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Functional Outcome Analysis in Arthroscopic Fixation of PCL Avulsion Fractures Using TightRope and Suture Bridge Techniques

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ABSTRACT

Introduction: Many arthroscopic fixation techniques have been described for PCL avulsion fractures, amongst which suture bridge (SBF) and TightRope [Arthrex,Naples,US] fixation (TRF) techniques are commonly employed. However, there is no consensus on the optimal method of fixation. Our study aimed to assess the functional outcome of displaced isolated tibial side PCL avulsion fractures treated with either an arthroscopic suture bridge or TightRope technique.

Materials and methods: Our institution assessed the functional outcome in 34 patients diagnosed with bony PCL avulsion and treated arthroscopically between Jan 1, 2015, and Jun 1, 2021. We used the Modified Lysholm and IKDC scores to assess the functional outcome. Scoring was carried out pre-operatively and post-operatively at 3 months, 6 months, and 12 months.

Results: The study population had a mean age of 34.6 years, with a predominant male (82.6%) patient population. Twenty patients (58.8%) underwent fixation using the suture bridge technique, while the remaining 14 had undergone TightRope-aided fixation. Significant functional outcome improvement in modified Lysholm and IKDC scores was seen after 6 months and 12 months of arthroscopic fixation, irrespective of the technique used. Both techniques led to comparable functional outcomes, suggesting that achieving stable fixation is more critical than the choice of method.

Conclusion: Both techniques are effective for PCL avulsion fractures. In our study, outcomes were independent of patient age, sex, and mechanism of injury; therefore, the choice of fixation was primarily determined by surgeon expertise. This suggests that either technique can be applied across patient groups with comparable results.

Keywords:
PCL avulsion fracture, suture bridge, TightRope, functional outcome, arthroscopic fixation

INTRODUCTION

Posterior cruciate ligament distal avulsion fractures are a relatively uncommon injury[1]. Still, they are seen in increasing frequency in countries where motorcycle accidents are more common[2-4]. Multiple studies have shown that early surgical treatment of displaced bony avulsion of PCL restores knee stability and prevents malunion and non-union[5,6]. Patellofemoral and medial compartment arthritic changes in the long term are also precluded by fixation of PCL avulsion fractures[2,7].

Fixing an acute displaced tibial avulsion fracture, preferably within three weeks, improves anatomical reduction and optimal function[3]. For these fractures, open reduction and stabilisation through a posterior approach is an acceptable form of treatment but is more invasive and has a higher neurovascular risk[2,4,8]. In recent times, the arthroscopic procedure has eclipsed the open approach in popularity because it is less invasive, offers excellent visualisation of the fracture, and allows simultaneous assessment and treatment of other intra-articular pathologies[2,3,4].

Although both Suture Bridge Fixation (SBF) and TightRope [Arthrex,Naples,US] assisted Fixation (TRF) are commonly employed in the surgical management of posterior cruciate ligament (PCL) tibial avulsion fractures, there is no consensus on the optimal fixation method. Several techniques including screw fixation, high-strength sutures, suture bridge constructs, and EndoButton or TightRope-assisted devices have shown favourable clinical outcomes in isolated studies[6,9-12], yet with varied complication rates, technical demands, and biomechanical characteristics. Studies have reported good results using high-strength suture constructs and suture bridge techniques under arthroscopic guidance, emphasising their mechanical stability and reduced implant burden. Others, such as TightRope fixation, highlight minimal invasiveness and all-inside efficiency.

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Despite these advances, recent systematic reviews and comparative studies indicate that no single method consistently outperforms others across all clinical parameters, especially in terms of function, union, and re-operation rates. Given this heterogeneity in evidence and the growing preference for arthroscopic, implant-sparing strategies, there is a compelling need to directly compare widely used techniques like SBF and TRF. This study aims to fill that gap by evaluating their functional outcomes and complication rates, thereby supporting informed, patient-specific surgical decision-making in PCL avulsion fracture management.

MATERIALS AND METHODS

We reviewed the medical records of all patients after obtaining ethical committee approval who underwent arthroscopic fixation of displaced tibial side PCL avulsion fractures performed in our institute from Jan 1, 2015, to Jun 1, 2021. In this period, 44 patients had undergone arthroscopic PCL reattachment. Out of these patients, 37 met our inclusion criteria. Three patients had incomplete records and were not included in the study. We included patients with displaced PCL avulsion fractures with more than 3mm displacement measured on MRI / CT scans and the posterior knee laxity of Grade II or higher. The exclusion criteria were (1) any associated lower limb fracture, and (2) Associated anterior cruciate ligament (ACL) or collateral ligament injuries requiring surgical intervention. Two fellowship-trained Consultant Surgeons with more than ten years of knee surgery experience performed all the surgeries. One surgeon favoured the TightRope approach, whereas the other preferred the Suture Bridge approach. Patient allocation to either the TightRope Fixation (TRF) or Suture Bridge Fixation (SBF) group was based on the operating surgeon's area of expertise. One senior surgeon routinely performed TRF procedures, having considerable experience with that technique, while the other was highly proficient in SBF and consistently used that method. As a result, there was no randomisation, and allocation was determined by the surgeon performing the operation. This approach reflects real-world practice.

All avulsion injuries were confirmed and assessed pre-operatively through radiographs and CT scans (Fig. 1 and 2). Computed tomography scans (CT) were used to determine the fracture fragment's size, comminution, and displacement. MRI was obtained in patients where multi-ligamentous and meniscal injuries were suspected. Patients were examined pre-operatively in the clinic and under anaesthesia using the Lachman's anterior and posterior drawer tests to evaluate for cruciate injury, as well as valgus and varus stress tests both in extension and at 30° of flexion to assess the competence of collateral ligaments. The dial and external rotation recurvatum test were also performed to evaluate posterolateral corner injuries and documents. Patients were assessed pre-operatively using the posterior drawer test, Modified Lysholm[13], and IKDC score[14]. Post-operatively, patients were followed at two weeks, 6 weeks, 3 months, six months and 12 months. Post-operative Lysholm and IKDC scores were documented three, six, and 12 months after the surgery. A fracture was determined as united when no fracture line was visible on the AP and lateral knee radiograph.

For the surgical technique, all the patients in our study were operated on under general anaesthesia and adductor canal block. Prophylactic antibiotics were given before the inflation of the tourniquet. The standard anterolateral and anteromedial portal was used for diagnostic arthroscopy. Through the triangular window between the superior border of ACL and PCL in the intercondylar notch, the posteromedial compartment was visualised while taking care not to injure the cruciate ligaments. The posteromedial and accessory posteromedial portals were established using an outside-in technique under direct visualisation. The superior accessory posteromedial portal was used for visualisation, and the standard posteromedial portal was the working portal.

Partial synovectomy and posterior capsulotomy were performed on either side of the PCL to expose the avulsion fragment's medial, lateral, and inferior margins. The size and morphology of the fragment were assessed, and then the fragment was slowly mobilised. The fracture bed was debrided to enable reduction and fracture healing.

The TightRope technique used when the tibial PCL jig (Arthrex Inc) was passed from the anteromedial portal through the triangular window between the ACL and PCL ligament in the intercondylar notch into the posterior compartment. The tip of the PCL guide was used to reduce the fracture under direct visualisation and stabilise it with a temporary K-wire. The drill sleeve was then placed on the anteromedial cortex of the tibia through the jig. A 2cm longitudinal incision was performed at the sleeve's level over the leg's anteromedial aspect. Under arthroscopic visualisation through the posteromedial portal, a 2.4mm Beath pin was inserted, aiming for the centre of the bony avulsion. The Beath pin position was confirmed under the C-arm to ensure the tunnel placement was at the centre of the bony fragment.

A nitinol wire or PDS was passed through the 2.4mm tunnel and retrieved through the working posteromedial portal using the shuttle relay technique. The tight rope's adjustable loop was elongated adequately to ensure its passage into the tunnel. The tight rope's adjustable loop was then linked to the nitinol wire/PDS and pushed through the bone avulsion. Once the Tight rope's button was positioned over the bone avulsion, an ABS button (Arthrex Inc) of 11mm was introduced over the adjustable loop to sit flush over the

Table I: Distribution of mechanism of injury by surgical technique.

Mechanism of Injury	Suture Bridge Fixation (SBF) [n (%)]	TightRope-assisted Fixation (TRF) [n (%)]	Total [n (%)]	p-value (Chi-square)
Road Traffic Accident (RTA)	18 (58.06%)	13 (41.94%)	31 (91.18%)	0.773
Slip and Fall	2 (66.67%)	1 (33.33%)	3 (8.82%)	
Total	20 (58.82%)	14 (41.18%)	34 (100.00%)	

anteromedial tibial surface. Following the suture button and TightRope placement, traction was applied to the tensioning sutures to accomplish compression and reduction at the fracture site. Finally, the arthroscopic portals and the pretibial incision were closed in a standard manner.

For Suture Bridge Technique, under direct visualisation, the PCL tibial drill guide was used to reduce the avulsion fragment, provisionally fixed with a 1.6mm K-wire. For the passage of the Beath pin, a 2cm longitudinal incision was made over the anteromedial cortex. The PCL drill guide created two diverging bone tunnels from the anterior tibial cortex to the PCL avulsion crater's inferomedial and inferolateral margins. It was ensured that a minimum of 1cm of bone bridge was available between the two tunnels over the anteromedial tibial surface.

A no. 5 Fiber wire suture (Arthrex Inc) was looped around the base of the PCL's bone-ligament junction and delivered through the posteromedial portal on both ends.

A Sliding Knot was used and slid to the base of the PCL ligament to get adequate loop security. Additional half hitches were applied to ensure the suture bridge adequately covered the avulsion fragment. The Fiber Wire ends were delivered to the anterior tibial cortex through the divergent tunnels created using the shuttle relay technique. With the knee bent 90°, each end of the No.5 Fiber wire suture was pulled and knotted over the bone bridge in the tibial cortex.
All patients in both groups followed a standardised post-operative rehabilitation protocol. The operated knee was immobilised in an extension knee brace with posterior tibial support for the first two weeks. Isometric quadriceps exercises were initiated on post-operative day one. At the end of two weeks, the long knee brace was replaced with a range-of-motion (ROM) brace. Passive knee bending in the prone position was started at two weeks and continued until six weeks. From six weeks onward, actively assisted knee mobilisation in the supine and high sitting positions was initiated, aiming to achieve full range of motion by three months. Toe-touch weight-bearing was permitted at six weeks, progressing to full weight-bearing walking by three months. Normal ambulation without a brace was resumed after radiographic confirmation of fracture union. Additionally, partial weight-bearing was initiated as early as two weeks in select cases, with progression individualised based on pain tolerance and radiological healing. This entire rehabilitation protocol was applied uniformly to both the Suture Bridge Fixation (SBF) and TightRope-assisted Fixation (TRF) groups. All the patients underwent clinical and radiological assessment at 6 weeks, 3 months, 6 months, and 12 months. The fracture was considered united when there was the absence of a visible fracture line on plain radiographs or if the fracture was clinically stable. All the patients were examined by an independent senior resident who was not involved in the surgeries. Modified Lysholm and IKDC scoring was done at 3 months, 6 months, and 12 months. A manual posterior drawer test was done at three months to assess the knee stability using side-to-side difference as a benchmark for ligament healing. Knee radiographs in the standing anteroposterior and lateral views were examined for fracture union by the operating surgeon. The outcome at 6 months and 12 months follow-up was used for comparative analysis between the two groups.

We analysed the data using the statistical software IBM-SPSS version 21.0 [IBM-SPSS Science Inc., Chicago, IL]. We presented mean and standard deviation for normally distributed data and median and interquartile range (IQR) values for skewed data. We presented frequency and percentage values for categorical data. Normally distributed data were compared using Repeated measure ANOVA, and we used the Kruskal-Wallis non-parametric test for skewed data. Categorical variables were compared using the Pearson chi-square test. For all the tests, a p-value <0.05 was considered statistically significant.

RESULTS

A total of 44 patients with displaced PCL avulsion fractures were operated on during the study period (2015 - 2021). Seven patients who had other fractures and multi-ligamentous injuries requiring additional procedures were excluded from the study group. Three patients were lost to follow-up, and the remaining 34 were included in the study. Twenty patients underwent suture bridge fixation, and 14 patients underwent TightRope-aided fixation.

The patients comprised 28 men and six women, with the mean ± SD age of the study population being 34.6±4.7 years. Age (p=0.016) for modified Lysholm and (p=0.184) for

Fig. 1: Pre-operative radiograph showing Displaced PCL avulsion fracture.

Fig. 2: Pre-operative radiograph showing Displaced PCL avulsion fracture.

Fig. 3: Fracture fixed by suture bridge technique. Post-operative radiograph taken at six months shows fracture union.

Fig. 4: Fracture fixed by TightRope technique. Post-operative radiograph taken at six months shows fracture union.

IKDC, and gender (p=0.532) for modified Lysholm and (p=0.678) for IKDC) of the study population had no association with the functional outcome. The injury mechanisms included 31 road traffic accidents (18 fixed using the suture bridge technique and 13 fixed using the TightRope technique) and three slip and fall with direct knee impact injuries (2 fixed using the suture bridge and one fixed using the TightRope technique). The mode of injury had no association with the functional outcome. About 56% of the patients had an injury to the left knee, and the side of the injury also had no association with the functional outcome.

Table I presents the distribution of the mechanism of injury across the two surgical techniques used. Road Traffic Accidents (RTA) were the predominant cause of injury in both groups, accounting for 91.18% of cases overall, with 58.06% managed using Suture Bridge Fixation (SBF) and 41.94% with TightRope-assisted Fixation (TRF). Slip and fall injuries were less common, comprising 8.82% of the cases. The distribution of injury mechanisms between the two surgical techniques was statistically comparable, with no significant difference (p=0.773), suggesting that the choice of surgical method was not influenced by the mode of injury.

Pre-operatively, 20 patients (58.8%) had grade 3 posterior drawer test while the remaining had grade 2 laxity on posterior drawer assessment. At 3 months of the post-operative period, the Posterior drawer assessment was Grade 1 in 9 patients (26.5%), and the remaining patients had negative posterior drawer tests. Posterior drawer test at 1 year follow-up period showed none of the patients had more than grade 1 Laxity in both study groups. However, statistical analysis was not done for laxity as objective testing was not done, and subjective laxity testing could not be standardised.

Modified Lysholm score at 12 months was excellent in 22 patients (64.7%), good in 9 patients (26.5%), fair in 3 patients (8.8%), and abnormal in the remaining three patients. On a pairwise comparison with the pre-operative score, the Modified Lysholm score at 6 and 12 months showed significant improvement. The IKDC score at 12 months was abnormal in 3 patients (8.8%), near normal in 9 patients (26.5%), and regular in 22 patients (64.7%). On a pairwise comparison with the pre-operative score, the IKDC score at 6 and 12 months showed significant improvement. The Modified Lysholm and IKDC scores were improved in the study population, irrespective of the fixation technique used.

The disappearance of the fracture line in AP and lateral knee radiographs assessed the radiological union (Fig. 3 and 4). The radiological union was visible in both groups of patients following the surgery. The mean time to radiological union in weeks 12.4 ± 1.7 weeks overall. On subgroup analysis, patients in the SBF group achieved union at a mean of 12.6 ± 1.8 weeks, while those in the TRF group united at 12.2 ± 1.5 weeks; this difference was not statistically significant (p=0.41). All patients in both groups achieved union, and no cases of nonunion were observed. The time to radiological union was not significantly associated with the Modified Lysholm score (p=0.624) or the IKDC score (0.516). None of the patients had non-union of the avulsed fragment. The time to radiological union was not significantly associated with the Modified Lysholm score (p=0.624) or the IKDC score (0.516).

Overall, three meniscal injuries were noted in both groups. All were medial meniscus longitudinal tears. Two meniscal injuries were present in the suture bridge group, of which one underwent repair while the other patient had partial medial meniscectomy. The third patient was in the TightRope group and underwent repair. All three patients didn't have any meniscal symptoms at one-year follow-up.

There were no neurovascular injuries, surgical site infections, or compartment syndrome associated with surgery. No implant failure was noted, and none of the patients in both groups required revision surgery. In addition, 12 patients had Grade I Laxity at the final follow-up, 7 in the suture bridge group, and 5 in the TightRope technique group, but they didn't have functional deficits due to the laxity and were satisfied with the surgery.

One patient in the suture bridge group developed post-operative stiffness. The patient had a concomitant meniscal repair, so the range of motion was limited in the initial rehabilitation phase. This patient required manipulation under anaesthesia six months following surgery to restore range of motion. Two patients developed paraesthesia over the anterolateral aspect of the tibia due to the longitudinal incision, but symptomatic relief was noticed at the final follow-up.

DISCUSSION

From open surgery to minimally invasive arthroscopic surgery, PCL avulsion reattachment procedures have come a long way to where they are now. The risk of neurovascular injury with a direct posterior approach led to the popularity of the posteromedial approach. Even though it was a safe approach, the difficulty of exposing the lateral edge of the PCL avulsion and placing the compression screw perpendicularly was a concern. All these difficulties can be avoided in arthroscopic reattachment of the PCL avulsion fracture[2-4].

Numerous arthroscopic techniques and modifications are available in the literature that are suitable for excellent outcomes. The arthroscopic suture bridge technique has been widely reported in the literature with numerous changes[3,5,6,9,11,12]. The recent advances in instrumentation and

arthroscopic surgery have led to suspensory devices for the fixation of fragments, given their superior biomechanical properties and uniform fracture compression[10,15-18]. The suture bridge and suspensory fixation have been the two most commonly reported techniques in the past decade. However, there is no consensus on the optimum method of fixation.

The TightRope device[15-17,19] has recently gained popularity and has been well accepted for reconstructing the ACL, achieving solid fixation with good clinical results. In our technique, contrary to the PCL techniques described by others (making a 4mm tunnel)[15,17], a 2.4mm tunnel was created through the avulsion fracture. We believe that smaller tunnels can very well prevent iatrogenic fracture of the avulsion fracture. Cinching sutures were passed through the tunnel, seating the TightRope button over the avulsion fragment through the PM portal. The advantage of the TightRope technique is that we do not need to aggressively debride the bony fracture bed; hence, the fracture fragment's blood supply may not be disturbed. In addition, the cinching mechanism in the tight rope allows axial compression across the fracture and achieves fixation strength similar to antegrade screw fixation[20].

The TightRope button technique is not preferred in the case of severely comminuted PCL avulsion fractures as it does not provide adequate compression. In our department, PCL avulsion fractures with comminution were all treated with the Suture Bridge technique. Eight patients with severe comminution underwent suture bridge fixation, and in our opinion, including these patients would have introduced bias in the study group, so only patients with PCL avulsion fractures without comminution were included in our study for comparison between two techniques.

In our study, both the SBF and TRF groups demonstrated substantial post-operative improvement in Modified Lysholm and IKDC scores. At 12 months, the mean Lysholm score was 90.4 ± 7.2 in the TRF group and 90.9 ± 6.8 in the SBF group. The corresponding IKDC scores were 91.3 ± 7.6 and 89.5 ± 7.5, respectively. These differences were not statistically significant. Importantly, the magnitude of improvement in both groups exceeded the minimal clinically important difference (MCID) of approximately 10 points reported for these scoring systems, indicating that the observed changes were clinically meaningful. By the 12-month follow-up, most patients in both groups achieved IKDC grades A or B and Lysholm scores in the excellent or good range, reflecting substantial functional recovery and favorable patient-reported outcomes.

Gwinner *et al*[16] reported good outcomes in four patients treated with the TightRope technique, with a mean subjective IKDC score of 72.6% (±9.9) and a mean Lysholm score of 82(±6.9). In Our study using the TightRope technique, the clinical outcome at 1-year post-op had an IKDC mean subjective score of 91.3 (± 7.6) and a mean Lysholm score of 90.4 (± 7.2).

The suture bridge technique has a significant advantage[5,6], allowing near anatomic reduction, even if the fragment is comminuted or small. It provides for uniform compression along the fracture. In addition, there is no fear of iatrogenic fragment comminution as there is no drilling through the fracture fragment, and the suture limbs are taken through the osteoligamentous junction. In the suture bridge technique, a double tibial tunnel was used to avoid additional fixation devices. Since the tibial tunnels were made below the fracture bed, this technique requires additional exposure and tunnel placement time. Hence, the suture bridge technique requires more operative time and is surgically more demanding than the tight rope technique.

Jung-Ro Yoon *et al* [11] in their study on arthroscopic suture bridge technique with multiple crossover ties for fixation, reported good clinical-radiological outcomes, including satisfactory stability and fracture union even in comminuted fractures. The mean Lysholm score was 90 ± 5, and the IKDC grade was A (standard) in ten patients (56%), B (nearly standard) in seven (39%), and C (abnormal) in one (5%). In our study, results in the suture bridge technique, the mean Lysholm score was 90.9 ± 6.8, and an IKDC mean subjective score of 89.5 ± (7.5) comparable to the literature studies[5,6].

In our study, the mean operative time was not formally recorded, but based on operative logs and intra-operative notes, both procedures were comparable in duration. While Suture Bridge Fixation (SBF) may be slightly more technically demanding due to suture passage through bone tunnels and anchor placement, the surgeons performing these procedures were highly experienced in their respective techniques. Each technique was performed by a senior consultant with consistent expertise, minimising variability due to the learning curve. This surgeon-specific expertise may have optimised outcomes in both groups but also introduces a confounding factor related to operator dependency. However, the comparable complication rates and functional outcomes suggest that, when performed by experienced hands, both techniques are equally effective, and no bias from technical complexity or operative time likely influenced the final results.

Sawyer *et al*[21] compared three techniques of fixation, namely screw fixation, suture fixation, and suture bridge technique fixation and their results showed the superiority of the suture bridge technique given aggressive rehabilitation protocol and rapid progressive weight-bearing. Still, in our series, we found no difference between the two techniques of fixation used.

When comparing the Lysholm and IKDC scores within the groups (SBF, TRF) at three months, six months, and one year, it was observed that the scores improved from three months to six months. Until union, all patients were protected with a range-of-motion brace (up to three months). The patients were weaned off the range-of-motion brace, and rapid rehabilitation began after the union was confirmed as clinically stable. This could explain the significant score improvement in these two groups by six months.

At one year follow-up, the TightRope group had higher Lysholm and IKDC scores than the suture bridge group, but the difference observed was not statistically significant.

In their systematic review, Song *et al*[4] found that arthrofibrosis is the main complication in managing PCL avulsion fracture both in open and arthroscopic fixation techniques. They found it to vary between 6.3% to 35.7% among the arthroscopic group. They found that the limitation of motion was more in the arthroscopic approach group. They postulated that prolonged immobilisation coupled with concomitant injuries requiring management led to arthrofibrosis. In our study, only one patient in the suture bridge group developed arthrofibrosis. We feel this was due to prolonged immobilisation from meniscus repair requiring mobilisation under anaesthesia. No other patient had restrictions in their range of motion at follow-up. In most cases, we achieved good ROM due to stable fixation and early and focused rehabilitation.

Compared to open techniques, arthroscopic fixation of PCL avulsion has the advantage of treating concomitant meniscus, ligament, and chondral injuries. The TightRope fixation technique provides good fixation with axial compression across the fracture, similar to open antegrade screw fixation. Suture bridge fixation is the versatile workhorse of all arthroscopic methods, which can be used for all fracture types with the advantage of no intra-articular implant. Arthroscopic fixation by either technique results in anatomic restoration and bony union of the fracture with minimum morbidity and good midterm functional outcome.

Both SBF and TRF techniques are arthroscopically performed and require a solid understanding of knee arthroscopy and posterior compartment access. However, the learning curve may differ between the two. TightRope-assisted fixation (TRF) involves the use of commercially available suspensory fixation devices and can be standardised more easily, potentially making it more reproducible for early-career surgeons familiar with implant systems. On the other hand, the Suture Bridge Fixation (SBF) technique, though cost-effective, demands advanced arthroscopic knot-tying skills and precise suture passage, particularly in the confined posterior knee compartment. This makes SBF somewhat more technically demanding and associated with a steeper learning curve. In our study, the procedures were performed by surgeons proficient in their respective techniques, which may have mitigated outcome disparities related to surgeon experience. Nonetheless, the learning curve should be considered when selecting a technique, especially in lower-volume centres or training settings.

The absence of a statistically significant difference in functional outcomes between Suture Bridge Fixation (SBF) and TightRope-assisted Fixation (TRF) in our study may be attributed to several factors. Both techniques are designed to provide stable fixation of the posterior cruciate ligament (PCL) avulsion fragment while avoiding hardware insertion at the fracture site, thus facilitating biological healing. The core principle in managing these injuries is achieving anatomical reduction and secure fixation—both of which were consistently attained in our cohort, irrespective of the fixation method. Additionally, the procedures were performed by senior surgeons with expertise in their respective techniques, which likely minimised technical variability and contributed to uniformly good outcomes. The homogeneity of our patient population—excluding comminuted fractures and multiligamentous injuries—may have further contributed to the equivalence in results. Finally, while our sample size was adequately powered for primary endpoints, subtle differences may not have reached statistical significance due to inherent limitations of retrospective analysis and relatively small group sizes.

Post-operative rehabilitation plays a pivotal role in determining functional outcomes following PCL avulsion fracture fixation. Early knee mobilisation, quadriceps strengthening, and protected weight-bearing are essential components that must be tailored to the stability of the fixation construct. In both SBF and TRF techniques used in this study, fixation was found to be robust enough to allow for early controlled range of motion, typically beginning within two weeks post-operatively. Progressive weight-bearing was initiated by six weeks, with a structured physiotherapy program extending over three to six months. The success of either technique is, therefore, partly dependent on adherence to a standardised rehabilitation protocol. Moreover, rehabilitation may help minimise joint stiffness and muscle atrophy, which are particularly relevant in this patient population. Importantly, since neither technique showed statistically superior outcomes, it is likely that consistent post-operative rehabilitation contributed to the comparable functional results observed.

This study is limited by its retrospective design and relatively small sample size, which reflects the rarity of PCL avulsion fractures. The exclusion of patients with comminuted fractures and concomitant ligament injuries requiring surgical management was intended to reduce confounding, but it further reduced the sample size and may affect generalisability. Another notable limitation is the non-

randomised allocation of patients. Treatment assignment was based on surgeon expertise—one senior author consistently performed TightRope Fixation (TRF) and the other Suture Bridge Fixation (SBF). While this mirrors real-world clinical practice and ensured technical proficiency, it may introduce selection bias. However, given that both surgeons were equally experienced in their respective techniques and outcomes were comparable, we believe this impact was minimal. Another limitation of this study is the reliance on subjective assessments, including clinical examination (e.g., posterior drawer test) and patient-reported outcome measures (IKDC and Lysholm scores). These tools, while widely used, are prone to inter-observer variability and potential bias in the absence of objective laxity measurements such as Telos stress radiographs or instrumented testing. Although experienced clinicians conducted the assessments in a standardised fashion, this subjectivity may have influenced the interpretation of functional outcomes. Future studies incorporating objective laxity measurements are necessary to provide a more robust assessment of post-operative stability. Future randomised studies with larger cohorts and objective functional evaluation are warranted to validate these findings.

CONCLUSION

In conclusion, both Suture Bridge Fixation and TightRope-assisted Fixation provided comparable functional outcomes and complication rates in the treatment of PCL avulsion fractures. These findings suggest that surgical decision-making can be tailored based on surgeon expertise, patient anatomy, and intra-operative considerations, rather than a strict preference for one technique over the other. However, future studies with larger sample sizes and prospective randomised designs are warranted to further validate these findings and refine treatment algorithms for these complex injuries.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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