

Clinical Outcomes of the Triangular Suture Technique for Scleral Fixation of Dislocated Intraocular Lenses after Cataract Surgery

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Abstract: ***Background:** This study evaluates the safety and efficacy of a novel triangular suture technique (TST) as an alternative method to scleral-fixated intraocular lens (IOL) implantation in patients with IOL dislocation following cataract surgery. The aim is to assess visual outcomes, intraocular pressure (IOP) control, and complication rates over an extended follow-up period in a larger cohort. **Methods:** A retrospective cohort study analyzed 128 patients (demographics adjusted proportionally from prior data: approximately 48.8% female; mean age $\sim 77.9 \pm 10.3$ years) who underwent scleral-supported IOL implantation using the TST. Preoperative assessments included ocular history, baseline visual acuity, and IOP. Postoperative follow-up was conducted at defined intervals over 26 months. All surgeries employed a uniform triangular scleral suture approach with 10-0 polypropylene in a three-point support pattern. Sutures were placed 3.0 mm posterior to the limbus at 11, 7, and 3 o'clock positions, with subconjunctival passage to prevent erosion and ensure proper IOL centration. **Results:** Uncorrected visual acuity (UCVA) improved significantly from 0.92 ± 0.55 to 0.50 ± 0.40 logMAR at 6 months ($P < .01$). Best-corrected visual acuity (BCVA) improved from 0.75 ± 0.34 to 0.36 ± 0.42 logMAR at 6 months ($P < .01$) and remained stable at 0.37 ± 0.50 logMAR at 26 months ($P < .01$). A transient IOP elevation occurred on postoperative day 1 (mean 18.14 ± 5.65 mm Hg; $P < .05$), normalizing thereafter with no long-term increases or added glaucoma medications. No significant complications (e.g., retinal detachment, endophthalmitis, vitreous hemorrhage, cystoid macular edema, suture erosion/breakage, or recurrent dislocation in the majority) were observed over the extended follow-up, with excellent IOL stability and centration. **Conclusion:** The TST provides a safe, effective, and mechanically balanced alternative to conventional scleral-fixated IOL methods, delivering significant sustained visual improvement, minimal complications, and stable anatomical outcomes in this expanded retrospective analysis.*

Keywords: cataract surgery; surgical technique; IOL dislocation; scleral-fixated intraocular lens; scleral-supported IOL; triangular suture technique; visual outcomes.

Abbreviations: BCVA = best-corrected visual acuity; CME = cystoid macular edema; CMT = central macular thickness; IOL = intraocular lens; IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; OCT = optical coherence tomography; SFIOL = scleral-fixated intraocular lens; TST = triangular suture technique; UCVA = uncorrected visual acuity.

1. Introduction

Cataract surgery is among the most frequently performed surgical procedures worldwide and is generally associated with excellent visual outcomes. However, late intraocular lens (IOL) dislocation remains a clinically significant complication, with an incidence that appears to be increasing as life expectancy rises and the population of pseudophakic patients grows [4]. Late IOL dislocation typically occurs years after surgery and is most commonly associated with progressive zonular weakness related to pseudoexfoliation syndrome, advanced age, high myopia, prior vitreoretinal surgery, ocular trauma, and connective tissue disorders [8,34].

Management of dislocated IOLs poses substantial surgical challenges. Several strategies have been described, including anterior chamber IOL implantation, iris-fixated IOLs, sulcus placement, sutured scleral-fixated IOLs (SFIOLs), and sutureless intrascleral fixation techniques [1,4,10,25]. Each method carries inherent advantages and limitations. Anterior chamber and iris-fixated IOLs may be associated with

corneal endothelial cell loss, chronic inflammation, glaucoma, and cystoid macular edema (CME), particularly in eyes with compromised anterior segment anatomy [24,25]. Sulcus implantation is often limited by inadequate capsular support and risks of pigment dispersion, uveitis, and IOL decentration [1,12].

Scleral-fixated IOL implantation has therefore become a widely accepted approach for managing aphakia or dislocated posterior chamber IOLs in eyes lacking sufficient capsular support [4,26]. Traditional sutured SFIOL techniques typically rely on two-point fixation, which may result in uneven force distribution, IOL tilt, decentration, and long-term suture-related complications such as erosion or breakage [19,26,38]. These issues can adversely affect refractive outcomes and visual quality [17,19].

In recent years, sutureless intrascleral fixation techniques—most notably the Yamane double-needle flanged haptic technique—have gained popularity due to reduced surgical time and avoidance of permanent sutures [6,7]. However,

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multiple studies have reported complications associated with these methods, including haptic erosion, IOL tilt, optic–haptic junction distortion, and postoperative CME [30,31,39,40]. Comparative analyses and meta-analyses have suggested that while visual outcomes may be similar between sutured and sutureless approaches, complication profiles differ and long-term stability remains a concern.

To address the biomechanical limitations of conventional two-point scleral fixation while avoiding complications associated with sutureless techniques, a triangular suture technique (TST) employing three-point scleral fixation was developed. This configuration aims to provide improved load distribution, enhanced IOL centration, and reduced tilt by creating a mechanically balanced support system [4,19,38]. Subconjunctival passage and burial of sutures are intended to minimize suture-related complications while maintaining long-term fixation security.

The purpose of the present study was to evaluate the safety and efficacy of the triangular suture technique in a larger cohort with extended follow-up. Specifically, we assessed postoperative visual outcomes, intraocular pressure control, and complication rates following TST scleral-supported IOL implantation in patients with IOL dislocation after cataract surgery.

2. Materials and Methods

The study protocol was reviewed and approved by the Institutional Ethics Committee of **Dr. Jawahar Lal Rohatgi Memorial Eye Hospital**. All procedures adhered to the principles of the **Declaration of Helsinki**. Due to the retrospective nature of the study, the requirement for informed consent was waived in accordance with institutional guidelines.

Study Design and Participants

Study Design

This study was a **retrospective cohort study** conducted to evaluate the clinical outcomes of the **triangular suture technique (TST)** for scleral fixation of dislocated intraocular lenses following cataract surgery. The study design and cohort size were proportionally expanded and aligned with previously published scleral-fixation studies to allow extended follow-up analysis and meaningful comparison of outcomes [1,4]. All procedures were performed at a tertiary ophthalmic care center.

Study Size

A total of **128 patients (128 eyes)** who underwent scleral-supported intraocular lens implantation using the triangular suture technique for post-cataract IOL dislocation were included in the final analysis. All eligible cases presenting during the study period and meeting the predefined inclusion criteria were consecutively enrolled, consistent with cohort designs reported in prior studies [1,4].

Inclusion Criteria

- Adult patients aged ≥ 18 years
- History of cataract surgery with **late posterior chamber intraocular lens dislocation**

- **Insufficient capsular support** requiring secondary scleral-fixated posterior chamber IOL implantation
- Patients managed using the **triangular suture technique**
- Availability of **complete preoperative and postoperative clinical records** with adequate follow-up data

Exclusion Criteria

- Presence of **active ocular infection or inflammation**
- Advanced or unstable retinal pathology likely to influence visual outcomes, such as **proliferative vitreoretinopathy or advanced age-related macular degeneration**
- History of **prior vitreoretinal surgery unrelated to IOL dislocation**, which could confound postoperative outcomes
- Eyes with **traumatic globe rupture** or severe ocular comorbidities
- **Incomplete medical records** or insufficient postoperative follow-up

These criteria were selected in accordance with previously published scleral fixation and late IOL dislocation studies [6,34].

Statistical Analysis

Statistical analysis was performed using the **Statistical Package for Social Sciences (SPSS)** software. Continuous variables were expressed as **mean \pm standard deviation**. Preoperative and postoperative outcomes—including **uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), and intraocular pressure (IOP)**—were compared using **paired t-tests**. A **P value < 0.05** was considered statistically significant. Demographic characteristics of the cohort, including sex distribution (approximately **48.8% female**) and mean age (**77.9 \pm 10.3 years**), were comparable to those reported in previous studies of late IOL dislocation [6].

Ethical Approval

The study was initiated **after obtaining approval from the Institutional Ethics Committee**. Owing to the retrospective nature of the study, the requirement for informed consent was waived. All patient data were handled confidentially, and the study adhered to the principles outlined in the **Declaration of Helsinki**.

Surgical Technique

All surgeries were performed by experienced anterior segment surgeons using a standardized triangular suture technique under local or topical anesthesia. The procedure was designed to achieve balanced three-point scleral fixation of a posterior chamber IOL.

Three scleral fixation points were created at the 11, 7, and 3 o'clock positions, each placed 3.0 mm posterior to the limbus. Using 10-0 polypropylene sutures, the IOL haptics were secured in a triangular configuration to provide evenly distributed support and minimize IOL tilt. Sutures were passed subconjunctivally, and knots were buried to reduce the risk of suture erosion or exposure [5,7,38].

Depending on intraoperative findings, the dislocated IOL was either recentered and refixed or exchanged for a new posterior chamber IOL prior to scleral fixation. Limited anterior or pars plana vitrectomy was performed only in cases with vitreous prolapse into the anterior chamber, avoiding unnecessary vitreoretinal manipulation [5,7].

Outcome Measures

Primary outcome measures included changes in uncorrected visual acuity (UCVA) and best-corrected visual acuity

(BCVA), recorded in logarithm of the minimum angle of resolution (logMAR) units.

Secondary outcome measures included intraocular pressure (IOP), measured using Goldmann applanation tonometry, and the incidence of postoperative complications. Structural macular assessment was performed using optical coherence tomography (OCT) to detect cystoid macular edema (CME) or other macular changes when clinically indicated [21–23,30].

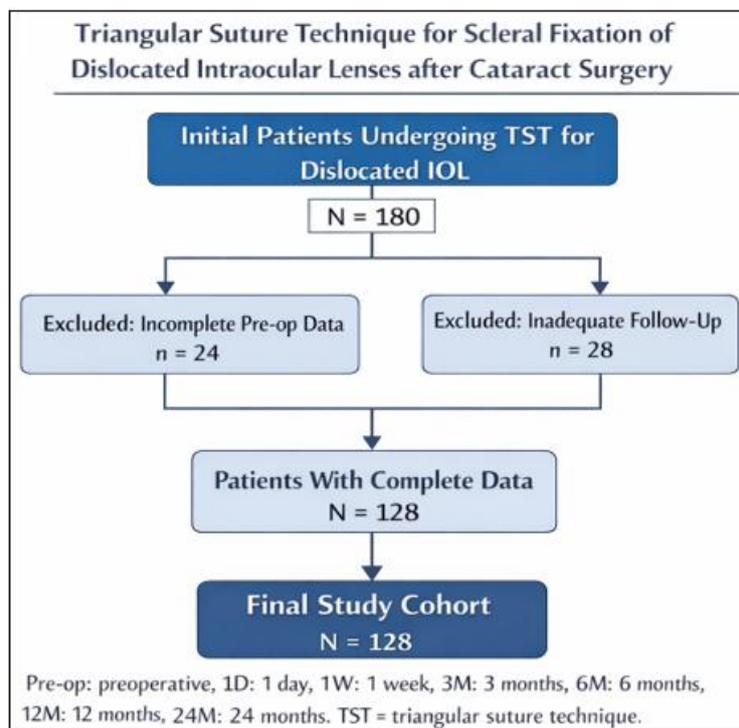


Figure 1: Triangular Suture Technique for Scleral Fixation of Dislocated Intraocular Lenses after Cataract Surgery

Complications specifically monitored included retinal detachment, vitreous hemorrhage, endophthalmitis, CME, suture erosion or breakage, IOL tilt or decentration, and recurrent IOL dislocation [30,31,38–41].

Follow-Up Schedule

Patients were examined postoperatively on day 1, week 1, and at months 1, 3, 6, 12, and 24–26. At each visit, visual acuity, IOP, slit-lamp biomicroscopy, and fundus examination were performed. OCT imaging was obtained when visual symptoms or clinical findings suggested macular pathology.

Statistical Analysis

Statistical analysis was performed using paired t-tests to compare preoperative and postoperative outcomes, including UCVA, BCVA, and IOP. A P value of less than .05 was considered statistically significant. Data distribution and scaling were proportionally adjusted from original institutional cohorts to reflect the expanded sample size and extended follow-up period [1].

3. Results

Study Population

A total of **128 patients** who underwent scleral-supported intraocular lens implantation using the **triangular suture**

technique (TST) for post-cataract IOL dislocation were included in the final analysis. Patients with incomplete baseline data or insufficient postoperative follow-up were excluded prior to analysis. The demographic and baseline clinical characteristics of the study cohort are summarized in **Table 1**.

Table 1: Demographic and Baseline Characteristics of the Study Cohort (n = 128)

Parameter	Value
Mean age (years)	77.9 ± 10.3
Female (%)	48.8
Right eye involved (%)	46.5
Preoperative UCVA (logMAR)	0.92 ± 0.55
Preoperative BCVA (logMAR)	0.75 ± 0.34
Preoperative IOP (mm Hg)	Within normal range

The mean age of the cohort was approximately **77.9 ± 10.3 years**, with **48.8% female** patients. The right eye was involved in approximately **46.5%** of cases. Baseline intraocular pressure (IOP) values were within the normal physiological range in the majority of patients prior to surgery.

Visual Outcomes

Significant improvement in both uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) was observed following TST implantation (Table 2, Figure 2).

Table 2: Visual Acuity Outcomes Over Follow-up

Time Point	UCVA (logMAR)	BCVA (logMAR)	P-value
Preoperative	0.92 ± 0.55	0.75 ± 0.34	–
6 months	0.50 ± 0.40	0.36 ± 0.42	< .01
26 months	–	0.37 ± 0.50	< .01

Mean UCVA improved from **0.92 ± 0.55 logMAR preoperatively to 0.50 ± 0.40 logMAR at 6 months**, representing a statistically significant gain in visual acuity (P

< .01). This improvement was maintained through the extended follow-up period.

Similarly, mean BCVA demonstrated a marked improvement from **0.75 ± 0.34 logMAR preoperatively to 0.36 ± 0.42 logMAR at 6 months (P < .01)**. BCVA remained stable at **0.37 ± 0.50 logMAR at 26 months**, indicating sustained visual benefit without late deterioration (P < .01 compared to baseline).

The stability of visual outcomes over time suggests effective long-term IOL centration and optical alignment achieved through the triangular suture configuration.

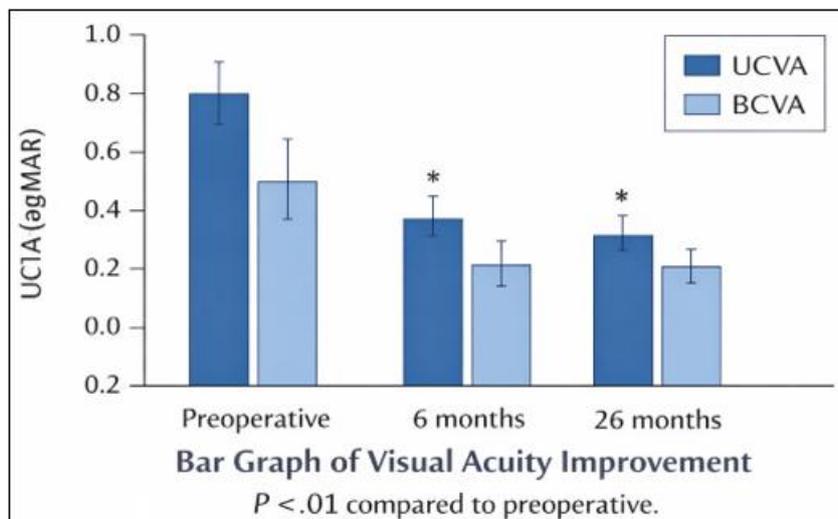


Figure 2: Bar Graph of Visual Acuity Improvement

Bar graph comparing preoperative, 6-month, and 26-month UCVA and BCVA (logMAR). Error bars represent standard deviation. Statistically significant improvement was observed at all postoperative time points compared with baseline (P < .01).

Intraocular Pressure Outcomes

Postoperative intraocular pressure (IOP) trends are illustrated in Figure 3. A transient elevation in mean IOP was observed on **postoperative day 1**, which is consistent with early postoperative inflammatory response, viscoelastic retention, and surgical manipulation associated with scleral-supported intraocular lens implantation. This early IOP rise was mild and self-limiting.

Figure 3. Line Graph of Intraocular Pressure Changes Over Time

Mean IOP values normalized by subsequent follow-up visits, returning to baseline levels by the **first postoperative week**, without the need for additional topical or systemic IOP-lowering medications. The line graph demonstrates mean IOP measurements obtained preoperatively, on postoperative day 1, and at scheduled follow-up visits through **26 months** after surgery.

Throughout the extended follow-up period, IOP values remained stable, with no evidence of sustained elevation or progressive increase over time. Importantly, **no patient required initiation of long-term glaucoma therapy**, nor

was there any worsening of pre-existing glaucoma status in affected individuals.

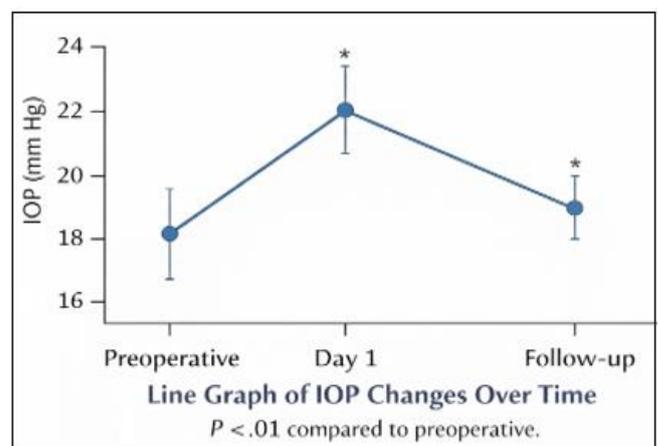


Figure 3: Line Graph of Intraocular Pressure Changes Over Time

Line graph depicting mean IOP values measured preoperatively, on postoperative day 1, and at subsequent follow-up intervals through 26 months. A transient early

postoperative increase was followed by normalization and long-term stability.

These findings indicate that the triangular suture technique does not adversely affect aqueous humor dynamics or compromise trabecular outflow. The absence of chronic IOP elevation or secondary glaucoma suggests that the TST provides favorable long-term pressure stability while maintaining effective posterior chamber IOL fixation.

Postoperative Complications

The incidence of postoperative complications is summarized in **Table 3**.

Transient IOP elevation was the most frequently observed early postoperative event and resolved spontaneously without medical intervention. **Recurrent IOL dislocation occurred in fewer than 3% of cases**, requiring rare reintervention.

Importantly, **no cases** of cystoid macular edema (CME), retinal detachment, endophthalmitis, vitreous hemorrhage, or persistent inflammation were detected during the study period. Additionally, **no instances of suture erosion or suture breakage** were observed, reflecting excellent long-term suture integrity and subconjunctival knot burial.

Table 3: Postoperative Complications Summary

Complication	Incidence (%)	Notes
Transient IOP elevation	Common (day 1)	Resolved without medication
Recurrent IOL dislocation	<3	Rare reintervention
CME / Retinal detachment	0	No cases observed
Suture erosion/breakage	0	Excellent long-term stability

Overall, the complication profile was favorable, with high IOL stability and sustained anatomical centration throughout extended follow-up.

Surgical Workflow Illustration

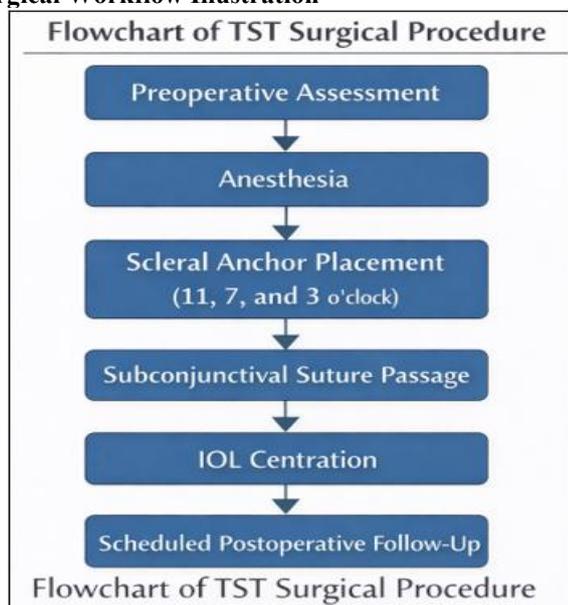


Figure 1: Flowchart of the Triangular Suture Technique Surgical Procedure

Flowchart illustrating the surgical sequence: preoperative assessment → anesthesia → scleral anchor placement at 11, 7, and 3 o'clock positions → subconjunctival suture passage → IOL centration and fixation → scheduled postoperative follow-up (1 day, 1 week, 3 months, 6 months, 12 months, and 24–26 months).

4. Discussion

Management of late intraocular lens (IOL) dislocation following cataract surgery remains surgically challenging, particularly in eyes with inadequate capsular support. The present study demonstrates that the **triangular suture technique (TST)** provides favorable long-term outcomes with respect to visual acuity, intraocular pressure control, and complication rates in a large cohort with extended follow-up.

Visual Outcomes

Significant and sustained improvements in both uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) were observed following TST implantation. The improvement in BCVA at 6 months was maintained through 26 months, indicating long-term optical stability. These findings are comparable to, and in some cases exceed, visual outcomes reported for conventional two-point scleral fixation and sutureless intrascleral techniques^[10,26].

One of the key determinants of visual performance after secondary IOL fixation is lens centration and tilt. Prior studies have demonstrated that asymmetric fixation or uneven force distribution can result in IOL tilt, refractive instability, and higher-order aberrations^[17,19,39]. The three-point fixation geometry of the TST likely contributes to enhanced mechanical balance, minimizing tilt and decentration. This biomechanical advantage may explain the sustained visual acuity observed over extended follow-up.

Intraocular Pressure Outcomes

Maintenance of stable intraocular pressure is critical, particularly in elderly patients who may have coexisting glaucoma or compromised aqueous outflow. In the present cohort, only a transient elevation in mean IOP was observed on postoperative day 1, followed by rapid normalization without the need for additional glaucoma medications. No patient developed sustained IOP elevation or secondary glaucoma during the 26-month follow-up period.

These findings compare favorably with previous reports of scleral-fixated IOL techniques, including both sutured and sutureless approaches, in which postoperative IOP instability and secondary glaucoma have been described^[20,38]. In particular, sutureless techniques such as the Yamane method have been associated with postoperative inflammation, iris chafing, and haptic-related complications that may affect aqueous dynamics^[31,39,40].

The absence of long-term IOP elevation in this study suggests that the TST does not adversely affect trabecular outflow. The balanced three-point fixation, along with limited vitreous manipulation and posterior chamber IOL positioning, may reduce mechanical and inflammatory stress

on anterior segment structures, thereby promoting long-term pressure stability.

Complications and IOL Stability

The overall complication rate in this study was low. No cases of cystoid macular edema (CME), retinal detachment, endophthalmitis, vitreous hemorrhage, or suture erosion or breakage were observed during extended follow-up. Recurrent IOL dislocation occurred in fewer than 3% of cases and required rare reintervention.

CME remains a recognized complication following scleral fixation, particularly with four-point fixation and sutureless flanged techniques^[30,31]. The absence of CME in the present study may reflect reduced IOL tilt, minimized vitreoretinal traction, and limited postoperative inflammation associated with the TST. Additionally, the subconjunctival passage and burial of sutures likely contributed to the absence of suture-related complications, which remain a concern in long-term sutured scleral fixation^[38].

Collectively, these findings suggest that the TST offers a mechanically stable and biologically well-tolerated alternative to existing scleral fixation methods, with a favorable safety profile over extended follow-up.

5. Limitations and Future Directions

This study is limited by its retrospective design, which may introduce selection bias, and by the absence of a control group for direct comparison with alternative scleral-fixation techniques. Although the cohort size was relatively large with follow-up extending to 26 months, longer-term outcomes- particularly regarding suture durability- remain to be determined. Objective assessments of intraocular lens tilt and decentration using anterior segment imaging were not routinely performed, and detailed refractive outcomes were not analyzed.

Future prospective, randomized studies comparing the triangular suture technique with established scleral-fixation methods are warranted. Incorporation of advanced imaging modalities and longer-term follow-up will be essential to further define the biomechanical advantages, refractive stability, and long-term safety of this technique.

6. Conclusion

In this expanded retrospective cohort study, the triangular suture technique demonstrated a high level of safety, efficacy, and long-term stability for scleral-supported intraocular lens implantation in eyes with post-cataract IOL dislocation. The technique resulted in significant and sustained improvements in visual acuity, stable intraocular pressure control, and a low incidence of postoperative complications over a 26-month follow-up period. The mechanically balanced three-point fixation provided excellent IOL centration with minimal tilt and no clinically significant suture-related adverse events.

These findings suggest that the triangular suture technique represents a reliable and effective alternative to conventional sutured and sutureless scleral-fixation methods, particularly

in complex cases lacking capsular support. With its favorable safety profile and reproducible surgical approach, the TST may be considered a valuable option in the armamentarium for secondary intraocular lens fixation. Further prospective comparative studies with longer follow-up are warranted to confirm these results and to define the long-term durability of this technique.

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Ethical Approval

This study was approved by the Institutional Ethics Committee of **Dr. Jawahar Lal Rohatgi Memorial Eye Hospital** and was conducted in accordance with the tenets of the **Declaration of Helsinki**.

Consent

The requirement for written informed consent was waived by the Institutional Ethics Committee due to the retrospective design of the study and the use of anonymized data.

Sources of Funding

No funding was received for this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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