Clinical Ophthalmology

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ORIGINAL RESEARCH

Late Spontaneous in-the-Bag Capsular Tension Ring - Intraocular Lens - Capsular Bag Complex Subluxation in a Low-PEX Region: A Series of 31 Cases

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Purpose: To evaluate the incidence, risk factors, and surgical management of CTR-IOL-CB complex subluxation/dislocation in a low-pseudoexfoliation area.

Methods: Patients with CTR-IOL-CB complex subluxation/dislocation who had complete medical records at the Qingdao Eye Hospital of Shandong First Medical University between January 1994 and April 2024 were selected. Patient demographic data, incidence, interval, risk factors, extent of zonular weakness, IOL and CTR design and material, surgical management, visual acuity (VA), and other complications.

Results: 31 cases aged 65.17 ± 7.19 years at CTR-IOL-CB complex subluxation/dislocation were reviewed; the interval was 41.23 ± 14.63 months after implantation of IOL and CTR. The incidence rate of CTR-IOL-CB complex subluxation/dislocation was 0.85%. The most common risk factors were ocular trauma and hypermature cataract. Extent of zonular weakness of ≥4 o'clock and the use of 1-piece hydrophilic acrylic and 3-piece hydrophobic acrylic IOLs were susceptible to complex subluxation/dislocation. VA was significantly increased after IOL repositioning or exchange; no other complications were present.

Conclusion: Zonular insufficiency stabilized with IOL and CTR alone still carries a risk of re-dislocation. Ocular trauma and hypermature cataract were the most common risks in a low-pseudoexfoliation region. IOL exchange or repositioning is effective for this complication.

Keywords: CTR-IOL-CB complex, subluxation/dislocation, incidence, zonule weakness, surgical management

Introduction

With aging, late in-the-bag intraocular lens (IOL) subluxation or dislocation is frequently reported as a serious complication, with incidence rates ranging from 0.2% to 3%.[1–4] It typically occurs on average 6–12 years after cataract surgery.[1,2,4–7] In cases of zonular instability, capsular tension rings (CTRs) are commonly used to stabilize the capsular bag and IOL during and after cataract surgery.[8] However, late in-the-bag CTR-IOL-capsular bag (CTR-IOL-CB) complex subluxation/dislocation also occurs in clinical practice, with one study reporting an incidence of 0.76%.[9] The implantation of CTRs and IOLs poses a challenge for the surgeon during the initial cataract surgery, and the additional cost of CTR increases the financial burden on patients. Re-dislocated CTR-IOL-CB complex undoubtedly increases surgery difficulty and related financial costs. Therefore, avoiding or reducing incidence of CTR-IOL-CB complex subluxation/dislocation is crucial.

To avoid or reduce such incidents, new considerations are needed in preoperative and intraoperative assessments, as well as postoperative follow-ups for cataract surgery. Zonular instability—including progressive zonular insufficiency and capsular bag contraction—is a common cause of in-the-bag dislocations. Predisposing factors for IOL dislocation

Received: 2 June 2025
Accepted: 1 September 2025
Published: 22 October 2025

include pseudoexfoliation (PEX),[10] ocular trauma or blunt head contusion,[11] other intraocular surgeries,[12] high myopia,[13] retinitis pigmentosa,[14] hypermature cataract,[15] and Marfan syndrome.[11] The most common risk factor is PEX. However, PEX incidence varies significantly across geographic regions, and China is not considered a high incidence area. A previous study found no association between CTR implantation and the risk of IOL dislocation in patients without PEX.[16] Therefore, this study analyzes of the incidence and predisposing factors of CTR-IOL-CB complex subluxation/dislocation in a low-PEX area by retrospectively examining 31 cases of late spontaneous CTR-IOL-CB complex subluxation/dislocation following cataract surgery for ectopia lentis.

Surgical management of CTR-IOL-CB complex subluxation/dislocation requires careful deliberation and planning, with approaches ranging from repositioning to exchange—including replacement with an anterior or a sutured posterior chamber IOL, or suturing the IOL through the bag to the iris or sclera.[1,16,17] However, IOL extraction and replacement are technically challenging and time-consuming, and the several inherent complications accompanying this procedure include intraocular pressure (IOP) and glaucoma change, the loss of corneal endothelial cells, cystoid macular edema, endophthalmitis, retinal hemorrhage, and retinal detachment.[1] Therefore, precise and careful surgical treatment, modified or new surgical techniques, and long-term follow-up are required in preventing CTR-IOL-CB complex subluxation/dislocation. This study also evaluates the outcomes of surgical management involving IOL exchange or reposition. This case series study may contribute to a more comprehensive understanding of late CTR-IOL-CB complex subluxation/dislocation in a low-PEX region.

Patients and Methods

Data Extraction

This retrospective study was designed to analyze cases with late spontaneous CTR-IOL-CB complex subluxation/dislocation following cataract surgery for ectopia lentis from 1 January 1994 to 1 April 2024 in the Qingdao Eye Hospital of Shandong First Medical University. This study was conducted in accordance with the Declaration of Helsinki. The study was approved by the hospital's ethics committee (2024(24)). And informed consent from the patient has been obtained.

A total of 3656 were surgically treated with cataract extraction and IOL and CTR implantation, of which 31 cases were with late spontaneous CTR-IOL-CB complex subluxation/dislocation (>3 months postoperative according previous study),[9] which were analyzed in detail, including for incidence, predisposing factors, extent of zonular weakness detected via ultrasound biomicroscope (UBM, ArcScan Inc, Morrison, CO, USA) was quantified by the circumferential range of abnormal zonules, with or without anterior vitrectomy during primary cataract surgery, design and material of IOL and CTR, interval (from implantation to dislocation) of CTR-IOL-CB complex, surgical management, uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA) at the time of CTR-IOL-CB complex subluxation/dislocation, and final follow-up.

Surgery Treatment

CTR-IOL-CB complex subluxation/dislocation requires careful management. The choice of surgical method depends on IOL design and the integrity of the capsular bag assessed by preoperative mydriatic slit-lamp examination and UBM, and intraoperative visualization. The procedure is briefly described below. In our study, CTR-IOL-CB complex reposition was implemented for cases with intact capsular bag or three-piece IOL. Dislocated CTR-IOL-CB complex was repositioned using ab externo scleral fixation. For cases in which the capsular bag was broken and the IOL was not three-piece, CTR-IOL-CB complex exchange was carried out. The dislocated CTR and capsular bag were extracted intact, and the IOL was cut by intraocular scissors (Alcon Grieshaber AG) in the middle but not cut off, extracted through a 3.0 mm clear corneal incision made by 3.0-mm keratome. A three-piece IOL was fixated to the sclera. For IOL repositioned or exchange surgery, we used polypropylene suture material with a suture size of 9–0 (Prolene®, Ethicon). The Z-suture technique was adopted for fixation proposed by previous study,[17] with a distance of 2.5 mm from the limbus, and transscleral fixation was performed.

Statistical Analysis

Data are expressed as mean ± standard deviation (SD). The Shapiro–Wilk test was employed to assess the normality of continuous data. Paired t-tests were applied to compare the UCVA and BCVA before and after surgery for IOL-CB-CTR complex dislocation, as well as the reposition and exchange groups. Unpaired t-tests were applied to compare the postoperative

UCVA and BCVA between these two groups. The rank-sum test was employed when normality assumptions were not met. Linear regression analysis examined the relationship between zonular weakness extent and the time interval of late IOL-CB-CTR complex dislocation. All analyses were performed using SPSS 20.0 (SPSS Software, Chicago, IL, USA). Differences were considered statistically significant at p values of <0.05 (*$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$).

Results

Demographics of Study Eyes

CTR-IOL-CB complex subluxation/dislocation occurred in 31 of 3656 eyes, for an incidence rate of 0.85%. Among the 31 patients presenting with late CTR-IOL-CB complex subluxation/dislocation, there were 23 males and 8 females and 16 right and 15 left eyes. The patients were aged 65.17 ± 7.19 years at CTR-IOL-CB complex subluxation/dislocation, which was performed 41.23 ± 14.63 months after implantation (Table 1).

Analysis of Predisposing Factors

In this study, we analyzed 31 cases, along with the total number of eyes corresponding to each indication for CTR implantation in the initial cataract surgery, and calculated the incidence of each indication. The results showed that the incidences were as follows: ocular trauma (1.46%, 7/479 eyes), hypermature cataract (1.04%, 6/576 eyes), high myopia (0.54%, 4/743 eyes), PEX (3.92%, 4/102 eyes), history of intraocular surgery (0.51%, 3/583 eyes), glaucoma (0.50%, 3/604 eyes), Marfan syndrome (0.88%, 2/226 eyes), retinitis pigmentosa (0.64%, 1/156 eyes), and uveitis (0.53%, 1/187 eyes). Additionally, among these indications, a history of intraocular surgery and ocular trauma were associated with a greater extent of zonular weakness, while hypermature cataract and PEX led to a milder extent of zonular weakness (Table 2). Therefore, regardless of the size of the ectopia lentis, CTR implantation alone still resulted in re-dislocation. In addition to PEX, ocular trauma and hypermature cataract were common predisposition factors for late CTR-IOL-CB complex subluxation/dislocation in this geographical area.

Table 1 Demographic Characteristics of the 31 Patients

Variable	Parameter
Age (years)	65.17 ± 7.19 (15–85)
Sex (%)	
Male	23 (74.2%)
Female	8 (25.8%)
Eye (%)	
Right	16 (51.6%)
Left	15 (48.4%)
Time interval (months)	41.23 ± 14.63 (11–79)

Table 2 Predisposing Factors of Zonular Insufficiency in the 31 Patients

Predisposing Factor	Extent of Ectopia Lentis (o'clock)
Ocular trauma	4-5 (4.43±0.53)
Hypermature cataract	1-4 (2.50±1.22)
Serve myopia	2-5 (3.63±1.25)
Pseudoexfoliation	1-4 (2.50±1.29)
History of intraocular surgery	5-6 (5.50±0.5)
Glaucoma	3-5 (4.00±1)
Marfan syndrome	3-4 (3.50±0.71)
Retinitis pigmentosa	4
Uveitis	4

https://doi.org/10.2147/OPTH.S544172

The extent of zonular weakness was from 1 to 6 o'clock (mean, 3.68 ± 1.29 o'clock), and as the extent of zonular weakness increased, the time interval of late IOL-CB-CTR complex dislocation decreased (Figure 1). There were 20 eyes with a degree of zonular weakness ≥4 o'clock, which was 1.82 times the degree of <4 o'clock (11 eyes). The mean interval (from implantation to subluxation/dislocation) of IOL-CB-CTR complex with a zonular weakness of <4 o'clock was 52.73 ± 13.18 months, which was significantly longer than the interval for ≥4 o'clock (mean, 34.90 ± 11.30 months, $p < 0.001$). In the <4 o'clock group (mean, 2.23 ± 0.82 o'clock), hypermature cataract (4 eyes) and PEX (3 eyes) were the main factors leading to secondary dislocation (Figure 2A); while in the ≥4 o'clock group (mean, 4.48 ± 0.64 o'clock),

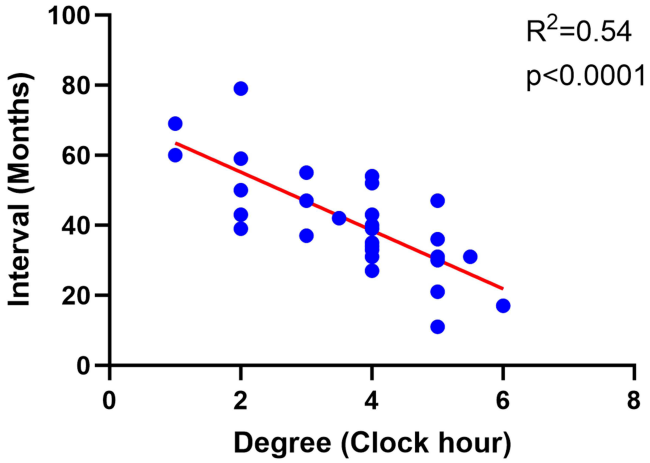

Figure 1 Relationship between the time interval and the degree of zonular weakness.

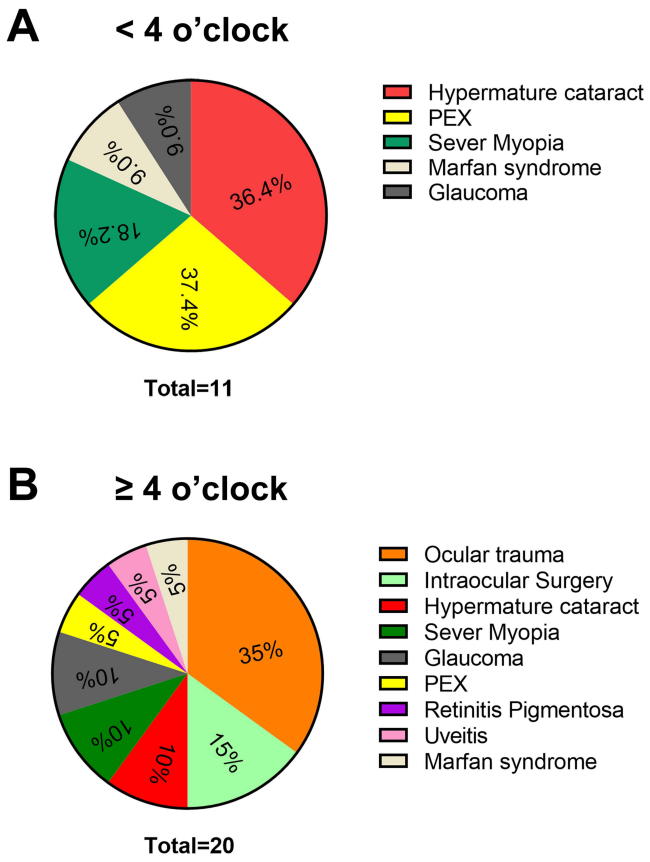

Figure 2 Distribution of predisposing factors in <4 (**A**) and ≥4 o'clock (**B**) groups.

Table 3 Design of IOL in the 31 Patients

Design	Number of Eyes (%)
1-piece hydrophilic acrylic	14 (45.16%)
3-piece hydrophobic acrylic	10 (29.03%)
1-piece hydrophobic acrylic	5 (16.13%)
1-piece hydrosmart	1 (6.5%)
1-piece polymethyl methacrylate	1 (6.5%)

ocular trauma (7 eyes) was the major cause (Figure 2B). Therefore, crystalline lens dislocation in the ≥4 o'clock extent with CTR-alone treatment was susceptible to CTR-IOL-CB complex dislocation; meanwhile, for patients with hypermature cataract or PEX complicated with lens dislocation, CTR implantation alone also led to re-dislocation even though the extent of dislocation was <4 o'clock.

The IOLs implanted in these cases included 1-piece hydrophilic acrylic (n = 14), 3-piece hydrophobic acrylic (n = 10), 1-piece hydrophobic acrylic (n = 5), 1-piece hydrosmart (n = 1), and 1-piece polymethyl methacrylate (PMMA) (n = 1) designs (Table 3). All CTRs (Morcher, Ophtec BV, Eye Bright, or Acri.Tec/Zeiss) were made of PMMA with a diameter of 12.5 or 13 mm. These results suggest 1-piece hydrophilic acrylic and 3-piece hydrophobic acrylic may have contributed to CTR-IOL-CB complex subluxation/dislocation.

Surgical Management and Follow-Up

The surgical treatment methods for IOL-CB-CTR complex subluxation/dislocation were IOL exchange or repositioning, and all operations were successful. Among them were 18 cases with IOL exchange; 11 cases were surgically treated with IOL repositioning (7 cases with CTR fixation and 4 cases with IOL fixation), and 2 cases were kept under follow-up because of mild dislocation, better vision (0.15 and 0.3 logMAR, respectively), and disagreeing to surgical treatment.

Mean UCVA and BCVA were significantly improved from 1.17 ± 0.54 logMAR and 0.58 ± 0.28 logMAR to 0.32 ± 0.25 logMAR and 0.24 ± 0.14 logMAR after re-dislocation surgery (p <0.0001 for UCVA and BCVA) at the final follow-up (mean 11.94 ± 4.76 months), respectively. No significant differences were observed in the UCVA and BCVA between IOL exchange and repositioning patients postoperatively (Figure 3A and B). No case occurred with corneal endothelial decompensation, glaucoma, macular edema, retinal detachment, endophthalmitis, or re-dislocation after IOL exchange or repositioning surgery. Therefore, surgery for IOL exchange or repositioning is an effective, feasible, and acceptable treatment for CTR-IOL-CB complex subluxation/dislocation.

Discussion

The CTR is used as an intraoperative support tool to improve the stability of IOL after cataract extraction in patients with zonular insufficiency by recruiting and redistributing tension from healthy zonules to reinforce areas of weak zonules.[8] However, CTR-IOL-CB dislocation or subluxation occurred; it is serious, and few studies have reported on them.[9,16] In addition, re-dislocation causes economic and surgery burden and decreased quality of life for patients and increased surgical difficulty for surgeons. This study described the incidence of late spontaneous CTR-IOL-CB complex subluxation/dislocation and provided analysis of predisposing factors and the effect of IOL repositioning and exchange in a center in China, which is an area with low incidence of PEX.

One study reported the incidence of CTR-IOL-CB complex subluxation/dislocation to be 0.76%; in 1828 CTRs from 1998 to 2004, 14 were dislocated.[10] In our retrospective study, a total of 3656 CTRs were implanted, and subluxation/dislocation occurred in 31 cases for an incidence rate of 0.85%, which was slightly higher. This rate may not be accurate, however, because patients might have been lost to follow-up. PEX is the most common predisposing factor for late IOL dislocation. But it is worth noting that East Asia has a lower rate of PEX syndrome (0.4% to 3.4).[18–20] This study reviewed cases with late spontaneous CTR-IOL-CB complex subluxation/dislocation in the Qingdao Eye Hospital of Shandong First Medical University of China. Therefore, the causes and risk factors of CTR-IOL-CB complex subluxation /dislocation require elaboration.

https://doi.org/10.2147/OPTH.S544172

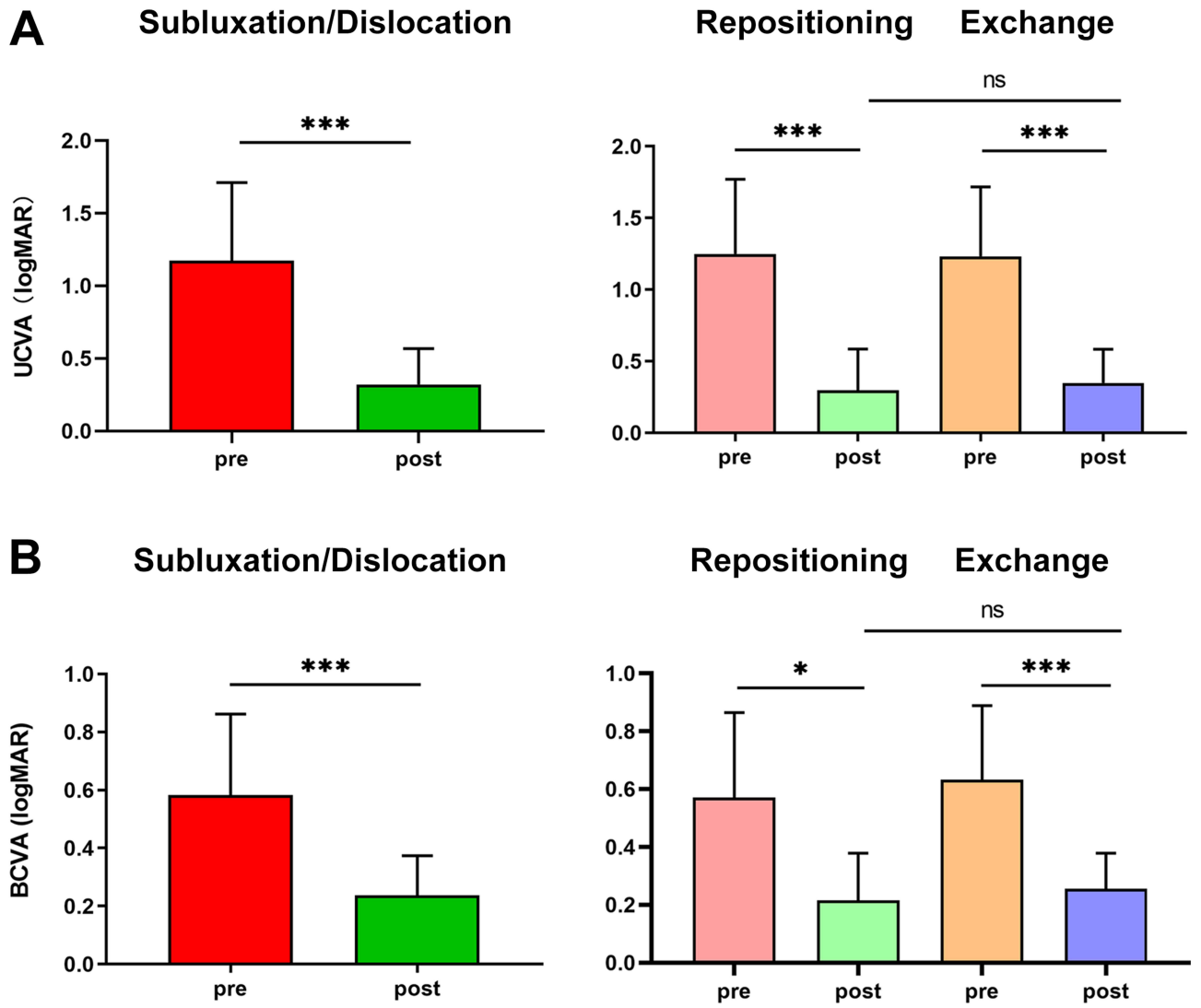

Figure 3 Comparison of UCVA (**A**), BCVA (**B**) before and after IOL dislocation treatment. UCVA: uncorrected visual acuity; BCVA: best-corrected visual acuity. * $p < 0.05$, *** $p < 0.001$, ns $p > 0.05$.

With aging populations and the number of cataract surgeries increasing, late IOL dislocation has attracted more attention from clinicians. Researchers have reported the time interval between cataract surgery and in-the-bag IOL dislocation as ranging from 6 to 12 years.[2,3,5,9,21–24] However, a shorter interval was reported for eyes with the use of a standard CTR compared to those without.[16,25] In the present study, the mean interval was 41.23 ± 14.63 months in CTR-IOL-CB dislocation cases, shorter than in previous studies. This could be attributed to heightened zonular instability due to progressive lens epithelial cell proliferation and capsular contraction in these relatively younger patients (mean, 65.17±7.19 years), while the average age reported in most literature is 68–83 years.[2,3,5,9,23,25–27] Furthermore, CTRs may decrease the degree of capsule contraction, but they do not eliminate the contraction and safeguard against late dislocation. Additionally, this shorter interval is probably the result of selection bias, with a CTR being implanted in the worst cases, or increased zonular damage in perioperative CTR implantation, thereby increasing susceptibility to subsequent dislocation.

The predisposing factors of IOL dislocation are also present for CTR-IOL-CB dislocation. In addition, a comparison between potential risk factors and their corresponding total number of surgeries may better reflect the incidence. In this study, the predisposing factor were ocular trauma (1.46%, 7/479 eyes), hypermature cataract (1.04%, 6/576 eyes). Ocular blunt trauma was reported the important predisposing factor of ectopia lentis and IOL dislocation in China.[28,29] The mean extent of zonular weakness resulting from trauma was 4.43±0.53 o'clock and was larger than other factors in this study.

Therefore, history of ocular trauma was one of the main factors of CTR-IOL-CB complex dislocation. In our previous study, we found that age, educational attainment, knowledge of cataract, and individual income all played roles in the delay of cataract surgery in China,[30] and hypermature cataract was common. Although hypermature cataract was associated with smaller extent of zonular weakness (2.50±1.22 o'clock) in this study, it was also a main predisposing factor of CTR-IOL-CB complex dislocation.

Standard CTRs are usually indicated in cases of mild zonular instability, with zonulysis observed in <3-4 o'clock, or signs of mild degree of zonular weakness such as mild phacodonesis. Initial analysis that is suitable for a standard CTR is also important for the prevention of CTR-IOL-CB complex dislocation. Therefore, the relationship between the degree of zonular insufficiency and CTR-IOL-CB complex dislocation was investigated. In the 31 cases with CTR-IOL-CB complex subluxation/dislocation, there was a negative correlation between the extent of zonule weakness and the time interval to late CTR-IOL-CB complex dislocation. The interval of CTR-IOL-CB complex of patients with preexisting zonular insufficiency ≥4 o'clock was 35.24 ± 11.13 months, which was significantly shorter than that for zonular insufficiency <4 o'clock, which was 53.8 ± 13.38 months. Therefore, when the zonular weakness was ≥4 o'clock, late spontaneous CTR-IOL-CB complex subluxation/dislocation was prone to occur. Meanwhile, for patients with hypermature cataract or PEX, CTR implantation alone was also a predisposition factor, even though the extent of zonule weakness was <4 o'clock. These results require clinical attention and a search for new preventive measures.

Previous studies have analyzed whether the type of posterior chamber IOL influences the risk of in the-bag dislocation.[21] Although studies have reported that a 3-piece hydrophobic acrylic IOL may reduce capsular contraction through a combination of decreased anterior capsule fibrosis and greater haptic rigidity, the most commonly dislocated IOL in recent years has been 3-piece hydrophobic acrylic IOL.[9,21] Foregone studies reported that 1-piece PMMA IOLs were the most commonly dislocated type.[31] However, Davis et al[2] found PMMA IOLs in 28 cases, silicone IOLs in 33 cases, and hydrophobic acrylic IOLs in 25 cases, indicating that any type of IOL is at risk for late in-the-bag dislocation. In this study, we identified 1-piece hydrophilic acrylic IOL in 14 cases (45.16%) and 3-piece hydrophobic acrylic IOL (29.03%) in 10 cases. Although hydrophilic acrylic IOLs are more associated with lens epithelial cell proliferation leading to posterior capsule opacification,[32,33] no reported studies have evaluated the risk for spontaneous late dislocation associated with a particular IOL material or design because of the lack of a control group. Therefore, whether hydrophilic IOLs are more prone to dislocation requires further research for verification.

The management of CTR-IOL-CB complex dislocation requires special considerations. IOL exchange and repositioning for CTR-IOL-CB complex subluxation/dislocation are usually used in clinical settings to improve VA.[5,22,34] In our study, surgical treatments for patients with CTR-IOL-CB complex dislocation/subluxation were implemented with IOL repositioning or IOL exchange. Surgical options vary from repositioning to exchange, although the optimum approach for each case remains unclear because the surgical indications and best timing for management have not been established. IOL repositioning was implemented in 11 cases and IOL exchange in18 cases; 2 cases were kept under follow-up without treatment. Both surgical techniques harvested good VA outcomes without other complications. But both entailed scleral fixation using 9–0 polypropylene suture. Studies have reported rates of IOL re-dislocation with 10–0 polypropylene scleral fixation of 0%-28%.[35,36] Therefore, long-term follow-up is necessary. To avoid CTR-IOL-CB subluxation/dislocation, modified surgical techniques and CTR may be considered as potential approaches. Some surgeons have attempted the use of modified CTR or capsular tension segment (CTS) with scleral fixation to prevent IOL dislocation; however, the standards for their application and long-term outcomes remain to be clarified. Therefore, it is necessary to conduct further research, including long-term follow-up with larger sample sizes, before proposing the widespread adoption of modified surgical procedures, CTR, or CTS.

Conclusion

The incidence rate of late spontaneous CTR-IOL-CB complex subluxation/dislocation was 0.85% in this study. The main predisposing factor was ocular trauma and hypermature cataract. An extent of zonule weakness ≥4 o'clock and the use of 1-piece hydrophilic acrylic IOL and 3-piece hydrophobic acrylic IOL were susceptible to late CTR-IOL-CB complex dislocation. IOL exchange or repositioning is effective for the complication. But modified surgical treatment and CTRs or CTS that may contribute to preventing the subluxation/dislocation of late spontaneous CTR-IOL-CB complex are recommended.

Data Sharing Statement

The data supporting this study's findings are available upon request from the corresponding author, Xiubin Ma, upon reasonable request.

Funding

This study was supported by the National Natural Science Foundation of China (82301190) and the Natural Science Foundation of Shandong Province (ZK2022MH277 and ZR2023QH156).

Disclosure

All authors have no conflicts of interest to declare in this work.

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