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Comparison of three surgical methods for displaced posterior cruciate ligament tibial insertion avulsion fractures: a retrospective study

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Abstract

Background The aim of this study was to evaluate the clinical outcomes of three surgical methods, three types of arthroscopic suture fixation, suspension fixation with EndoButton, and open screw fixation, in the treatment of displaced posterior cruciate ligament tibial insertion avulsion fractures.

Methods A retrospective analysis of the clinical data of 104 patients with posterior cruciate ligament avulsion fractures between 2010 and 2023 was performed. The patients were divided into three groups according to the surgical approach used: suture fixation in Group A (24 patients), suspension fixation with EndoButton in Group B (37 patients), and hollow screw fixation in Group C (43 patients). The Lysholm score, International Knee Documentation Committee (IKDC) score, Tegner activity score, and postoperative imaging findings of all patients were collected. The final follow-up data were used to compare the differences among the three groups.

Results There was no statistically significant difference in the general information of the three groups of patients. Among the 104 patients, the mean postoperative Lysholm score was 92.9 (CI, 91.0-94.8) in Group A, 93.4 (CI, 92.3–94.6) in Group B, and 93.5 (CI, 92.6–94.4) in Group C. Postoperative IKDC subjective assessment of knee function was considered normal or near normal in more than 95% of the patients in all three groups. More than 93% of the patients in all three groups did not have severe abnormalities in knee range of motion. The mean postoperative Tegner activity score was 6.7 (CI, 6.3–7.1) in Group A, 7.0 (CI, 6.7–7.3) in Group B, and 6.9 (CI, 6.6–7.1) in Group C. Imaging at 3 months after surgery revealed bone healing, and no serious postoperative complications were found in any of the three groups.

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Conclusion All three treatments yielded good clinical results and imaging healing. In particular, arthroscopic suspension fixation with EndoButton is recommended as the preferred treatment because of its low invasiveness, good mechanical properties and low complication rate.

Keywords Avulsion fractures, EndoButton, Hollow screw, Suture, Posterior cruciate ligament

Introduction

The posterior cruciate ligament (PCL), an important component of the knee joint, extends from the medial femoral condyle to the posterior slope of the tibial plateau [1]. Previous scholars generally believe that the different bundle branches of the PCL function differently, but recent reports indicate that the double bundle branches of the PCL act in a codominant manner [2]. The primary function of the PCL is to prevent posterior translation and excessive external rotation of the tibia relative to the femur [3, 4]. In knee replacements, CR-type prostheses are used to preserve this important structure [5]. In Europe and the United States, the incidence of PCL injuries is approximately 3–38% [6, 7], and in Asia, the rate is expected to be higher because of the popularity of electric vehicles.

PCL injuries may result from high-energy trauma, such as traffic accidents and sports injuries, and are often accompanied by multiple injuries [8]. Posterior cruciate ligament avulsion fracture (PCLA) is a special type of PCL injury. The PCL tightens when the knee flexes, and direct trauma to the anterior space results in a PCLA [9]. PCLA is frequently associated with injuries to the PCL. For grade I and II laxity, conservative treatment is typically employed. In contrast, early surgical intervention is more effective for grade III interstitial injuries [10].

During the past two decades, remarkable progress has been made in the diagnosis and treatment of PCLA [11]. The current classification system originates from MH Meyers and FM McKeever's classification of intercondylar crest fractures of the tibia [12], which can be divided into three types: undisplaced type I, mildly displaced type II, and displaced type III [13]. The open fixation approach, simplified or modified by Burks and Schaffer [14], was once favored by scholars because surgeons could directly inspect the avulsed bone mass and facilitate fixation. However, the popliteal artery is in close proximity to the tibial insertion of the PCL, presenting a challenge for surgeons [15]. Because arthroscopic technology has been further advanced, leading to its minimal invasiveness and consequent lower risk of complications, its efficacy has become comparable to that of open surgery, leading to its emergence as a suitable treatment option. When discussing treatment options for PCLA, although arthroscopic suture fixation [16–18], suspension fixation with EndoButton [19–21] hollow screw [22, 23] and Kirschner wire fixation [24] have shown good clinical results, these methods are still controversial and frequently discussed.

The main objective of this retrospective study was to compare the clinical effects of arthroscopic suture fixation, suspension fixation with EndoButton, and hollow screw fixation in the treatment of PCLA, with the aim of providing a valuable clinical reference for treatment.

Methods

This retrospective study included 132 patients who underwent surgery for posterior cruciate ligament avulsion fractures between February 2010 and August 2023. The study was approved by the hospital ethics committee, and all patients signed an informed consent form.

Inclusion criteria

1. The diagnosis of PCLA was confirmed by imaging data, and the displacement distance of the avulsion bone fragments was more than 5 mm.
2. The patient agreed and was able to complete the surgical treatment and follow-up.

Exclusion criteria

1. Patients with combined anterior cruciate ligament injuries.
2. Patients with a tibial plateau fracture.
3. Patient with Grade III lateral collateral ligament injury (complete tear).
4. Patients with posterior cruciate ligament body injury (e.g., tear).
5. Patients with severe systemic diseases or other medical conditions that may interfere with surgical treatment or postoperative recovery.

Because combined meniscal injuries are relatively common in patients with PCLA and would not have significantly affected the primary purpose of this study, patients with these injuries were not excluded. On the basis of the above criteria, 132 patients were initially included, but 28 patients were lost to follow-up; thus, the final sample analyzed included 104 patients. The demographics of the study patients are detailed in Table 1. The patients were divided into three groups according to the surgical method used: Group A, suture fixation (24 patients); Group B, suspension fixation with EndoButton

Table 1 Patient demographics of the three groups

	Group A($n=24$)	Group B($n=37$)	Group C($n=43$)	*P*-value
Sex (M/F), n	13/11	26/11	29/14	0.406
Age mean ± SD (range), y	43.3 ± 15.4(21–70)	40.0 ± 15.3(10–66)	41.8 ± 13.6(12–66)	0.666
Time from injury to surgery, mean ± SD, days	9.1 ± 4.4	10.0 ± 4.4	9.1 ± 4.6	0.608
Surgical time, mean ± SD, min	105.4 ± 26.0	87.0 ± 23.9	131.7 ± 43.8	AB,<0.05
				AC,<0.01
				BC,<0.01
Postoperative length of stay, mean ± SD, day	5.2 ± 3.2	4.3 ± 1.6	9.7 ± 6.0	AB,=0.419
				AC,<0.01
				BC,<0.01
Degree of displaced avulsed bone fragment, mean ± SD, mm	7.3 ± 1.3	7.0 ± 1.4	6.9 ± 1.3	0.675
Degree of comminution of avulsed bone fragments, number of fragments, n				0.211
1	17	16	28	
2	6	18	13	
3	1	3	2	
Manner of injury, n				
Vehicle accident	11	21	24	
Fall	10	14	16	
Sports injury	3	2	3	
Combined injury, n				
MCL (Grade I, II)	1	2	2	
LCL (Grade I, II)	0	0	2	
Meniscus	3	5	6	

SD: Standard deviation; MCL: Medial collateral ligament; LCL: Lateral collateral ligament; P-value: Overall comparisons were performed using one-way ANOVA or chi-square test, while specific group comparisons (AB, AC, BC) were analyzed with post-hoc tests

(37 patients); and Group C, hollow screw fixation (43 patients).

Surgical technique

All patients underwent surgery under general anesthesia. First, a drawer test was performed on the affected knee to assess laxity, and the results were recorded. All patients were given a preop tourniquet.

Arthroscopic surgical techniques

The patient is placed in the supine position, and after establishing a conventional anterolateral and anteromedial portal, the joint is examined, and the patient with combined meniscal injury is treated. A posterior medial portal was subsequently established to obtain a better view of the posterior cruciate ligament avulsion site and room for operation. A 3 cm long incision was made anteromedially in the tibial tuberosity to create a tibial tunnel.

Suture fixation technique

A shaver was used to remove soft tissue and bone fragments to expose the avulsion fragment and bone bed. The PCL guide is positioned 2 mm medial–lateral to the avulsion fragment. Two tibial tunnels are created by drilling from the anterior tibia into the posterior slope of the tibia using a 2-mm Kirschner wire and expanding the hole with a 3.4-mm cannulated drill. A double-stranded No. 2 Ethibond suture is passed through one tunnel, looped around the PCL root, crossed, and pulled through the contralateral tunnel. Using the PDS II high-strength thread as a guide, the Ethibond suture is pushed from the anterior tibial tunnel into the posterior medial compartment, and the Ethibond suture is pulled out of the tibial tunnel. With the knee flexed at 90°, the suture is pulled through the button anteriorly at the tibia, and the tail end of the suture is fixed. The posterior drawer test is performed again to check for knee laxity. A schematic diagram of the procedure is shown in Fig. 1.

Suspension fixation technique

The avulsion fracture site was removed with a shaver to expose the bone fragments and bed. A PCL guide was inserted, and its anterior end was used to adjust the avulsion of the bone fragments to achieve anatomical repositioning. A hole was punched from the anterior tibia toward the avulsion fragments using a 2 mm Kirschner wire. The tunnel is expanded to 4.5 mm using a cannulated drill. A PDS II wire guides the EndoButton through the tunnel into the posterior compartment, and then the EndoButton is secured over the avulsion fragments. With the knee flexed at 90°, the loop is tensioned to compress the fragment (Fig. 2). An inference screw is then inserted into the tibial tunnel. The end of the loop can be refixed to the anterior tibial cortical bone using the inserted screw for secondary fixation. A posterior drawer test was

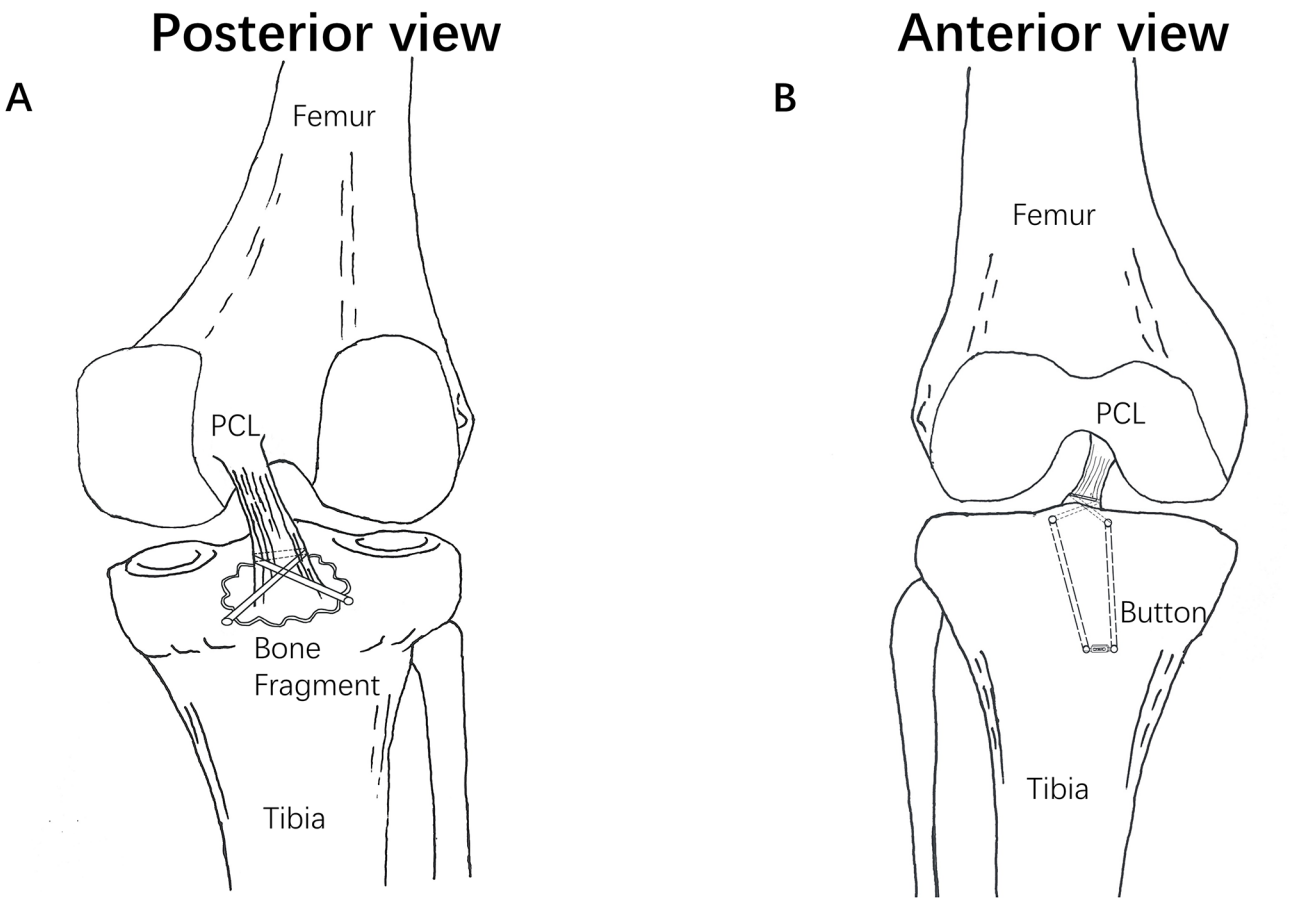

Fig. 1 Schematic diagram of suture fixation procedure **A**: A high strength suture was passed through the PCL and wrapped in a "figure of eight" at the distal end of the PCL. **B**: The high-strength suture was then pulled anteriorly out of the tibia through both tibial tunnels and secured by tying it through the button

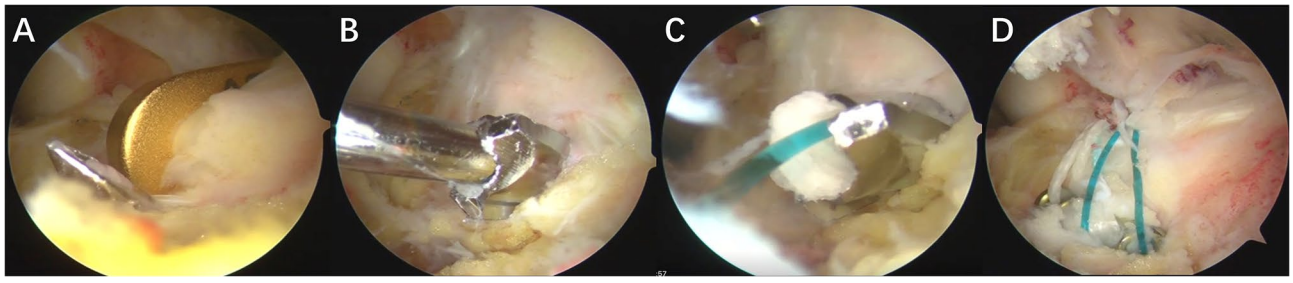

Fig. 2 **A**: The Kirschner wire was inserted anteriorly through the tibia and through the avulsion fragment under the guidance of the PCL guide. **B**: Expand the hole along the Kirschner wire with a 4.5 mm cannulated drill. **C**: The PDS wire was used as a guide wire and transmitted into the joint cavity by the cannulated drill. **D**: The PDS guidewire was passed through the button loop from the anterolateral approach to the top of the avulsion fragment and compressed

performed again before suturing. A schematic diagram of the procedure is shown in Fig. 3.

Open fixation surgical technique

The patient is positioned prone for a posterior approach. The skin incision is an inverted 'L' shape, starting along the back of the knee across the popliteal fossa and then curving downward along the medial head of the gastrocnemius muscle. Medial retraction of the semimembranosus and gastrocnemius and lateral retraction of the biceps femoris and neurovascular bundle expose the posterior capsule. The avulsion fracture site was identified, and the fragment was temporarily stabilized with a 2.0 mm Kirschner wire. Definitive fixation is achieved using a hollow screw directed toward the tibial tuberosity (Fig. 4). Multiple screws may be used for ≤ 3 large

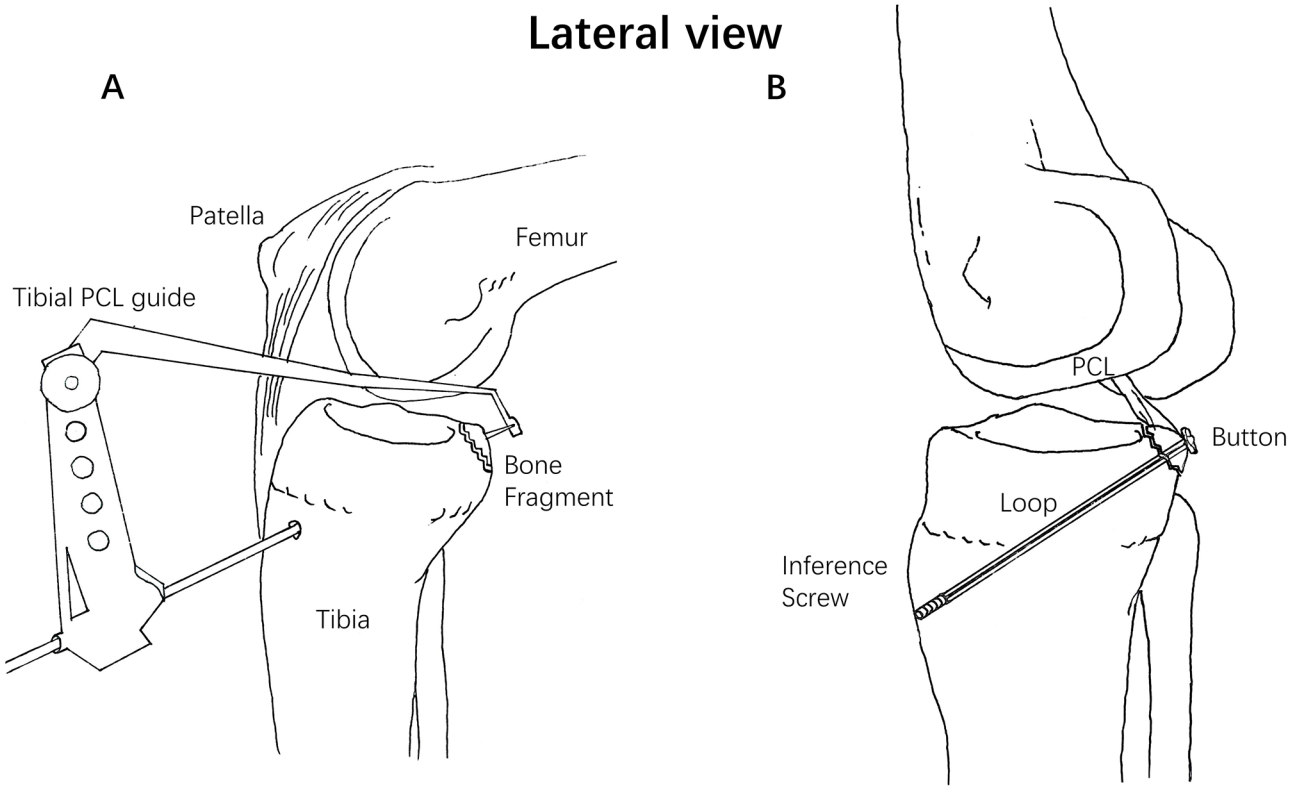

Fig. 3 Schematic diagram of suspension fixation procedure **A**: A Kirschner wire was passed from the anterior tibia through the center of the avulsion fragment with the assistance of the PCL guide. **B**: The EnduButton was adjusted in position and the avulsion fragment was compressed. The loop was pulled from the anterior tibia and then the tail of the loop was secured to the bone cortex with an interference screw

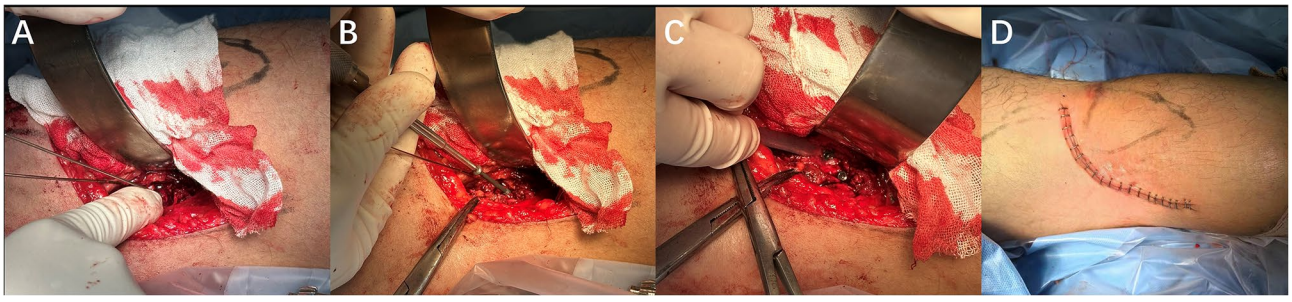

Fig. 4 **A**: A Kirschner wire was drilled into the tibial insertion of the posterior cruciate ligament. **B**: A hollow screw was screwed into the tibia along the Kirschner wire. **C**: The hollow screws fixed the avulsion fragments. **D**: The inverted "L" shaped incision was sutured

fragments; smaller fragments are fixed with anchors or sutures. After repositioning and fixation, a posterior drawer test is performed to assess the degree of ligamentous laxity. A schematic diagram of the procedure is shown in Fig. 5.

Postoperative rehabilitation

All three groups of patients wore a brace for 8 weeks. Patients were encouraged to perform only quadriceps isometric contraction exercises and ankle pump exercises from the first postoperative day to the first postoperative week. From the second to the sixth postoperative week, passive knee flexion exercises were performed, starting at 30° and increasing by 15° each week. Active knee flexion and extension exercises were started in the seventh postoperative week. Starting at six weeks postoperatively, the patients were allowed to walk with crutches and were capable of touchdown weight bearing (TDWB). Weight-bearing was gradually increased during week 7, and full weight-bearing was allowed at week 8. All patients returned to the hospital at 6 weeks, 3 months, 6 months, and 1 year postoperatively for follow-up examinations, and their recovery was assessed by physical examination of cruciate ligament laxity, Lysholm and IKDC rating scales, and imaging examinations.

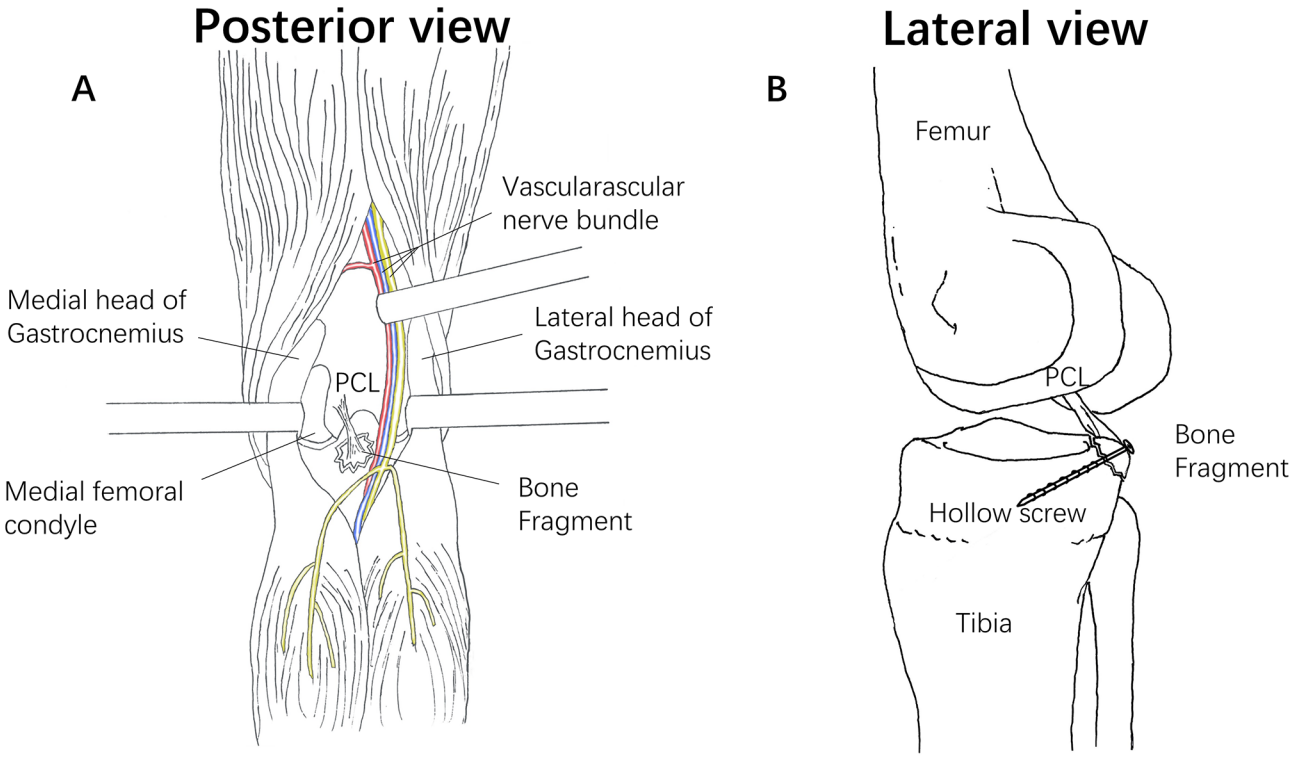

Fig. 5 Schematic diagram of the hollow screw fixation procedure **A**: The medial head of the gastrocnemius muscle was retracted medially, while the vascular nerve bundle and the lateral head of the gastrocnemius muscle were retracted laterally, thereby exposing the avulsion fragment following the incision of the joint capsule. **B**: Under the guidance of a Kirschner wire, a hollow screw was inserted into the avulsion fragment, oriented towards the tibial tuberosity

Follow-up and assessment indicators

Comprehensive preoperative and postoperative imaging assessments were performed. Preoperative functional metrics (Lysholm scores, IKDC subjective scores, range of motion) were systematically recorded. Monthly follow-ups encompassing clinical evaluation and radiographic monitoring (X-rays assessing alignment, joint space, and degenerative changes) continued until fracture healing, defined as the radiographic absence of fracture lines. Longitudinal outcome measurements utilizing standardized scales (Lysholm, Tegner, IKDC) were conducted throughout the follow-up period. The final follow-up data served as the basis for the intergroup comparative analysis.

Statistical analysis

Statistical analyses were performed in SPSS (version 26.0; SPSS, Chicago, IL). Assessment of normality for each of the three datasets. Normally distributed continuous variables were subjected to one-way ANOVA with post hoc multiple comparisons, whereas nonnormally distributed data were analyzed using Wilcoxon signed-rank tests. Categorical variables were assessed via chi-square tests. A post hoc power analysis (G*Power v3.1.9.7) performed by selecting the main postoperative outcome metrics (Tegner scores) revealed that the study cohort ($N = 104$) had high statistical power ($1\text{-}\beta = 0.77$) and a moderate effect size (Cohen's $f = 0.146$) at $\alpha = 0.05$ (two-tailed), confirming the robustness of the analytic approach.

Results

In this study, a total of 132 patients with PCLA met the inclusion criteria, with 28 patients lost to follow-up, leaving 104 patients for final analysis. The cohort comprised 68 males and 36 females (mean age: 41.5 ± 14.5 years; range: 10–70 years), divided into three surgical groups: Group A (arthroscopic suture fixation, $n = 24$, typical case Fig. 6), Group B (arthroscopic EndoButton fixation, $n = 37$, typical case Fig. 7), and Group C (hollow screw fixation, $n = 43$, typical case Fig. 8). The demographic and injury mechanism distributions are summarized in Table 1. The mean injury-to-surgery interval was comparable across groups (Group A: 9.1 ± 4.4 days; Group B: 10.0 ± 4.4 days; Group C: 9.1 ± 4.6 days), with follow-up averaging 52.2 ± 40.2 months (range: 12–170 months). No significant differences were observed in the degree of displaced avulsed bone fragments among the three groups (Group A: 7.3 ± 1.3 mm; Group B: 7.0 ± 1.4 mm; Group

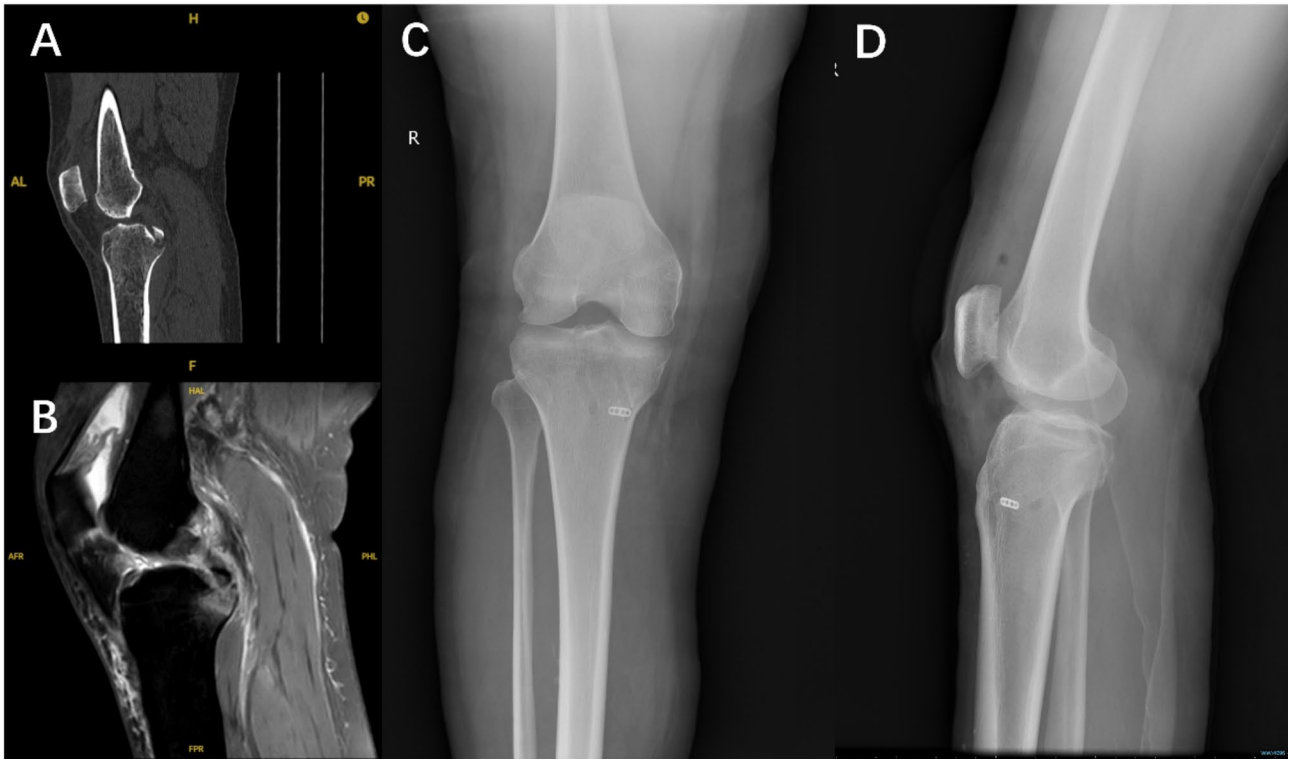

Fig. 6 Typical cases in Group **A** Female, 57 years old, vehicle accident. **A**, **B**: Preoperative CT and MRI showing displaced PCLA, MRI suggesting moderate laxity of the PCL. **C**, **D**: 3-month postoperative radiographs

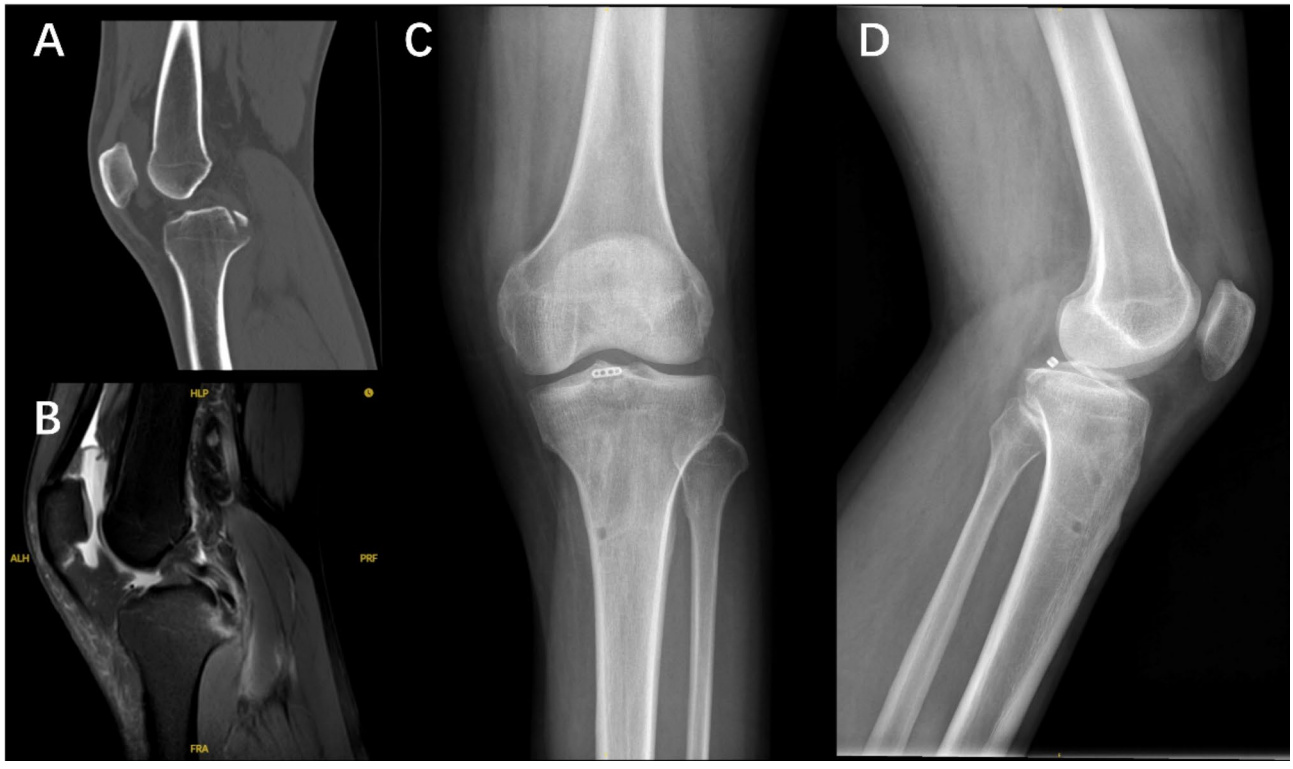

Fig. 7 Typical cases in Group B Male, 33 years old, fall. **A**, **B**: Preoperative CT and MRI showing displaced PCLA, MRI suggesting moderate laxity of the PCL. **C**, **D**: 3-month postoperative radiographs

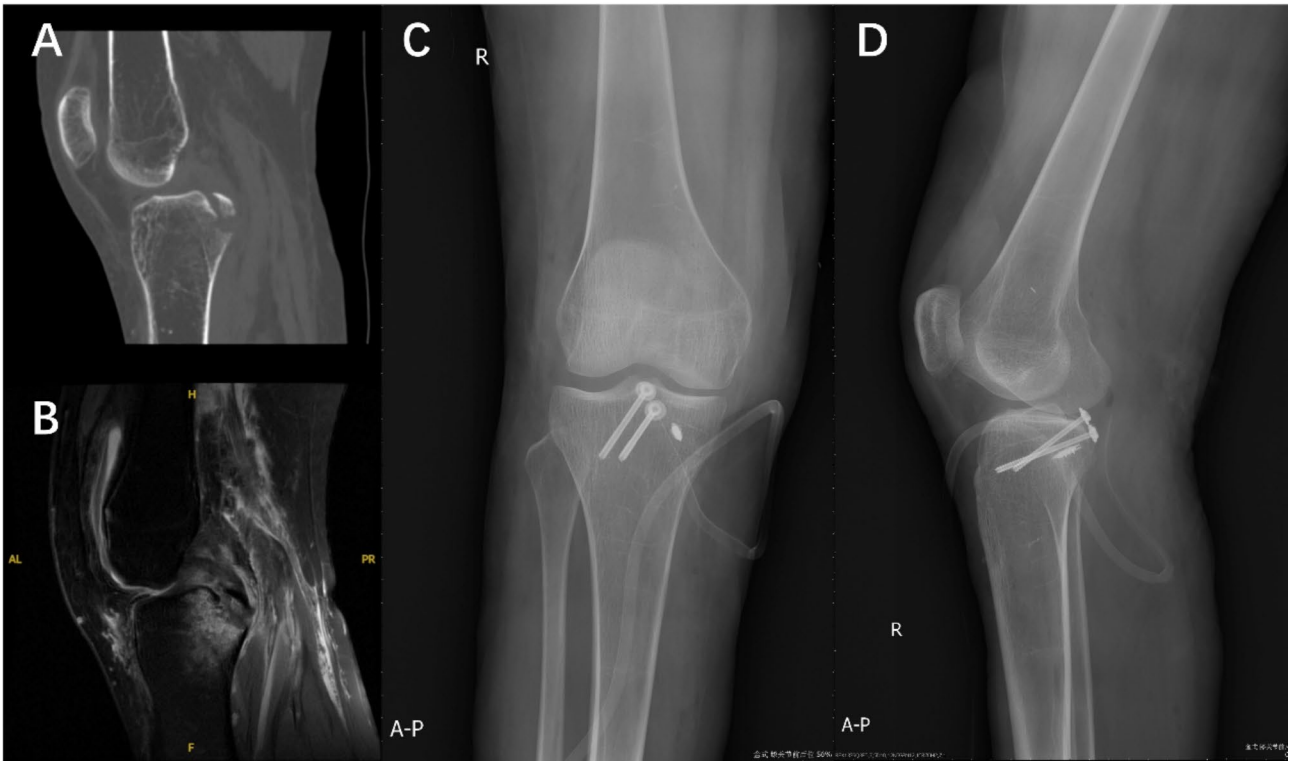

Fig. 8 Typical cases in Group C Female, 39 years old, vehicle accident. **A**, **B**: Preoperative CT and MRI showing displaced PCLA, MRI suggesting moderate laxity of the PCL. **C**, **D**: 3-month postoperative radiographs

C: 6.9 ± 1.3 mm; $P = 0.675$). Similarly, the comminution of avulsed bone fragments, categorized by the number of fragments, demonstrated no statistically significant intergroup variation ($P = 0.211$).

Group B had the shortest operative time (87.0 ± 23.9 min), which was significantly shorter than that of both Group A (105.4 ± 26.0 min, $P < 0.05$) and Group C (131.7 ± 43.8 min, $P < 0.01$) (Table 1). Group C required the longest postoperative hospitalization (9.7 ± 6.0 days vs. 5.2 ± 3.2 days in Group A and 4.3 ± 1.6 days in Group B; $P < 0.01$ for both comparisons). No significant differences in the length of hospital stay were observed between Groups A and B ($P > 0.05$; Table 1).

At the final follow-up, the Lysholm, Tegner, and IKDC scores, as well as range of motion (ROM) assessments, showed no statistically significant intergroup differences (all $P > 0.05$; Table 2). More than 95% of patients in all groups exhibited IKDC ratings of "B" or higher, with no severe functional limitations reported. No significant intergroup differences in the IKDC grade were observed ($P = 0.180$). Similarly, the posterior drawer test revealed no statistically significant differences among the groups ($P = 0.440$).

All fractures exhibited radiographic union by 3 months postoperatively, with no cases of osteoarthritis, nonunion, or graft failure observed at the final follow-up. Two Group C patients developed incisional fat liquefaction, which resolved with conservative management. No neurovascular injuries, deep infections, or arthrofibrosis occurred. Lateral collateral ligament injuries (degree I, II, $n = 7$) observed in all three groups of patients were treated conservatively. Combined meniscus injuries in Group A ($n = 3$) and Group B ($n = 5$) were treated concurrently with PCLA surgery. In Group C, 6 meniscal injuries were noted on postoperative days 36, 103, 111 and 120, and 2 patients who underwent arthroscopic treatment at another hospital were treated with secondary arthroscopic surgery after the initial surgery (Table 1).

Discussion

Posterior cruciate ligament avulsion fractures (PCLA) may lead to knee instability and early onset of osteoarthritis if not treated appropriately [9]. In this study, arthroscopic suture fixation, EndoButton suspension fixation, and hollow screw fixation demonstrated good clinical outcomes during the follow-up period. Moreover, other studies revealed fair to good clinical outcomes for these surgical approaches in the treatment of displaced PCL avulsion fractures [20, 21, 23, 24]. Compared with that in the EndoButton fixation cohort, the operation time in the arthroscopic suture fixation cohort (Group A) was longer (Group B), possibly because of the technical demands associated with dual bone tunnel creation

Table 2 Pre-and postoperative follow-up outcomes in three groups of patients

	Group A(*n* = 25)		Group B(*n* = 38)		Group C(*n* = 45)		
	Preoperative	**Postoperative**	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**	***P-value***
Lysholm score, mean ± SD	34.6 ± 5.0	92.9 ± 4.4(CI,91.0-94.8)	35.6 ± 4.3	93.4 ± 3.4(CI,92.3–94.6)	31.9 ± 6.0	93.5 ± 2.9(CI,92.6–94.4)	AB,0.573 AC,0.504 BC,0.919
Tegner score, mean ± SD	3.0 ± 1.0	6.7 ± 1.0(CI,6.3–7.1)	3.0 ± 0.8	7.0 ± 0.9(CI,6.7–7.3)	2.7 ± 0.7	6.9 ± 0.9(CI,6.6–7.1)	AB,0.268 AC,0.512 BC,0.581
ROM, mean ± SD, °	33.3 ± 7.5	133.3 ± 7.8(CI,130.0-136.6)	33.8 ± 7.8	134.0 ± 7.0(CI,131.7-136.4)	32.6 ± 7.9	134.4 ± 9.9(CI,131.3-137.5)	AB,0.720 AC,0.599 BC,0.859
Posterior drawer test, n							0.180
Grade 1	0	16	0	32	0	34	
Grade 2	16	8	23	5	26	9	
Grade 3	8	0	14	0	17	0	
IKDC grading, n							0.440
A	0	13	0	24	0	22	
B	8	9	9	13	5	18	
C	12	2	20	0	26	3	
D	4	0	8	0	12	0	

SD: Standard Deviation; CI-95% Confidence Interval; *P-value*: Overall comparisons were performed using one-way ANOVA or chi-square test, while specific group comparisons (AB, AC, BC) were analyzed with post-hoc tests

and intra-articular suture threading under arthroscopic visualization. Although it has been suggested that there is no significant difference in operative time between open and arthroscopic surgery [25], our data revealed that the duration of hollow screw fixation was significantly longer than that of both arthroscopic suture fixation and EndoButton fixation. This may be because hollow screw fixation required fine dissection of the posterior joint capsule during the operation and multiple intraoperative X-ray fluoroscopies to ensure that the grafts were correctly positioned. In addition, as our team become quite experienced in arthroscopic surgery since its inception, proficiency in arthroscopic surgery is also an important factor affecting the operation time.

Arthroscopic suture fixation is similar to Jung-Ro Yoon's [16] modified suture bridge technique, which uses a double-stranded high-strength thread that wraps around the distal PCL in an '8' shape and passes through the tibial tunnel. This reduces friction between the suture and the tunnel opening, lowering the risk of suture breakage [18]. This approach is less invasive, causes less damage to surrounding tissues, is associated with lower risks of postoperative pain and infection, and is known for less visible scarring. However, this technique is difficult to perform, has a steep learning curve, and requires that surgeons have a high level of skill. Despite good clinical results, according to Philipp Forkel [26], the strength of suture fixation should be considered when selecting the postoperative rehabilitation method because suture fixation cannot withstand aggressive rehabilitation.

Hollow screw fixation is performed using a modified inverted 'L'-shaped posterior approach through the gastrocnemius gap, which avoids separating important blood vessels and nerves and reduces injury [25]. This method is suitable for large avulsion fractures, providing strong fixation and preventing displacement of the fracture fragments. However, the procedure is more traumatic, increasing the difficulty of postoperative recovery and the risk of complications. Although no serious popliteal vascular nerve injury was found in this study, two patients (4%) in Group C developed popliteal fat liquefaction postoperatively, and the wounds eventually healed after the removal of subcutaneous sutures and frequent dressing changes. The incidence of postoperative complications was also similar to that reported in the published literature [22, 25].

The arthroscopic EndoButton suspension fixation method was originally proposed by Wajsfisz et al. [19] in 2011 and was modified by our team. This button incorporates a suture loop that is long enough to cover the entire tibial tunnel and effectively reduces the risk of the suture being cut in the bone tunnel [21]. This type of fixation is not only minimally invasive but is also suitable for all types and degrees of fracture, especially complex avulsion fractures that are difficult to fix with traditional methods, as it provides strong fixation. Mechanical

analyses have shown that its structural properties are comparable to those of direct screw fixation techniques. However, despite the good biocompatibility of the EndoButton, a small number of patients may develop a foreign body reaction, such as local inflammation or pain. EndoButtons were placed at the tendon–bone junction area in two patients with small bond fragments. MRI revealed good ligamentous structure and good functional recovery of the posterior cruciate ligament, and all relevant functional tests were negative. The patients' IKDC and Lysholm scores were greater than 90, indicating the clinical effectiveness of this method [27].

Importantly, ligament and meniscus injuries associated with PCL avulsion fractures cannot be treated in a single open procedure, as a second arthroscopic procedure is often required. Arthroscopic fixation can be used to concurrently treat lateral collateral ligament, meniscus, and cartilage injuries, which are often associated with PCL avulsion fractures. Compared with open surgery, arthroscopic fixation is less invasive and associated with a lower risk of complications, causes less damage to the popliteal neurovascular structures, and results in shorter postoperative recovery and hospitalization times, resulting in lower patient care costs. In addition, all combined injuries (8 meniscal injuries) in this study were effectively treated via arthroscopic surgery.

In a study of anterior cruciate ligament avulsion fractures, May et al. [28] found that the effect of the degree of comminution of the avulsed bone mass on the prognosis of operated patients tended to be significant. However, our team prefers to fix the avulsion fragments attached to the PCL and anchor the remaining large fragments. The avulsed bone fragments that could not be fixed were removed.

The study is mainly limited by its retrospective design, which is known for inherent selection bias. In addition, we did not use the KT-1000 or KT-2000 arthrometer for quantitative assessment of knee stability, nor did we include stress radiographs as part of our routine examination. Considering the low incidence of PCLA and the inconsistency in the size of the avulsed bone fragments, it is difficult to conduct a prospective study. The statistical validity (0.77) was close to 0.80. The results of this study need to be interpreted with caution. In the early stages of arthroscopic surgery, the operative time is much longer than that of open surgery. When surgeons become more experienced, the time of arthroscopic surgery decreases. Our team is committed to training arthroscopists and the establishment of a "standardized training process", which will be the topic of our future research.

Conclusion

All three methods—arthroscopic suturing, suspension fixation with EndoButton, and hollow screw fixation—are effective in the treatment of acute posterior cruciate ligament avulsion fractures. However, arthroscopic suspension fixation with EndoButton is particularly recommended because of its minimal invasiveness, excellent mechanical properties, low complication rate, and support for early intensive rehabilitation.

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Author contributions
G-AW wrote the manuscript. Z-PJ and C-LC participated in critical revision of the manuscript for intellectual content and screened the relevant literatures. SF revised the paper. WS conducted statistical analysis on clinical data. WZ designed the outline and revised the paper. All authors have read and approved the final version of this manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee. Ethics Committee of the Affiliated Hospital of Xuzhou Medical University. Ethical Approval Number: [XYFY2023-KL115-01]

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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