• Clinical Research •

Sulcus fixation of a standard capsular tension ring in cataract surgery with capsular instability

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Received: 2025-08-04 Accepted: 2025-12-22

Abstract

● **AIM:** To introduce a novel technique for stabilizing the capsular bag in cataract surgery.

● **METHODS:** This retrospective observational case series included eyes with unstable capsular bag that underwent cataract surgery. A standard capsular tension ring (CTR) with 10-0 Prolene sutures was inserted into the capsular bag and fixated to the sulcus to stabilize the bag, enabling in-the-bag intraocular lens (IOL) implantation. Uncorrected distance visual acuity, corrected distance visual acuity (CDVA), and slit-lamp examination were performed preoperatively and at 1 and 6mo postoperatively.

● **RESULTS:** Of the 17 eyes from 15 patients (mean age 51.20±19.60y, male/female=11/6), 8 had subluxation due to Marfan syndrome, 3 due to trauma, 5 due to zonular weakness, and 1 due to acute angle closure glaucoma. The preoperative mean CDVA (logMAR) was 0.56±0.67 (mean spherical equivalent: −6.39±4.78 D). At 1mo postoperatively, the mean CDVA improved to 0.21±0.37 (mean spherical equivalent: −0.35±1.07 D). At 6mo, the mean CDVA was 0.32±0.39, and the mean spherical equivalent was −0.34±0.99 D. All patients showed significant visual improvement at both postoperative visits (P<0.05), with stable IOLs in all cases.

● **CONCLUSION:** This technique offers a viable surgical option in complex cataract cases with zonulysis.

● **KEYWORDS:** cataract; zonulysis; capsular tension ring; sulcus fixation; intraocular lens implantation

DOI:10.18240/ijo.2026.04.08

Citation: Eah KS, Lee H, Jeon YY, Chung HS, Lee H, Kim JY. Sulcus fixation of a standard capsular tension ring in cataract surgery with capsular instability. *Int J Ophthalmol* 2026;19(4):696-700

INTRODUCTION

Cataract surgery has been considered the safest and most effective surgery, particularly since the introduction of small-incision phacoemulsification and in-the-bag intraocular lens (IOL) implantation[1]. However, surgical challenges may be encountered in eyes with compromised zonular support due to various etiologies, such as inherited conditions like Weill-Marchesani syndrome and homocystinuria[2-3]. These challenges can be overcome using different surgical methods, often aided by endocapsular supporting devices[4-6].

In cases of severe zonular weakness, the Cionni-modified capsular tension ring (CTR) provides stabilization of the capsular bag, allowing for in-the-bag IOL implantation in both adult and pediatric patients[7-10]. Despite its effectiveness, this device may not always be readily available, particularly in resource-limited settings or when severe zonulysis is unexpectedly encountered during surgery. Additionally, its use requires precise surgical planning and technical expertise, which may increase surgical time and the risk of complications. Scleral fixation of a standard CTR has been proposed by previous studies[11-12]. However, this approach requires puncturing of the capsular bag, which may increase the risk of capsular tears or vitreous prolapse.

In this study, we introduce a safe and efficient technique for sulcus fixation of a standard CTR using a simpler and quicker technique in cases of severe lens subluxation. This method enables in-the-bag IOL implantation even in the presence of severe zonulysis, without the need for specialized endocapsular support devices.

PARTICIPANTS AND METHODS

Ethical Approval This retrospective, observational case series was conducted at the Asan Medical Center, University of Ulsan College of Medicine, Seoul, Republic of Korea. The study was approved by the International Review Board (Approval No.2025-2487) of the hospital and adhered to the principles of the Declaration of Helsinki. Medical records were reviewed for patients who underwent lens extraction with sulcus fixation of a standard CTR at Asan Medical Center between July 2017 and November 2021.

Study Participants The inclusion criteria encompassed patients diagnosed with subluxated crystalline or cataractous lenses due to conditions such as Marfan syndrome, ocular trauma, pseudoexfoliation, or other underlying causes of zonular instability. Patients who were assessed to have a zonular defect of more than 180 degrees, either during the preoperative dilated slit-lamp examination or intraoperatively, were included in this study. Patients were excluded if they had a history of retinal disease requiring treatment, preoperative intraocular pressure (IOP) ≥25 mm Hg despite ongoing treatment with eye drops, evidence of inflammatory ocular disease, or a postoperative follow-up period of less than 6mo.

Preoperative and Postoperative Evaluation All patients underwent comprehensive ophthalmologic evaluations both before and after surgery. These assessments included uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA) measured using a Snellen chart at a 4-meter distance, IOP measurement, and dilated slit-lamp biomicroscopy. Postoperative complications were categorized as early if they occurred within one month of surgery and as late if they developed thereafter. Hypotony was defined as an IOP <6 mm Hg, and elevated IOP as >25 mm Hg.

Surgical Procedure All procedures were performed by a single surgeon (Kim JY) under retrobulbar anesthesia. A 2.2-mm main limbal incision was made using a keratome, followed by continuous curvilinear capsulorhexis with capsulorhexis forceps. In cases of severe zonulysis, iris retractors (Alcon Laboratories, Inc., Fort Worth, TX, USA) were used to stabilize the capsular bag. Phacoemulsification was then performed through the main limbal incision.

A 10-0 polypropylene monofilament nonabsorbable suture, doubled-armed with two curved needles (Ethicon, Inc., Somerville, NJ, USA), was tied around the standard CTR using a Lark's head (cow hitch) knot technique (Figure 1). The standard CTR was then implanted into the capsular bag through the main incision.

Following insertion of the CTR into the capsular bag, conjunctival dissection was performed at the site of maximum zonular weakness. An angled sclerotomy was created 2 mm posterior to the limbus using a bent 26-gauge wall needle to retrieve the first curved needle. A second sclerotomy was made next to the first to pass the second curved needle. The sutures were carefully tightened, allowing the Lark's head knot to slide along the CTR and achieve appropriate tension. The sutures were then securely tied at the scleral surface to center and stabilize the capsular bag. A single-piece monofocal ZCB00 IOL (Johnson & Johnson Vision, Santa Ana, CA, USA) was implanted into the capsular bag. The suture knot was buried beneath the conjunctiva, which was then repositioned.

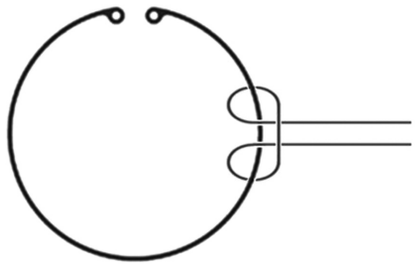

Figure 1 Schematic illustration of the Lark's head knot method used to secure a 10-0 polypropylene suture to a standard capsular tension ring.

All patients received postoperative topical treatment consisting of bromfenac 0.1% (Bronuck®, Taejoon, Seoul, Republic of Korea) twice daily, along with 1% prednisolone acetate (Pred Forte®, Allergan, Santa Ana, CA) and 1.5% levofloxacin (Cravit®, Santen Pharmaceutical Co., Ltd., Osaka, Japan) four times daily for one month after surgery.

Statistical Analysis The Wilcoxon signed-rank test was used to evaluate the differences between preoperative and postoperative UDVA, CDVA, and IOP. A *P*-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS software, version 23.0 (IBM Inc., Armonk, NY, USA).

RESULTS

A total of 15 patients (17 eyes) were included in the study. The etiology of lens subluxation included Marfan syndrome (8 eyes), zonular weakness (5 eyes), ocular trauma (3 eyes), and angle-closure glaucoma (1 eye). Table 1 summarizes the baseline characteristics of the study population.

Table 2 shows the preoperative and postoperative outcomes. The mean preoperative CDVA logMAR was 0.56±0.67. At 1 and 6mo postoperatively, the mean CDVA significantly improved to 0.21±0.37 and 0.32±0.39, respectively (both $P<0.001$). Similarly, the mean UDVA improved from 0.88±0.59 preoperatively to 0.39±0.41 at 1mo ($P=0.001$) and to 0.34±0.40 at 6mo postoperatively ($P=0.02$).

The mean preoperative spherical equivalent was −6.39±4.78 D. Postoperatively, it improved to −0.35±1.07 D at 1mo and −0.34±0.99 D at 6mo, consistent with the target refraction. At the 6-month postoperative dilation examination, all IOLs remained well centered and stable.

No intraoperative complications were observed. There were no cases of posterior capsular rupture, vitreous loss, significant IOL tilt, or the need for additional surgical intervention. No patients developed postoperative hypotony, ocular hypertension, or endophthalmitis during the study period.

DISCUSSION

In this study, we introduced a novel technique to manage capsular bag instability due to zonular weakness during cataract surgery through sulcus fixation of a standard CTR and evaluated its surgical outcomes. All cases of zonular weakness

Table 1 Baseline patient characteristics

Characteristics	Data
Number of eyes (patients)	17 (15)
Age (y)	
Mean±SD	51.20±19.60
Range	15–85
Gender (male/female)	11/6
Diagnosis (number of eyes)	
Subluxated crystalline lens	8
Trauma	3
Zonulysis	5
Acute glaucoma	1
Axial length (mm)	
Mean±SD	25.60±2.30
Range	23.17–31.63
Baseline CDVA (logMAR)	
Mean±SD	0.56±0.67
Range	0.00–2.70
Baseline refraction (D)	
Mean±SD	−6.39±4.78
Range	−13.13−1.25
Follow-ups (mo)	
Mean±SD	23.70±14.60
Range	6.00–49.00

SD: Standard deviation; CDVA: Corrected distance visual acuity; D: Diopters; logMAR: logarithm of the minimum angle or resolution.

Table 2 Comparative evaluation of preoperative and postoperative outcomes mean±SD

Outcomes	Preoperative	Postoperative 1mo	*P*	Postoperative 6mo	*P*
UDVA (logMAR)	0.88±0.59	0.39±0.41	0.001	0.34±0.40	0.020
CDVA (logMAR)	0.56±0.67	0.21±0.37	<0.001	0.32±0.39	<0.001
IOP (mmHg)	17.20±4.60	16.10±3.39	0.439	16.40±2.60	0.288
Spherical equivalence (D)	−6.39±4.78	−0.35±1.07[a]		−0.34±0.99[a]	

[a]Targeted refraction has been taken into account. SD: Standard deviation; UDVA: Uncorrected distance visual acuity; CDVA: Corrected distance visual acuity; logMAR: Logarithm of the minimum angle or resolution; IOP: Intraocular pressure; D: Diopters.

were successfully managed using this technique. Both mean visual acuity and spherical equivalent improved significantly after surgery. There were no significant changes in IOP and no intraoperative or postoperative complications were observed during the 6-month follow-up period. These results suggest that sulcus fixation of a standard CTR is a reliable and efficient approach to manage capsular instability due to zonular weakness in cataract surgery.

Depending on the severity of lens subluxation, various surgical techniques are available. In cases with zonular weakness, the use of a standard CTR is generally recommended[13-14]. However, when zonulysis is severe, treatment options may be limited. One option is scleral fixation of the IOL after complete removal of the unstable capsular bag. While this approach avoids potential later in-the-bag IOL dislocation, it carries a risk of vitreoretinal complications, such as retinal breaks[15]. Modern scleral fixation techniques are varied, including sutureless flanged methods, four-point fixation, and modified double-knot techniques, each with its own profile of risks and benefits[16-18]. The Cionni-modified CTR remains an effective method to manage severe zonulysis, with recent studies continuing to affirm its utility, particularly in pediatric patients[19]. Sandhu *et al*[20] reported favorable long-term visual outcomes in 41 eyes treated with lens extraction and capsular bag fixation using the Cionni-modified CTR, with a mean follow-up of more than 9y. However, some have reported complications such as posterior capsular opacification[21-22]. Moreover, the Cionni-modified CTR may not be readily available at the time of surgery, especially in cases of unexpected severe zonulysis or in resource-limited settings. In contrast, the standard CTR is more widely accessible.

To address the limitations of existing approaches, alternative techniques using standard CTRs to manage severe zonulysis have been proposed. Ma *et al*[12] have introduced a technique for scleral fixation of a standard CTR in cases of lens dislocation. In their technique, a 10-0 polypropylene suture was tied to the end of the standard CTR, and the needle was passed through the capsular bag at the zonular weakness site and withdrawn through the sclera. Three patients with zonulysis involving more than 180 degrees were managed using this method and showed stable visual acuity after an average follow-up period of 22.7mo, with no major postoperative complications. Li *et al*[11] also have reported a technique for managing severe zonulysis by scleral fixation of a standard CTR using a double-stranded 8-0 polypropylene suture tied in the middle of the CTR. In their study, 9 eyes showed improved CDVA after a mean follow-up of 11mo, with no major complications. However, this method requires creating a capsulotomy at the capsular equator, where zonular weakness is present, using a 23-gauge vitrector or capsulorhexis forceps. Both techniques require tying the suture to the standard CTR with careful placement at the site of maximum zonular weakness, which can be time-consuming and technically demanding. They also require a transcapsular approach for scleral fixation, which may lead to capsular tear or vitreous prolapse. Such complications may force the surgeon to abandon in-the-bag IOL implantation and convert to scleral fixation of the IOL.

Our method is distinguishable from others in that it provides a faster and simpler approach to managing severe zonulysis in cataract surgery using a standard CTR. In our study of 17 eyes, all cases showed improvement in CDVA after a follow-up period of at least 6mo, with stable results. The postoperative

follow-up ranged from 6 to 49mo, and notably, there were no cases of posterior capsular opacification, which is a common complication after cataract surgery, associated with the use of the Cionni-modified CTR[21-22]. Our technique uses a double-armed 10-0 polypropylene suture tied to the standard CTR using a Lark's head knot. This method is considerably less time-consuming compared to tying the suture at the end or midpoint of the CTR and allows for easy placement at the site of maximum zonulysis. This adaptability is a key advantage, as it allows the surgeon to create primary incisions in the optimal location for phacoemulsification, independent of where the zonular weakness is located. By carefully pulling the transscleral suture, the knot can be smoothly positioned along the CTR after it has been implanted in the capsular bag, avoiding rotation of the ring and thereby minimizing stress on the already weak zonular fibers. Additionally, the suture loop encircles the anterior capsule for sulcus fixation, similar to the sulcus fixation approach used with the Cionni-modified CTR. This ensures stable and excellent IOL centration without violating the integrity of the capsular bag[23]. Overall, our technique reduces operative time and lowers the risk of complications, enhancing surgical efficiency in managing severe lens subluxation.

The limitations of this study include the relatively small sample size and the short-term duration of follow-up in some cases. Furthermore, while our results showed excellent stability, the long-term durability of single-point fixation in conditions with progressive zonulopathy, such as Marfan syndrome, requires further investigation to confirm its efficacy against potential late dislocation of the IOL-capsular bag complex. Additionally, we were unable to quantitatively assess the tilt of IOL postoperatively owing to the lack of anterior segment optical coherence tomography. The quantitative assessment of IOL tilt and decentration is an important metric for surgical success, and multiple recent studies have focused on identifying its determinants and risk factors[24-26]. However, we believe that detailed dilated slit-lamp examinations provided sufficient evidence of stable IOL centration and absence of significant tilt after surgery.

In conclusion, the Lark's head knot method combined with sulcus fixation of a standard CTR provides a safe and efficient surgical approach for managing patients with cataract with severe zonulysis. This method may be an effective way to manage severe lens dislocation even in regions with limited access to Cionni-modified CTR. Further studies with larger sample sizes and longer follow-ups are required to confirm the long-term outcomes of this technique.

ACKNOWLEDGEMENTS

Conflicts of Interest: Eah KS, None; **Lee H,** None; **Jeon YY,** None; **Chung HS,** None; **Lee H,** None; **Kim JY,** None.

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