

Risk factors, complications, and outcomes of phacoemulsification cataract surgery complicated by retained lens fragments in Asian eyes: A 10-year retrospective study

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Abstract:

PURPOSE: To study the risk factors, visual outcomes, and sequelae of phacoemulsification surgery complicated by retained lens fragments (RLFs).

METHODS: This single-center case–control study enrolled consecutive eyes complicated by RLF and compared them to age- and gender-matched uneventful cataract surgery cases at a tertiary care teaching hospital. Biometric, intraoperative, and postoperative data were collected. The primary outcome measures were risk factors, visual outcomes, and rate of postoperative complications.

RESULTS: The study and control groups included 282 and 289 eyes, respectively. The estimated incidence of RLF was 1.47% during the study. We found a statistically higher risk of RLF among diabetics ($P < 0.001$), those with a history of intravitreal injections ($P = 0.001$), eyes with dense nuclear sclerosis, anterior capsular cataract ($P < 0.001$), and posterior polar cataract ($P = 0.01$). There was a statistically higher risk of RLF in eyes with a higher mean preoperative visual acuity (logarithm of the minimum angle of resolution) ($P < 0.001$) and in cases performed by trainees ($P < 0.001$). Most eyes in the RLF group ($n = 207$, 73.4%) retained their preoperative vision or experienced a one-line improvement in visual acuity and 14 eyes (5.3%) experienced more than one-line improvement in vision.

CONCLUSION: Although RLFs are rare, they can affect the quality of postoperative vision and outcomes of complicated phacoemulsification surgery.

Keywords:

Cataract surgery, complications, ophthalmology training, retained lens fragments

INTRODUCTION

Phacoemulsification remains the preferred surgical approach for cataract removal since Charles Kelman introduced it in the 1960s.^[1] The subsequent introduction of continuous curvilinear capsulorhexis by Gimbel and Neuhann and the advent of foldable intraocular lenses (IOLs) further improved safety and outcomes.^[2,3] These advances led to increased acceptance of phacoemulsification for cataract removal. Phacoemulsification is associated with faster visual recovery compared to other approaches for cataract removal, and

patients can return to their normal routine within a few days after surgery. Numerous developments in surgical instrumentation and fluidics for phacoemulsification had led to less aggressive and safer cataract removal.^[4-8]

Training programs kept pace with the technologic advances and surgeons now prefer to teach phacoemulsification to residents before introducing extracapsular cataract extraction (ECCE).^[9] Thus, various risk stratification-scoring systems have been developed to train young surgeons to operate on cases appropriate to their proficiency level.^[10-12]

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Although phacoemulsification is a safe, fast, and effective procedure, there can be complications. One complication is retained lens fragments (RLFs) in the anterior chamber and posterior capsular tear with posterior displacement of the remaining nucleus. The incidence of RLF (also called retained lens material) appears to have increased in recent years.^[13] Many techniques have been described for lens rescue in cases with a posterior capsular tear, including, posterior-assisted levitation, and phacoemulsification above a Sheet's glide.^[14] However, these techniques require a high level of experience. Although RLF is considered an uncommon complication, it can lead to secondary complications such as glaucoma, prolonged inflammation, cystoid macular edema (CME), retinal detachment, and corneal decompensation.^[15-21]

This study investigates the visual outcomes of phacoemulsification cataract surgery complicated with RLF at a tertiary eye care hospital and examines the factors that led to this complication. In this study, most of the procedures were performed by trainee surgeons while being supervised by skilled surgeons in the focused settings of a teaching hospital. To the best of our knowledge, there are no comparable longitudinal studies in the peer-reviewed literature.

METHODS

The study was approved by the Institutional Research Board at King Khaled Eye Specialist Hospital. The tenets of the Declaration of Helsinki were followed at each step of the study and all data were coded to ensure privacy and confidentiality of participants. A chart review was performed of consecutive patients who underwent cataract surgery complicated with RLF performed at the hospital from January 2006 and June 2015 (RFL group). A control group was also included comprised of age- and gender-matched cases from a pool of eyes that underwent uneventful phacoemulsification surgery during the same period. RLFs were defined as any lens material (cortical, nuclear) of any size that can be detected clinically or by ultrasonography within the anterior chamber or vitreous cavity. The following preoperative parameters were reviewed: patient's age and gender, ocular and systemic comorbidity, previous intravitreal injection, and vitrectomy. In this hospital, clinicians usually follow the Oxford Clinical Cataract Classification and Grading system to describe and grade the cataractous lens.^[22] The following signs were usually highlighted preoperatively to ensure proper case planning: presence of pseudoexfoliation (PXF), phacodonesis, corneal pathology, poor pupil dilation, extreme axial lengths, and IOL power. In addition, the following intraoperative variables were evaluated: surgeon level (resident, fellow, attending consultant), complications, timing of IOL implantation, type of IOL fixation technique, phacoemulsification time, and phacoemulsification machine. Cases planned for manual ECCE and those undergoing combined surgical procedures were excluded. Vitrectomy was performed when there was persistent uveitis and/or raised intraocular pressure (IOP) or when the amount of intravitreal

lens material was considered great enough to produce chronic inflammation.

Standard surgical techniques were used in both groups, including wound size, instrumentation, phacoemulsification machines, and IOL placement techniques. Data were collected on biometry, intraoperative, and postoperative outcomes for both groups. Many phacoemulsification platforms were used for cataract removal including, Whitestar Sovereign Phacoemulsification System (Abbott Medical Optics [AMO], Santa Ana, CA), the Infiniti Vision System with standard and Intrepid cassettes (Alcon Laboratories, Fort Worth, TX, USA), Whitestar Signature Phacoemulsification System (AMO, Santa Ana, CA), and Visalis 100 (Carl Zeiss Meditec, Jena, Germany). Data were also collected on intraoperative and postoperative complications that might be correlated to the outcome.

IOL power was calculated with the Holladay 1 IOL formula. The Holladay 1 formula provided suitable outcomes over a wide range of axial lengths. It was also incorporated in the IOLMaster-500 (Carl Zeiss Meditec, Jena, Germany), allowing fast selection of the suitable IOL without manually entering data.^[23] In cases of sulcus or iris fixated IOLs, IOL power was adjusted accordingly. During the study, trained technicians were responsibly performed the measurements for IOL calculation. Keratometry readings were obtained with a standard keratometer (Bausch and Lomb Inc., Rochester, NY, USA), and axial length was measured with the Aviso S system A-scan (Quantel Medical, Bozeman, MT, USA). The IOLMaster-500 was placed in the hospital in 2012 (Carl Zeiss Meditec, Dublin, California, USA) and was subsequently used for the majority of cases at the hospital. Visual outcomes and complications were compared between groups.

Statistical analysis

Frequencies and percentages were calculated to describe categorical variables. Continuous variables are reported as mean and standard deviations. The Chi-square test or Fisher's exact test and Student's *t*-test correlated outcomes with categorical and continuous data, respectively. A two-tailed $P < 0.05$ was considered statistically significant. All analyses were performed using SPSS software (version 26.0; SPSS Inc., Chicago, Illinois, USA).

RESULTS

During the study, 19,171 phacoemulsification cataract surgeries were performed and 282 eyes with RLF were identified. The overall 10-year incidence of RLF after phacoemulsification surgery was 1.47% [95% confidence interval (CI): 1.30–1.64].

Demographic data such as age and gender were similar in the study and control groups. Table 1 summarizes the profiles for both groups. There were a statistically significantly greater number of diabetics in the RLF group ($P < 0.001$). The RLF group received more intravitreal injections preoperatively ($P = 0.001$) than the control group. Preoperative data are presented in Table 2. The grading of nuclear cataract

Table 1: Demographic data of study participants in both groups

	RLF group (n=282), n (%)	Control group (n=289), n (%)	P
Gender			
Male	165 (58.5)	158 (54.7)	0.36†
Female	117 (41.5)	131 (45.3)	
Age (years)			
<50	10 (37.0)	17 (63)	0.06†
50-59	51 (54.3)	43 (45.7)	
60-69	76 (53.2)	67 (46.9)	
70-79	109 (51.7)	102 (48.3)	
80 and above	36 (37.5)	60 (62.5)	
Systemic comorbidities			
Diabetes	189 (67.0)	34 (11.8)	<0.001†

†Chi-square test. RFL: Retained lens fragments

Table 2: Preoperative assessment and biometric data of included eyes

Grade of cataract	RLF group, n (%)	Control group, n (%)	P
Nuclear			
Grade 1	25 (8.9)	41 (14.2)	<0.001†
Grade 2	108 (38.3)	143 (49.5)	
Grade 3	55 (19.5)	58 (20.1)	
Total cataract	56 (19.9)	13 (4.5)	
Posterior capsular cataract			
Grade 1	29 (10.3)	26 (9.0)	0.25†
Grade 2	68 (24.1)	61 (21.1)	
Grade 3	42 (14.9)	32 (11.1)	
Anterior capsular cataract			
Grade 1	6 (2.1)	0	<0.001†
Grade 2	6 (2.1)	0	
Grade 3	1 (0.4)	1 (0.3)	
Posterior polar cataract	15 (5.3)	4 (1.4)	0.01§
Axial length (mean±SD)	23.5 (1.7)	23.9 (2.0)	0.004‡
Preoperative visual acuity logMar (mean±SD)	1.3 (0.85)	0.8 (0.6)	<0.001‡
Previous intravitreal injection	18 (6.4)	3 (1.0)	0.001§

†Chi-square test, ‡Student's t-test, §Fisher's exact test. RFL: Retained lens fragments, SD: Standard deviation

was significantly different between groups [Table 2]. Total cataract formation was greater in the RLF group than in the control group (ratio 4:1) ($P < 0.001$) [Table 2]. A higher grade of anterior capsular opacity was reported in 13 eyes in the RLF group compared to one eye in the control group ($P < 0.001$) [Table 2]. The presence of the posterior polar cataract was statistically significantly greater in the RLF group ($P = 0.01$) [Table 2]. Phacodonesis was statistically more common in the RLF group (22 eyes) than in the control group (1 eye) ($P < 0.001$). There was a statistically significantly higher correlation between the presence of PXF and a previous diagnosis of angle-closure glaucoma and the occurrence of RLF ($P < 0.001$). The mean preoperative visual acuity (logarithm of the minimum angle of resolution) was statistically significantly higher in the RLF group (1.3 ± 0.9) compared to the control group (0.8 ± 0.6) ($P < 0.001$).

Other data collected from the operative reports differed significantly between groups [Table 3]. Complicated phacoemulsification with RLF was statistically significantly more common in eyes undergoing surgery by trainees – residents (11.3% vs. 17%) and fellows (55.7% vs. 41.9%)—compared to experienced surgeons (33% vs. 52.2%) ($P < 0.001$).

Older phacoemulsification platforms such as Sovereign and Zeiss seem to be correlated with increased risk of complication between groups ($P < 0.001$). However, the rates of complications with the other phacoemulsification machines were comparable between groups.

Table 4 summarizes the timing of RLF with most of the cases (207; 73.4%) identified during the primary surgery. Nuclear RLFs were noted in 189 (67%) eyes, the RLFs were in the vitreous cavity in 240 (85.1%) eyes [Table 4]. In 164 (85.2%) eyes, the RLF was larger than 25% of the lens. In this study, a vitreoretinal surgeon managed 235 (83.3%) cases. The mean time to subsequent surgery was 8.5 ± 22.7 days (range: 0–240 days). There was no statistical association between the timing of vitreoretinal surgery and visual outcome at 3 months (Chi-square test, $P = 0.9$). Most cases ($n = 207$, 88.1%) that underwent positive predictive value (PPV) had no complications at 3 months' postoperatively (Chi-square test, $P = 0.005$).

The mean duration of follow-up was 20.05 ± 23.40 (CI 17.31–22.79) months in the RLF group and 7.24 ± 8.34 (CI 6.27–8.20) months in the control group ($P < 0.001$).

Short-term complications such as corneal edema, transient high IOP, and anterior uveitis were overrepresented, especially at 1 day and 1 month postoperatively. These complications were resolved by 3 months postoperatively in most cases. During the first 6 months postoperatively, one endophthalmitis case was noted in each group and successfully treated with a vitreous tap and injection based on the endophthalmitis vitrectomy study protocol.^[24] Long-term complications observed at last follow-up (more than 6 months after the primary surgery) included IOP ($n = 22$), corneal edema ($n = 2$), persistent lens matter in the vitreous ($n = 3$), and retinal detachment ($n = 1$).

Compared to preoperative visual acuity, both groups experienced a significant difference in vision over the duration of the postoperative period ($P < 0.001$). An improvement of more than one line was noted in 14 eyes (5.3%) in the RLF group and in 37 (12.8%) eyes in the control group. Most eyes in both groups (RLF group: $n = 207$ [73.4%] and control group: $n = 228$ [78.9%]) retained preoperative vision or experienced a one-line improvement in visual acuity. Decreased visual acuity was noted in 60 (21.3%) eyes in the RLF group and 21 (7.3%) eyes in the control group.

DISCUSSION

The incidence of RLF in this study was 1.47%, which is similar to the range reported from nonteaching hospitals where

Table 3: Intraoperative data of both retained lens fragments and nonretained lens fragments groups

	RLF group (n=282), n (%)	Control group (n=289), n (%)	P
Operating surgeon level			
Consultant	93 (33.0)	151 (52.2)	<0.001†
Fellow	157 (55.7)	121 (41.9)	
Resident	32 (11.3)	17 (5.9)	
IOL implanted			
Yes	201 (71.3)	289 (100)	<0.001†
No	33 (11.7)	0	
Delayed	48 (17)	0	
Machine used			
Infiniti	157 (55.9)	230 (80.1)	<0.001†
Signature	25 (8.9)	38 (13.2)	
Sovereign	51 (18.1)	19 (6.6)	
Zeiss	48 (17.1)	0	

†Chi-square test. RLF: Retained lens fragments, IOL: Intraocular lens implant

Table 4: Characteristics and management of eyes with retained lens fragments (n=282)

	n (%)
Identification time of retained lens fragments	
During surgery	207 (73.4)
Postoperative clinically	48 (17)
Both during surgery and postoperatively	18 (6.4)
Postoperatively by B-scan	9 (3.2)
Type of identified retained lens fragments	
Nuclear	189 (67.0)
Cortical	74 (26.2)
Both	13 (4.6)
Undefined	6 (2.2)
Location of identified retained lens fragments	
Anterior chamber	32 (11.3)
Vitreous	240 (85.1)
Both	6 (2.1)
Size of identified retained lens fragments (%)	
<25	95 (33.7)
>25	164 (58.2)
Management of identified retained lens fragments	
Surgical	235 (83.3)
Medical	47 (16.6)

the surgeries are performed by experienced surgeons (RLF range: 0.3%–1.48%).^[16,19,20,25] Similar to previous reports, the occurrence of RLF is associated with a lower level of surgeon experience.^[18,21] To reduce the incidence of cataract complications in eyes performed by trainees, the residency training department at our hospital organized mandatory hands-on training for junior residents before performing phacoemulsification on real patients. The virtual surgical simulator, such as the EyeSi (VR, Magic AG, Mannheim, Germany), was also incorporated in the cataract surgery training curriculum. Virtual reality training systems have been beneficial for phacoemulsification training, increasing the safety of the procedure and reducing complications when trainees perform surgery.^[26,27] Other factors that may contribute

to the overall reduction in the incidence of RLFs are the improvements in phacoemulsification technologies and more efficient phacodynamics over time.^[28]

In our study population, there seem to be, several factors or associations related to the increased risk of RLF. Similarly, these factors were correlated to the greater occurrence of RLF in previous studies.^[10-12,29] Therefore, calculating cataract risk based on any of the published cataract risk grading systems can be helpful to reduce the risk of intraoperative complications.^[30] Trainees, especially those in the early learning curve, should not operate on cases with a higher number of risk factors.

Hahn *et al.* reported that a history of anti-VEGF intravitreal injection was associated with a 126% increase in the risk of performing subsequent RLF removal within 28 days of cataract surgery.^[31] Diabetes mellitus is a common in our region, with an estimated prevalence of approximately 7 million diabetics.^[32] Intravitreal injection of anti-vascular endothelial growth factor or steroids for diabetic complications is commonly performed at our hospital. Therefore, a thorough review of the patient’s medical and ocular history is needed, including the number of intravitreal injections received and whether their vision significantly and abruptly dropped after the injections, indicating a possible lens touch during the administration of the drug.^[33] Our outcomes indicate that poor preoperative visual acuity was associated with a higher occurrence of RLF. This could be due to significantly dense cataracts. Hence, a higher risk of complications should be anticipated. The outcomes from the age-related eye disease study that aimed to explore cataracts and cataract surgery risk factors reported that increasing age was a significant factor for all cataract types: Cortical cataract was more common in females and smokers while posterior subcapsular cataract was more prevalent among diabetics and myopic patients.^[34] Myopia was also associated with an increased risk of nuclear cataract.^[34] In the same study, a higher educational level was associated with decreased risk of cataract, although the mechanism remains unknown.^[34] Furthermore, cataract development was less prevalent among whites, a racial disparity the authors correlated to the likelihood of limited healthcare access in the nonwhite populations.^[34] In our study, most of our participants were 60 and older at the time of surgery. Although we did not inquire about the included education levels, we believe some were illiterate or had attended just primary school.^[35]

The timing between complicated cataract surgery and PPV in cases with RLF has long been a topic of debate.^[15] A systematic review and meta-analysis reported that early PPV for eyes with RLF yielded better visual outcomes and reduced the risk of secondary complications such as retinal detachment, high IOP, endophthalmitis, and intraocular inflammation.^[36] Our institute is a specialized tertiary center with many vitreoretinal surgeons available in case of complications. Screening patients for RLF in eyes with refractory corneal edema, decreased visual acuity, and posterior capsule rupture in our institute is a standard protocol. That explains the early secondary vitreoretinal

intervention to remove RLF in the study group. Likewise, our study observed that the postoperative complications in the eyes with RLF resolved after the 3rd month of the primary surgery.

The decrease in vision despite early fragment removal in some of our patients may be related to the development of postoperative CME. This finding suggests that the need for reoperation or increased ocular inflammation from RLF may predispose patients to CME.^[37]

In this study, nonvitrectomized eyes in this study (16.6%) tolerated small cortical or nuclear fragments, their intraocular inflammation and transient high IOP were managed medically, and the risks of vitrectomy complications were weighed against conservative treatment. Rossetti and Doro found that small cortical fragments were reabsorbed within 3 months in most cases, whereas nuclear material reabsorbed slowly within 6 months, except in one eye where it was detected even 2 years after complicated phacoemulsification.^[38]

The strengths of this study include its use of longitudinal data, which provide patient details that span the entire perioperative course, and comparison to a matched control group. However, this study is limited by the historical medical record from which the data were extracted and the fact that the surgeries were performed between 2006 and 2015. In addition, over time, the fluidics of phacoemulsification machines have improved, and cataract instrumentation and techniques have evolved dramatically. This continuous improvement in fluidics, phacoemulsification tips, and phacoemulsification techniques has been associated with greater safety and efficacy.^[39] This variable potentially affected our results and outcomes. Other limitations that need to be considered in a future prospective study are surgeon-dependent factors such as caseload, fatigue, and operating habits. Additional strengths of this study include a long study period and follow-up that allowed for modification and revision of surgical training curriculums to ensure patient safety and improve outcomes. Although such comparisons are beyond the scope of this study, the data collected here would be useful for future studies in our region to compare the current incidence of RLF, especially after the introduction of virtual reality surgical simulation training, new phacoemulsification platforms machines, and newer instrumentation.

CONCLUSION

RLFs were associated with more postoperative complications during the 1st month after surgery. However, the impact of these complications decreased after 3 months postoperatively. This finding seems likely due to the early vitreoretinal surgical intervention. Preoperative assessment of each case for suitability for trainee residents is a crucial step to prevent avoidable complications.

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Conflicts of interest

There are no conflicts of interest.

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