0.049*
Axial length (mm), mean ± SD	23.6 ± 1.8	23.4 ± 1.4	0.523
ACD (mm), mean ± SD	2.9 ± 0.4	3.1 ± 0.3	0.004*
Preoperative BCVA (logMAR), mean ± SD	0.92 ± 0.45	0.68 ± 0.38	0.004*

*Statistically significant (p<0.05); ACD: Anterior chamber depth; BCVA: Best-corrected visual acuity

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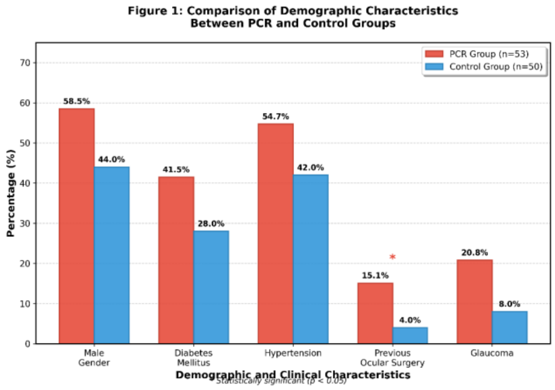

Fig 1: Bar chart comparing demographic characteristics between PCR and control groups

Preoperative Ocular Characteristics:

Analysis of preoperative ocular characteristics revealed several significant differences between groups. The mean dilated pupil diameter was significantly smaller in the PCR group (5.8 ± 1.2 mm) compared to controls (6.8 ± 0.9 mm; p<0.001). Nuclear density grading showed a higher proportion of dense cataracts (LOCS III grade ≥4) in the PCR group (60.4%) versus the control group (24.0%; p<0.001). Table 2 summarizes the preoperative ocular characteristics.

Table 2: Preoperative Ocular Characteristics

Parameter	PCR Group (n=53)	Control Group (n=50)	p-value
Dilated pupil diameter (mm), mean ± SD	5.8 ± 1.2	6.8 ± 0.9	<0.001*
Small pupil (<6 mm), n (%)	28 (52.8)	9 (18.0)	<0.001*
LOCS III nuclear grade, n (%)			<0.001*
- Grade 1-2	6 (11.3)	18 (36.0)	
- Grade 3	15 (28.3)	20 (40.0)	
- Grade 4-5	32 (60.4)	12 (24.0)	
Pseudoexfoliation syndrome, n (%)	14 (26.4)	3 (6.0)	0.005*
Posterior polar cataract, n (%)	7 (13.2)	0 (0.0)	0.008*
Zonular weakness, n (%)	9 (17.0)	1 (2.0)	0.009*
Corneal pathology, n (%)	6 (11.3)	2 (4.0)	0.168
Glaucoma, n (%)	11 (20.8)	4 (8.0)	0.072
High myopia (AL>26mm), n (%)	5 (9.4)	2 (4.0)	0.283

*Statistically significant (p<0.05); LOCS III: Lens Opacities Classification System III; AL: Axial length

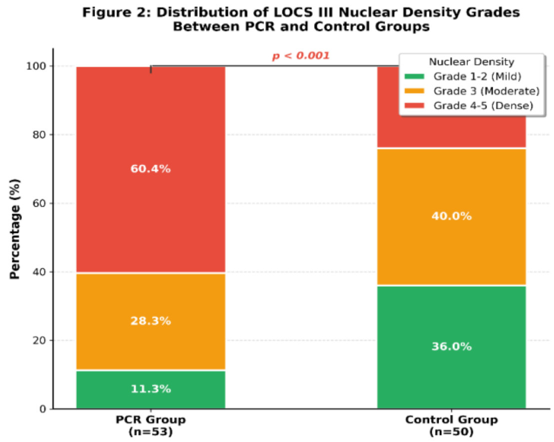

Fig 2: Stacked bar chart showing distribution of LOCS III nuclear grades between groups

Intraoperative Characteristics of PCR Cases:

Among the 53 PCR cases, vitreous loss occurred in 38 eyes (71.7%). The timing of PCR recognition varied: during phacoemulsification of nucleus in 23 cases (43.4%), during cortical aspiration in 17 cases (32.1%), during hydrodissection in 8 cases (15.1%), and during IOL implantation in 5 cases (9.4%). Table 3 details the intraoperative characteristics.

Table 3: Intraoperative Characteristics of PCR Cases (n=53)

Parameter	n (%)
Timing of PCR	
- During hydrodissection	8 (15.1)
- During nucleus phacoemulsification	23 (43.4)
- During cortical aspiration	17 (32.1)
- During IOL implantation	5 (9.4)
Vitreous loss	38 (71.7)
Anterior vitrectomy performed	36 (67.9)
Retained lens fragments	7 (13.2)
- Requiring secondary surgery	3 (5.7)
IOL placement	
- In-the-bag	18 (34.0)
- Sulcus with optic capture	24 (45.3)
- Sulcus without optic capture	6 (11.3)
- ACIOL	3 (5.7)
- Aphakic (secondary IOL planned)	2 (3.8)

IOL: Intraocular lens; ACIOL: Anterior chamber intraocular lens

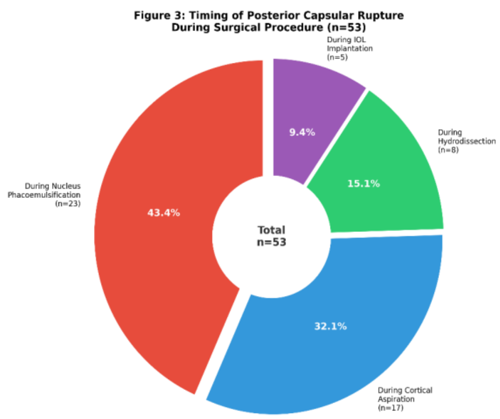

Fig 3: Pie chart showing timing of PCR during surgical steps

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Risk Factor Analysis:

Univariate analysis identified several factors significantly associated with PCR, including small pupil diameter, dense nuclear cataract, pseudoexfoliation syndrome, posterior polar cataract, zonular weakness, shallow anterior chamber depth, previous ocular surgery, and worse preoperative visual acuity (all p<0.05).

Multivariable logistic regression analysis revealed four independent risk factors for PCR: dense nuclear cataract (LOCS III ≥4) with OR 4.12 (95% CI: 1.67-10.18; p=0.002), small pupil (<6 mm) with OR 3.89 (95% CI: 1.52-9.96; p=0.005), pseudoexfoliation syndrome with OR 4.68 (95% CI: 1.18-18.54; p=0.028), and posterior polar cataract with OR 8.45 (95% CI: 1.02-70.12; p=0.048). Table 4 presents the complete regression analysis results.

Table 4: Multivariable Logistic Regression Analysis for PCR Risk Factors

Risk Factor	Adjusted OR	95% CI	p-value
Dense nuclear cataract (LOCS III ≥4)	4.12	1.67-10.18	0.002*
Small pupil (<6 mm)	3.89	1.52-9.96	0.005*
Pseudoexfoliation syndrome	4.68	1.18-18.54	0.028*
Posterior polar cataract	8.45	1.02-70.12	0.048*
Zonular weakness	3.24	0.38-27.89	0.284
Shallow ACD (<2.5 mm)	2.18	0.72-6.61	0.168
Previous ocular surgery	2.86	0.54-15.12	0.217

*Statistically significant (p<0.05); OR: Odds ratio; CI: Confidence interval; ACD: Anterior chamber depth

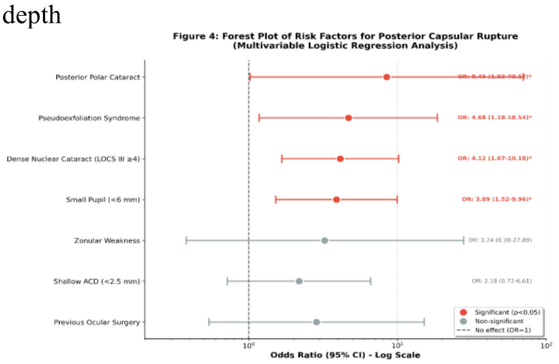

Fig 4: Forest plot displaying odds ratios with 95% CI for independent risk factors

Visual Outcomes:

Visual outcomes were analyzed at three postoperative time points. At 3 months postoperatively, mean BCVA improved significantly in both groups compared to baseline. However, the PCR group achieved significantly worse final BCVA (0.24 ± 0.28 logMAR) compared to the control group (0.08 ± 0.12 logMAR; p<0.001). A BCVA of 20/40 or better was achieved in 73.6% of PCR cases versus 96.0% of controls at 3 months (p=0.002). Table 5 presents the visual outcome data.

Table 5: Visual Acuity Outcomes

Time Point	PCR Group (logMAR)	Control Group (logMAR)	p-value
Preoperative	0.92 ± 0.45	0.68 ± 0.38	0.004*
1 week postoperative	0.42 ± 0.35	0.22 ± 0.18	<0.001*
1 month postoperative	0.32 ± 0.30	0.12 ± 0.14	<0.001*
3 months postoperative	0.24 ± 0.28	0.08 ± 0.12	<0.001*
BCVA ≥20/40 at 3 months, n (%)	39 (73.6)	48 (96.0)	0.002*

*Statistically significant (p<0.05); BCVA: Best-corrected visual acuity

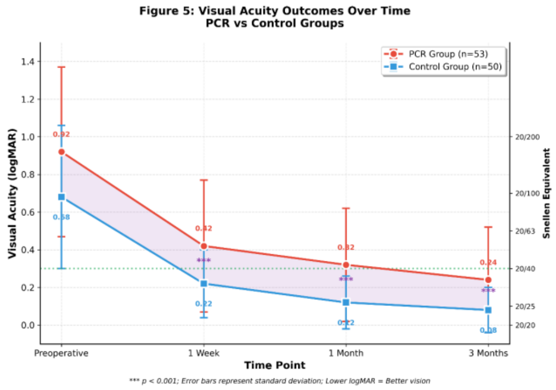

Fig 5: Line graph showing visual acuity trends over time for both groups

Postoperative Complications:

The PCR group demonstrated significantly higher rates of postoperative complications. Cystoid macular edema occurred in 9 cases (17.0%) in the PCR group versus 1 case (2.0%) in controls (p=0.009). Elevated IOP requiring treatment occurred in 8 PCR cases (15.1%) compared to 2 controls (4.0%; p=0.054). Retinal detachment occurred in 2 PCR cases (3.8%) during the follow-up period; no retinal detachments occurred in the control group.

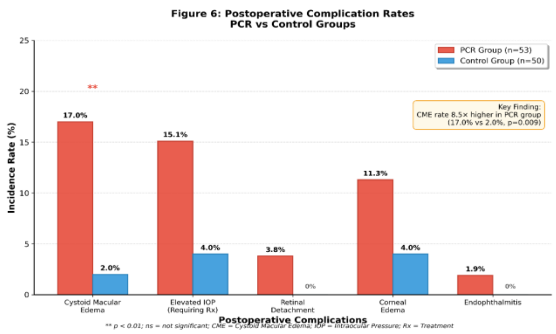

Fig 6: Grouped bar chart comparing complication rates between groups

DISCUSSION:

This retrospective study examined the incidence and risk factors associated with posterior capsular rupture during phacoemulsification at a single tertiary eye care center. Our findings demonstrated a PCR incidence of 1.86%, which falls within the range reported in contemporary literature. Four independent risk factors were identified: dense nuclear cataract, small pupil, pseudoexfoliation syndrome, and posterior polar cataract. Visual outcomes were significantly compromised in eyes experiencing PCR compared to uncomplicated cases.

The PCR rate observed in our study is consistent with published benchmarks from similar institutional settings. The Royal College of Ophthalmologists has suggested that a PCR rate below 2% represents an acceptable standard of care for experienced surgeons [31]. Large database studies have reported varying rates depending on case complexity and surgeon experience levels. The EUREQUO database, encompassing over 1.5 million cataract surgeries across Europe, reported an overall PCR rate of 1.92% [32]. Similarly, the Swedish National Cataract Register documented rates ranging from 0.4% to 2.8% across different surgical units [33].

Our observation of a declining trend in annual PCR rates over the study period, although not statistically significant, aligns with the learning curve phenomenon documented in surgical literature. Several studies have demonstrated that institutional PCR rates tend to decrease as surgical teams gain experience with challenging cases and implement quality improvement measures [34]. The adoption of femtosecond laser-assisted cataract surgery for high-risk cases at our institution during the latter part of the study period may have contributed to this trend, although this was not systematically analyzed.

Dense nuclear cataract emerged as the strongest modifiable predictor of PCR in our multivariable analysis, with patients having LOCS III grade 4 or higher demonstrating a four-fold increased risk. This finding corroborates extensive literature linking nuclear density to surgical complexity and complication rates. Hard cataracts require greater phacoemulsification energy and prolonged surgical time, increasing the risk of thermal injury, Descemet membrane folds, and posterior capsular stress [35]. Narendran and colleagues reported that cataracts with nuclear opalescence grades exceeding 5.0 were associated with a significantly higher risk of vitreous loss compared to softer lenses[36].

Small pupil diameter represents both a technical challenge and an established risk factor for intraoperative complications. Our finding of a nearly four-fold increased PCR risk in patients with dilated pupil diameters below 6 mm is consistent with previous reports. Inadequate pupillary dilation compromises surgical visualization, limits instrument maneuverability, and increases the likelihood of iris trauma and capsular complications [37]. Several strategies have been proposed to mitigate this risk, including intracameral phenylephrine, pupil expansion devices such as iris hooks and Malyugin rings, and sphincterotomies. The implementation of standardized protocols for pupil management in high-risk cases has been shown to reduce complication rates [38].

Pseudoexfoliation syndrome (PXF) was identified as a significant independent risk factor in our study, conferring a 4.68-fold increased risk of PCR. This association is well-established and attributed to the characteristic zonular weakness, poor pupil dilation, and capsular fragility observed in PXF eyes [39]. The deposition of pseudoexfoliative material on the lens capsule and zonular apparatus leads to progressive zonular dehiscence and increased susceptibility to surgical trauma. Shingleton and colleagues reported PCR rates of 5.2% in PXF eyes compared to 1.5% in non-PXF eyes undergoing routine phacoemulsification [40].

The strongest independent risk factor identified in our analysis was posterior polar cataract, although the wide confidence interval reflects the limited number of cases in this subgroup. Posterior polar cataracts pose unique surgical challenges due to the inherent weakness of the posterior capsule in the region of the polar opacity. Studies have reported PCR rates ranging from 26% to 36% in posterior polar cataract surgery using conventional techniques [41]. The adoption of specialized surgical strategies, including inside-out delineation, slow-motion phacoemulsification, and avoidance of hydrodissection, has been shown to reduce PCR rates in these challenging cases [42].

Several factors demonstrated significance in univariate analysis but did not retain independent significance in the multivariable model. Shallow anterior chamber depth, while initially associated with PCR, likely represents a confounding factor related to lens density and anterior segment crowding. Similarly, previous ocular surgery and zonular weakness showed trends toward significance that may have achieved statistical power in a larger sample.

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The timing of PCR during the surgical procedure provides valuable insights for targeted preventive strategies. Our finding that the majority of PCR events occurred during nuclear phacoemulsification (43.4%) aligns with published literature and underscores the importance of careful technique during this critical phase [43]. The substantial proportion of PCR occurring during cortical aspiration (32.1%) highlights the need for vigilance throughout the procedure and careful irrigation-aspiration settings to prevent capsular aspiration.

Vitreous loss occurred in 71.7% of PCR cases in our series, necessitating anterior vitrectomy in the majority. The rate of vitreous loss following PCR varies in the literature depending on the timing of recognition and surgical experience in managing the complication. Prompt recognition and appropriate management of PCR are crucial in minimizing vitreous-related complications [44]. Our protocol of immediate OVD injection and systematic anterior vitrectomy appears consistent with best practices, although comparison with other management strategies was beyond the scope of this study.

Visual outcomes following PCR were significantly inferior to uncomplicated cases at all postoperative time points. The proportion of patients achieving BCVA of 20/40 or better at three months was 73.6% in the PCR group compared to 96.0% in controls. This disparity reflects the multifactorial impact of PCR on visual recovery, including suboptimal IOL positioning, corneal edema, cystoid macular edema, and retinal complications [45]. However, it is noteworthy that the majority of PCR patients still achieved functionally useful vision, emphasizing the importance of appropriate complication management and realistic patient counseling.

The higher rate of cystoid macular edema observed in PCR cases (17.0% vs. 2.0%) is consistent with published literature documenting the inflammatory sequelae of complicated cataract surgery. Vitreous loss and prolonged surgical time contribute to blood-aqueous barrier breakdown and increased prostaglandin release, predisposing to macular edema [46]. Prophylactic treatment with topical nonsteroidal anti-inflammatory drugs may be beneficial in managing PCR cases postoperatively.

Our study has several limitations that warrant consideration. The retrospective design introduces potential selection and information biases inherent to medical record review. The sample size, while adequate for identifying strong associations, may have been underpowered to detect modest risk factors or achieve narrow confidence intervals for rare conditions such as posterior polar cataract. The single-center design may limit generalizability to other surgical settings with different case mixes or surgical protocols. Additionally, surgeon experience level was not analyzed as a variable, as all surgeons in the study had completed their learning curves.

Despite these limitations, our study provides valuable institutional data that can inform quality improvement initiatives and preoperative risk stratification. The identification of modifiable risk factors enables targeted interventions, such as enhanced pupil dilation protocols, consideration of femtosecond laser assistance for dense cataracts, and subspecialty referral for posterior polar cataracts [47]. Future prospective studies with larger sample sizes and multicenter collaboration would strengthen the evidence base for PCR risk prediction and prevention.

CONCLUSION:

This retrospective single-center study demonstrated a posterior capsular rupture rate of 1.86% during phacoemulsification, which aligns with contemporary benchmarks for tertiary eye care institutions. Four independent risk factors were identified through multivariable analysis: dense nuclear cataract (LOCS III ≥4), small pupil diameter (<6 mm), pseudoexfoliation syndrome, and posterior polar cataract. These findings underscore the importance of comprehensive preoperative assessment to identify high-risk cases and enable appropriate surgical planning, patient counseling, and resource allocation.

Visual outcomes following PCR, while significantly inferior to uncomplicated cases, demonstrated that the majority of patients still achieved functionally useful vision with appropriate complication management. The identification of modifiable risk factors provides opportunities for targeted interventions, including optimized pupil dilation protocols, consideration of pupil expansion devices, and potential referral of complex cases to subspecialty surgeons.

The results of this study support the implementation of risk stratification models in preoperative cataract assessment workflows. Prospective multicenter studies are warranted to validate these findings and develop predictive algorithms that can enhance surgical safety and optimize outcomes in phacoemulsification surgery.

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