CLINICAL ARTICLE

Arthroscopic Direct Anterior-to-Posterior Suture Suspension Fixation for the Treatment of Posterior Cruciate Ligament Tibial Avulsion Fracture

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Objectives: A posterior cruciate ligament (PCL) avulsion fracture of the tibial attachment site is a specific type of PCL injury that is difficult and unpleasant to manage. The objective of this study is to report the preliminary results of a newly developed technique: arthroscopic endobutton-suture fixation using a single tibial tunnel.

Methods: From January 2016 to January 2018, 120 patients with PCL avulsion fracture who met our criteria were recruited. Sixty cases were treated by arthroscopic direct anterior-to-posterior suture suspension fixation (endobutton-suture group), and 60 cases were treated by arthroscopic screw-suture fixation (screw-suture group). All radiographic studies were recorded. The curative effect was evaluated by the range of motion (ROM), KT-2000, International Knee Documentation Committee (IKDC) scores, Tegner activity scale, and Lysholm scoring system. For statistical analysis the Student *t*-test was used.

Results: The average follow-up duration was 24 months. Findings and difficulties in surgery are the following. The lax anterior cruciate ligament is one of the diagnostic criteria. The anatomic location of PCL avulsion fractures is deep and surrounded by nerves and vessels; thus, operating through this region is difficult. After each tunnel drilling, the debris at the edge of opening needs to be cleaned to avoid obscuring the operator's vision or wearing the sutures. In endobutton-suture group, ROM improved from 0° preoperatively to 140.0° ± 5.6° at the last follow-up ($P < 0.001$). The postoperative KT-2000 arthrometric data at 90 N were available for all patients. The IKDC score was 23.6 ± 2.6 and 91.4 ± 4.1 pre- and postoperatively, respectively. The Tegner score improved from 1.2 ± 0.6 to 7.3 ± 2.3 ($p < 0.001$). The median Lysholm knee score increased from 40.4 ± 5.2 preoperatively to 90.1 ± 10.1 postoperatively ($p < 0.001$). The operative time was shorter in the endobutton-suture group ($p < 0.001$). The Lysholm knee score in the endobutton-suture group was lower than that in the endobutton-suture group (3.1 ± 1.2 *vs.* 4.2 ± 1.8, $p < 0.01$). No significant complications were noted in the study.

Conclusions: The arthroscopic direct anterior-to-posterior suture suspension fixation is a simple and reliable method that not only provides better clinical outcomes, but also fixes avulsion fragments of any size.

Key words: Arthroscopic technique; Avulsion fracture; Endobutton; Posterior cruciate ligament

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Introduction

A posterior cruciate ligament (PCL) avulsion fracture of the tibial attachment site is a specific type of PCL injury.[1,2] Improper treatment of this injury may lead to knee instability and osteoarthritis.[3,4] It has been assumed that this ligament consists of two bundles, an anterolateral bundle and a posteromedial bundle. Additionally, the PCL is the main statically stable factor of the knee joint. The PCL acts as the primary constraint to posterior displacement of the tibia on the femur, opposing 85%–100% of these backward forces. PCL injuries account for 3%–44% of knee injuries, the most common causes of which are traffic accidents. In the past, due to lack of awareness and limited examination equipment, misdiagnosis and underdiagnosis often led to untimely or nonsurgical treatment. The treatment effect was poor, and the risks of fracture displacement, delayed healing, and nonhealing were high. Varying degrees of knee dysfunction were observed in the terminal phase.

Most authors believe that surgical intervention is necessary to achieve the anatomical reduction of the articular surface and to restore the normal anatomical structure and physiological function of the PCL.[5] Previous treatments are based on open reduction and internal fixation, but the operation process is complex. Additionally, the trauma is severe, the risk for postoperative joint adhesion is high, the rehabilitation process is long, and the functional recovery is not satisfactory. Moreover, open surgery usually directly involves the posterior septum, and there is a high risk for damage to neurovascular structures.

In recent years, great progress has been made in the treatment of intra-articular fractures of the knee through arthroscopy. Because arthroscopic surgery has the characteristics of small incision and low levels of trauma, increasing numbers of doctors are willing to try to fix PCL avulsion fractures of the tibial attachment site under the arthroscope. Since arthroscopic repair has been developed extensively, a new minimally invasive alternative for the treatment of PCL avulsion fractures is available. Currently, mainstream arthroscopy technology can greatly reduce the rate of injury to popliteal neurovascular structures. However, due to the special nature of the fracture location, the possibility of mechanical complications remains high. With developments in materials science, tools for internal fixation, including hollow lag screws, steel wires, absorbable screws, suture anchors, and straddle nails, are available, providing surgeons with more therapeutic options.[6,7] Arthroscopic surgery has the advantages of simple operation, fast recovery, and low levels of trauma. Moreover, the operation field is clear. Additionally, surgeons can deal with other intra-articular injuries at the same time. The nature of the fracture also limits the selection of the material, and it is difficult to address cases with small or comminuted fragments.[8,9]

To address the abovementioned problems, we modified our previous techniques.[10] To the best of our knowledge, this is the first report of our arthroscopic suture fixation technique for the treatment of tibial avulsion fractures of the PCL, and the technique utilizes a suspensory device that surrounds not only the PCL but also the avulsed fragment from the anterior to the posterior region. Additionally, only a single tibial tunnel has been used not only to seat the PCL bony fragment but also to facilitate the passage of the sutures. We named this technique the arthroscopic direct anterior-to-posterior suture suspension fixation technique. An advantage of our technique is that among the histological structures behind the knee joint, only the posteromedial compartment is opened, which can preserve sufficient integrity of the posterior septum. Another advantage may be rigid fixation without the risk of small or comminuted fragments by suturing from the anterior to the posterior region. However, in the actual operation, the operator is required to have some experience in arthroscopic operation to suture the PCL well.

The first purpose was to report the clinical features and radiologic findings of surgically treated patients with PCL tibial avulsion fractures, including physical examinations, radiological assessments, and subjective measurements. The second purpose was to report the preliminary results of a newly developed technique: arthroscopic endobutton-suture fixation using a single tibial tunnel. We hypothesized that (i) clinical improvement would be observed in all patients and the effect would be satisfactory at the final follow-up; and (ii) arthroscopic direct anterior-to-posterior suture suspension fixation would be simple, relatively fast, and easily reproducible in routine clinical practice and could fix avulsion fragments of any size.

Materials and Methods

Inclusion Criteria and Enrolled Patients

The inclusion criteria for this study were as follows: (1) patients isolated PCL tibial avulsion fractures with >3 mm of displacement with or without comminution; (2) patients underwent arthroscopic endobutton-suture fixation; (3) successful completion of clinical and radiographic assessments. The exclusion criteria included (1) an associated tibial plateau fracture; and (2) other ligament tear that needed surgical treatment.[11] All patients with PCL tibial avulsion fractures were diagnosed by radiography (X-ray), computed tomography (CT), and magnetic resonance imaging (MRI) to better assess coexisting injuries (Figure 1).

All subjects completed a clinical examination during the period from January 2016 to January 2018. The time from injury to surgery was 3 to 8 days (mean, 4.3 days). We modified the arthroscopic screw-suture fixation technique that we initially proposed in 2009.[10] Sixty cases were treated by arthroscopic direct anterior-to-posterior suture suspension fixation (endobutton-suture group), and 60 cases were treated by arthroscopic screw-suture fixation (screw-suture group). This study was approved by the Foot and Ankle Research group at Nanjing First Hospital (#LM201500153B). Written informed consent was obtained from all patients.

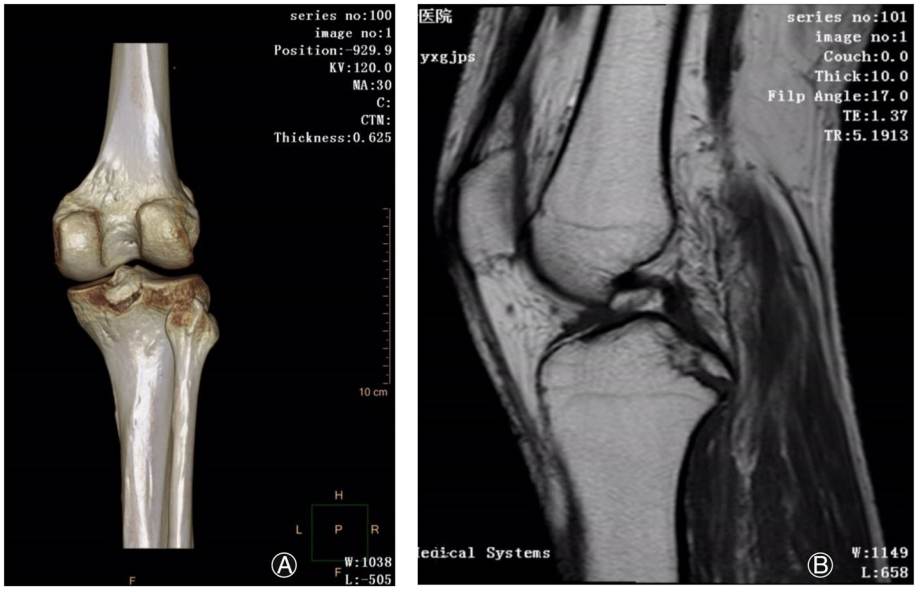

Fig. 1 Evaluation of the displacement and configuration of an avulsion fracture fragment of the posterior cruciate ligament tibial attachment by MRI (A) and CT (B). CT showed the tibial intercondylar eminence fracture. MRI showed the tibial intercondylar eminence fracture of PCL insertion

Surgical Technique

Anesthesia and Position

The operations were performed under general anesthesia. The patients were then placed in the supine position.

Approach and Exposure

The anterolateral (AL) and anteromedial (AM) portals were constructed initially.[12] The arthroscope was inserted through the AL portal. A motorized shaver was inserted through the AM portal. Standard diagnostic arthroscopy confirmed the existence of an isolated PCL avulsion fracture. A switching stick was inserted *via* the AM portal, and it was passed through the orifice between the PCL and the lateral wall of the medial femoral condyle (Figure 2A).

Pathological Changes

The switching sticks were replaced with the arthroscope to visualize the posteromedial compartment. The high posteromedial portal (hPM) and posteromedial portal (PM) were constructed by the percutaneous insertion of a spinal needle under direct arthroscopic guidance. The high posteromedial portal was located adjacent to the posteromedial femoral condyle and 3 cm above the joint line. While the arthroscope was held at the hPM portal, a motorized shaver was inserted through the PM portal. The fracture was released from soft tissue remnants by the shaver. Great care was taken to prevent detachment of the PCL ligament from its insertion on the bony fragment. With the arthroscope in the high posteromedial portal, the fracture bed was debrided by a shaver so that the margin of the crater of the avulsed fracture fragment could be visualized (Figure 2B). After the PCL drill guide was passed through the orifice between the PCL and the lateral wall of the medial femoral condyle, it was placed over the crater (Figure 2C).

Fixation

The external entry point of the guide wire was immediately medial to the tibial tuberosity at an angle of 50°. The tibial tunnel was created with a 4.5-mm cannulated drill bit (Figure 2D). An ACUFEX Surgical Instrument (Cuff Stitch: STRAIGHT 20° UP, Smith & Nephew) loaded with an ULTRABRAID suture (No. 5, Smith & Nephew) was introduced through the AM portal and advanced through the lateral border of PCL substance immediately above the avulsed fragment (Figure 2E). Similarly, another suture was passed through the medial border (Figure 2F). Both sutures are hooked directly through the PCL substance from the anterior to the posterior region of the joint cavity. The ends of the two sutures within the joint were grasped through the PM portal using a suture retriever. These two ends were held taut while the avulsion fracture was palpated and reduced to its anatomical position using a probe (Figure 2G). The two ends of the sutures in the PM portal were passed over the avulsed fragment and pulled out of the tibial tunnel, making the sutures cross over the avulsed fragment. The other two ends of the two sutures were also grasped through the tibial tunnel (Figure 2H).

Reconstruction

Then, the two sutures were passed over the rope of the ENDOBUTTON CL Fixation Device (Smith & Nephew). With the grasping forceps in the PM portal, the sutures were pulled in the direction of the tibial tunnel to achieve reduction and compression of the fracture (Figure 2I). Finally, the ends of the sutures were tied over the endobutton, and the

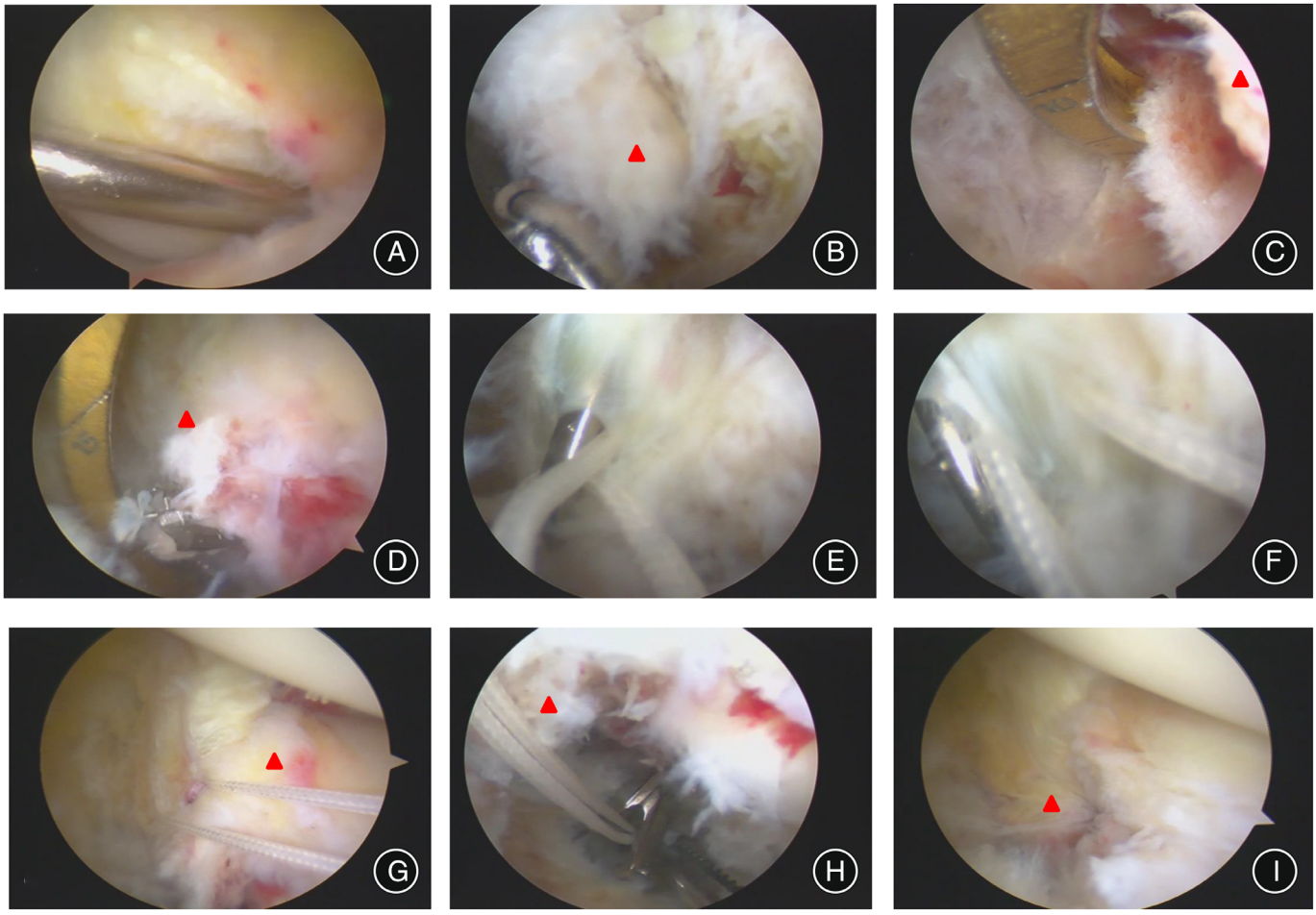

Fig. 2 Arthroscopic direct anterior-to-posterior suture suspension fixation technique. (A) A switching stick was passed through the orifice between the PCL and the lateral wall of the medial femoral condyle. (B) The fracture bed was debrided by a shaver so that the margin of the crater of the avulsed fracture fragment could be visualized (red triangle). (C) The PCL drill guide was placed over the crater. (D) The tibial tunnel was created with a 4.5-mm cannulated drill bit. (E) A hook loaded with an ULTRABRAID suture was advanced through the lateral border of PCL substance immediately above the avulsed fragment. (F) Another suture was passed through the medial border. (G) The two ends were held taut while the avulsion fracture was palpated and reduced to its anatomical position using a probe. (H) The two sutures were grasped though the tibial tunnel. (I) The sutures were pulled in the direction of the tibial tunnel to achieve reduction and compression of the fracture. PCL, posterior cruciate ligament

endobutton compressed the outer opening of the tunnel (Figure 3).

Clinical and Radiographic Assessment

Clinical and radiographic assessments were made pre- and postoperatively. Radiological evaluation was performed using X-ray, CT, and MRI. The KT-2000 arthrometer (MEDmetric, San Diego, CA) was used to assess the side-to-side difference of anteroposterior laxity at 30° of flexion.

Range of Motion (ROM)

The range of motion (ROM), which as measured using a goniometer, was used to measure knee mobility. The knee's lateral epicondyle, lateral malleolus, and greater trochanter were the landmarks for performing the angle measurements. The measurement results were recorded preoperatively and at each follow-up visit.

International Knee Documentation Committee (IKDC)

The IKDC score is a valid and reliable knee-specific measure which is appropriate for patients with a variety of knee problems. There are 18 items related to symptoms, function, and sports activity, which are able to differentiate patients with lower levels of function and higher levels of knee symptoms. The final grade of A (normal), B (nearly normal), C (abnormal), or D (severely abnormal) is determined by the lowest score in each category.

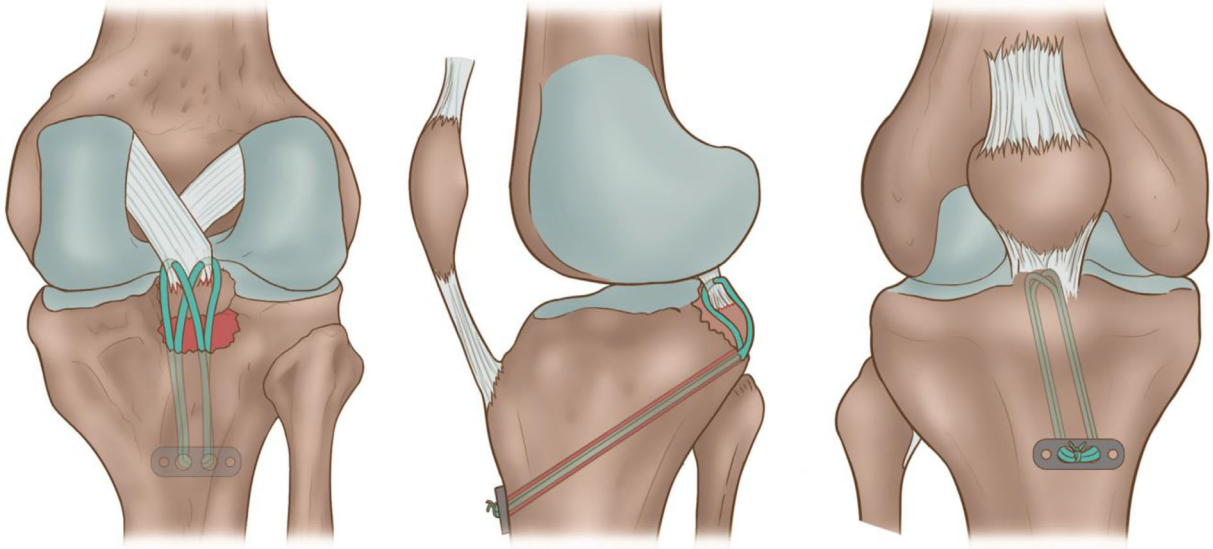

Fig. 3 Schematic diagram of the crossover tie configuration of multiple sutures piercing the posterior cruciate ligament. This crossover configuration of multiple fixation sutures enabled proper reduction and compression of elevated avulsed bony fragments

Tegner Activity Scale Score

The Tegner activity scale score is an instrument that evaluates the patient's level of work and sports activity on an 11-level scale: from 0 (sick leave or disability pension because of knee problems) to 10 (competitive sports). The higher scores represent higher levels of physical activity.

Lysholm Knee Scoring System

The Lysholm Scale System, a patient-reported outcome measure, is used to evaluate knee function. This system consists of eight items: pain (0–25), instability (0–25), locking (0–15), swelling (0–10), limp (0–5), stair climbing (0–10), squatting (0–5), and need for support (0–5). The sum of each response to the eight questions may range from 0 to 100. Higher scores indicate a better outcome.

Statistical Analysis

The correlation between preoperative and postoperative follow-up results was statistically analyzed. Student's t-test was used to compare the means between the pre- and postoperative groups. All analyses were conducted using SPSS 13.0 software (SPSS, Chicago, IL, US). The statistical significance was defined at a < 0.05 probability level.

Results

Clinical and Radiographic Assessment

Sixty patients who underwent arthroscopic endobutton-suture fixation were ultimately included in this study. The mean body mass index (BMI) was 28.8 (range: 22.2–33.4). According to the relevant policies of China, they were divided into two groups according to age. The young adults were 18–35 years old, and the middle-aged group was 36–55 years old. The average follow-up duration was 24 months (range, 4–36 months). The median age of patients was 34.5 years (range, 18–55 years). The mean operative time was 28 min (range, 20–40 min).

The radiographic evaluation at the last follow-up showed solid union at the fracture site in endobutton-suture group. X-rays taken at the last follow-up showed that bony fusion at the fracture site was achieved in theses 60 patients. Transverse CT, 3-D CT reconstructions, and radiographs of the knee were performed immediately after surgery to verify the button position and bone healing. Figures 4–6 represent the radiographic studies of three typical cases. The first is a 53-year-old man who fell from standing height for 4 days. Images at three discrete time points were selected: preoperative (Figure 4A,B), immediate postoperative (Figure 4C), and at last follow-up (Figure 4D). The second is a 40-year-old woman injured in a motor vehicle accident for 3 days. Images at three discrete time points were selected: preoperative (Figure 5A, B), immediate postoperative (Figure 5C), and at last follow-up (Figure 5D).The third is a 20-year-old man injured in a fall at work for 4 days. Images at three discrete time points were selected: preoperative (Figure 6A, B), immediate postoperative (Figure 6C), and at last follow-up (Figure 6D).

Active Range of Motion (ROM)

The knee active ROM significantly improved from 0° at preoperative assessment to $123.5 \pm 6.8°$ ($p < 0.001$) at the 1-year postoperative follow-up and to $140.0 \pm 5.6°$ ($p < 0.001$) at last follow-up. All patients returned to their preinjury level (Table 1).

Fig. 4 Radiographical materials of first typical case. Images at three discrete time points were selected: preoperative (A, B), immediate postoperative (C), and at last follow-up (D)

KT-2000 Arthrometric Data

The postoperative KT-2000 arthrometric data at 90 N were available for all patients. The mean side-to-side difference significantly improved from 8.2 ± 1.6 at preoperative assessment to 4.3 ± 1.8 ($p < 0.001$) at the 1-year postoperative follow-up and to 3.1 ± 1.2 ($p < 0.001$) at last follow-up (Table 1).

International Knee Documentation Committee (IKDC)

The IKDC score significantly improved from 23.6 ± 2.6 at preoperative assessment to 87.8 ± 6.3 ($p < 0.01$) at the 1-year postoperative follow-up and to 91.4 ± 4.1 ($p < 0.001$) at last follow-up. Improvement from preoperative to postoperative values was statistically significant (Table 1).

Tegner Activity Scale Score

The Tegner Activity Level significantly improved from 1.2 ± 0.6 preoperative assessment to 6.6 ± 3.3 ($p < 0.001$) at the 1-year postoperative follow-up and to 7.3 ± 2.3 ($p < 0.001$) at last follow-up. The activity levels significantly improved after surgery (Table 1).

Lysholm Knee Scoring System

The Lysholm knee scores between the pre- and postoperative groups are shown in Table 2. The Lysholm knee score at age 18–35 was lower than that at age 36–55 (38.8 ± 2.3 *vs* 89.1 ± 8.4, $p < 0.01$). This finding may suggest that younger patients may have worse preoperative symptoms than middle-aged patients, though there was not a significant between-group difference postoperatively (89.1 ± 8.4 *vs* 91.6 ± 5.5, $p = 0.204$). Moreover, there were no significant differences between the pre- and postoperative groups in terms of gender. In all, there was a significant improvement postoperatively at last follow-up. The median Lysholm knee score increased from 40.4 preoperatively to 90.1 postoperatively (40.4 ± 5.2 *vs*. 90.1 ± 10.1, $p < 0.001$).

Fig. 5 Radiographical materials of second typical case. Images at three discrete time points were selected: preoperative (A, B), immediate postoperative (C), and at last follow-up (D)

Comparisons between Two Techniques

The operation time of the endobutton-suture group was 28 (range, 20–40) min, and that of the screw-suture group was 48 (range, 38–60) min (Table 3). At last follow-up, there was a significant difference between the two groups ($p < 0.001$). There was no significant difference between the two groups in active ROM and Lysholm scores. The KT-2000 examination showed that the side-to-side difference was 3.1 ± 1.2 in the endobutton-suture group and 4.2 ± 1.8 in the screw-suture group ($p < 0.001$).

Complications

Our Plan—Do—Check—Action (PDCA) team was formed to reduce complications. Using the concept of the PDCA cycle, all members objectively evaluated and implemented the relevant events of the perioperative period. None of the patients experienced any major complications, including neurovascular injuries or perioperative wound infection.

The operated knee was immobilized in an extension position by use of adjustable knee brace with controllable movement for 2 weeks after the operation. Range of motion exercises in 0°–90° knee flexion were started 2 weeks after surgery for 2 weeks. Subsequently, a maximum flexion of 120° was permitted until 6 weeks after surgery. Four weeks were required for full weight bearing.

Discussion

In patients with PCL tibial avulsion fractures treated operatively: (1) arthroscopic treatment of PCL tibial avulsion fractures provides good clinical outcomes, radiologic healing, and stable knees; and (2) arthroscopic direct anterior-to-posterior suture suspension fixation is simple, relatively fast, and easily reproducible in routine clinical practice and can fix avulsion fragments of any size.

The PCL tibial stop is located outside of the articular capsule. The surrounding soft tissue can be easily inserted

Fig. 6 Radiographical materials of third typical case. Images at three discrete time points were selected: preoperative (A, B), immediate postoperative (C), and at last follow-up (D)

TABLE 1 Pre- and postoperative clinical outcome scores in endobutton-suture group

Parameter	Preoperative	Postoperative		*p*-value	t_1	t_2
		1 year	2 years			
Active ROM	0°	123.5 ± 6.8°	140.0 ± 5.6°	<0.001	1.4	1.9
KT-2000	8.2 ± 1.6	4.3 ± 1.8	3.1 ± 1.2	<0.001	1.3	2.0
IKDC grade[a], n						
A	0	17	47			
B	0	43	13			
C	10	0	0			
D	50	0	0			
Mean ± SD	23.6 ± 2.6	87.8 ± 6.3	91.4 ± 4.1	<0.001	7.3	10.8
Tegner, n						
0–3	60	0	0			
4–6	0	22	12			
7–10	0	38	48			
Mean ± SD	1.2 ± 0.6	6.6 ± 3.3	7.3 ± 2.3	<0.001	1.2	1.9

Abbreviations: IKDC, International Knee Documentation Committee; KT-2000, KT-2000 arthrometric data; ROM, range of motion; SD, standard deviation; Tegner, Tegner Activity Level; [a]A = normal; B = nearly normal; C = abnormal; D = severely abnormal. t_1: preoperative *vs*. 1 year; t_2: preoperative *vs* 2 year.

TABLE 2 Comparison of the Lysholm knee score in endobutton-suture group (last follow-up)

	Preoperative	Postoperative	Number	*p* value	t
Age (years)					
18–35	38.8 ± 2.3	89.1 ± 8.4	36	<0.001	3.5
36–55	42.8 ± 3.0	91.6 ± 5.5	24	<0.001	3.8
p value	<0.001	0.204			
t	5.8	1.3			
Gender					
Male	39.9 ± 2.2	89.2 ± 5.6	39	<0.001	5.1
Female	41.1 ± 3.8	91.8 ± 5.1	21	<0.001	3.7
p value	0.126	0.082			
t	1.6	1.8			
Total	40.4 ± 5.2	90.1 ± 10.1	60	<0.001	3.4

The data are presented as mean ± standard deviation.

between the fragment and fracture bed, which leads to difficulty in fracture reduction and a high rate of nonunion.[13] Fibrous union or nonunion will result in failure of the PCL, instability of the knee joint and, ultimately, the occurrence of knee osteoarthritis.[14] Therefore, displaced PCL avulsion fractures require surgical treatment.

Clinical Outcomes of the Arthroscopic Direct Anterior-to-Posterior Suture Suspension Fixation

Regarding knee outcomes, the number of patients with the IKDC grade A score, indicating a normal knee, significantly increased from 0 preoperatively to 47 (78.3%) at 2 years postoperatively. In a recent systematic review by Hooper *et al.* of nine studies with a total of 199 patients, consistent evidence has emerged that 78.9% reported a normal knee.[15] Perhaps less aggressive soft tissue dissection in the arthroscopic group creates less scar formation, thus improving function or reducing pain in the athletic population.[16] We compared pre- and postoperative Tegner scores, with means of 1.2 and 7.3, respectively. Three recent papers which are in agreement with our results have reported reaching a preinjury level of activity, and all patients returned to their previous levels or sports.[1,17,18] The preinjury score averaged 7.1, while the postoperative score averaged 6.8.

Multiple studies have shown that the Lysholm scores improved significantly pre- and postoperatively, from 36.5 to 95.0, respectively.[17,19–21] Similarly, we confirmed that the median Lysholm knee score increased from 40.4 preoperatively to 90.1 postoperatively. It was interesting that the Lysholm knee score at age 18–35 was lower than that at age 36–55. The probable reason is that patients have pain and dysfunction, which are correlated with age-specific expectations of surgery.[19] In terms of gender, a similar observation in India has been documented for the irrelative importance of gender on PCL avulsion fractures.[22] Since the cause of PCL is often accidental injuries, the injury generally has nothing to do with gender-specific lifestyles. Regarding the cause of injury, Ahmed *et al.* reported that motor vehicle accidents were the most frequent cause of injury;[23] this was the case in our study where 75% of the patients were injured in road traffic accidents. Overall, our clinical outcomes are consistent with Hooper *et al.*, who demonstrated that the arthroscopic group had somewhat higher subjective and objective knee outcome scores.[15]

Choice of Implant for Internal Fixation

Under arthroscopy, clinical management of avulsion fractures commonly utilizes screws, wires, or sutures. Kim *et al.* first reported the use of suture fixation under arthroscopy from the tibia for the treatment of PCL avulsion fractures.[21] In 2016, 18 patients with PCL avulsion fractures were treated with double-tunnel pull-out suture bridge fixation by Yoon *et al.*[11] It is recognized that PCL avulsion with a small fragment at the tibial attachment site can be reduced and fixed

TABLE 3 Comparison of follow-up data between the two groups (last follow-up)

Group	Operative time (min)	Active ROM, Mean ± SD	Lysholm score, Mean ± SD	KT-2000, Mean ± SD
Endobutton-suture group	28 (range, 20–40)	140.0 ± 5.6°	90.1 ± 10.1	3.1 ± 1.2
Screw-suture group	48 (range, 38–60)	138.0 ± 6.8°	94.2 ± 14.6	4.2 ± 1.8
t	5.1	1.8	1.8	3.9
p-value	<0.001	0.08	0.08	<0.001

Abbreviations: ROM, range of motion; KT-2000, KT-2000 arthrometric data. SD, standard deviation.

by sutures. Anthony Wajsfisz's method with a suspensory fixation device further enhanced the stiffness following fixation compared with simple suture fixation.[24] For these reasons, our technique involves endobutton-suture fixation with a single tunnel, which requires only a simple procedure and results in a definite clinical effect.

The two sutures were passed through the PCL base rather than the avulsed bone, reducing the risk of subsequent fractures. Both suture ends, which penetrated the PCL, were crossed over the endobutton and constituted a mesh, making the pressure distribution uniform and reducing the possibility of small displacements. This procedure is suitable for not only large bony fragments without comminution (≥15 mm) but also small fragments with comminution (≤10 mm).

Advantages of the Modified Surgical Approach

Figure 2 shows the intraoperative results of arthroscopic direct anterior-to-posterior suture suspension fixation technique. There are several findings and difficulties in surgery: (1) the patients' anterior cruciate ligament (ACL) must be lax under arthroscopy, which is also one of the diagnostic criteria for PCL avulsion fractures; (2) the anatomic location of PCL avulsion fractures is deep, around which there are some important nerves and vessels; thus, operating through this region is difficult; (3) after each drilling of the bone tunnel, the large amount of debris at the edges of the internal and external openings needs to be cleaned with a shaver to avoid obscuring the operator's vision or wearing the sutures.

Currently, the PM portal is one of the most common approaches.[25–27] There are various methods of internal fixation, but most suture fragments using this portal are all located posteriorly.[11] We modified the technique that we initially proposed in 2009.[10] Suturing from the anterior to the posterior region under direct vision provides a larger operating space and wider coverage of the fragments. The operation has a short duration and is simple, as only one bone tunnel needs to be drilled. Reduction and suture thread can be operated in the posteromedial compartment, without additionally opening the posterolateral compartment. We did not routinely use fluoroscopy during the procedure, and satisfactory results were achieved. Moreover, micromotions of the avulsed fragment may also be present; thus, external fixation is needed for 2 weeks postoperatively.

Limitations and Strengths

There are several limitations to our study. The number of cases in this study was small, and some patients were not very compliant. These issues led to a long follow-up time span and inconsistent last follow-up time, which may have generated some bias in the results. The minimum follow-up period is 4 months, and it is possible that the patients only achieved radiographic bone healing. Anyway, the lack of a control group remains a drawback of our study. Further randomized well-controlled comparative studies with a larger sample size should be established to confirm the conclusion derived from the current study. This research lacked related biomechanical research. Corresponding experiments will be added in the future to measure relevant mechanical data and to strengthen the evidence. Due to the long arthroscopy learning curve, proficiency in microscopy may have an impact on the operation time. This study was performed by the same senior surgeon in our department, and readers need multiple training sessions during actual application.

In our clinical practice, we modified our previous techniques which have been reported in 2009.[10] Our data exhibited improved stability when directly compared to our previous investigations. Patients had better scores and higher return to pre-injury activity in the present study. Also, we reported an effective simplified operation, so that surgeons do not require frequently changing portals and retraction sutures. Finally, sutures were tied over the endobutton rather than the screw. The endobutton-suture fixation has higher mechanical strength, which conforms to the principles of bio-fixation.

Conclusion

In summary, the arthroscopic direct anterior-to-posterior suture suspension fixation technique for PCL avulsion fractures has potential to be a safe, simple, and effective procedure. Furthermore, this technique could potentially be used at all hospital levels. But, how to make the surgical effect more minimally invasive and at a lower cost still requires further research.

Ethics Approval and Consent to Participate

This study was approved by Ethics Committee of Nanjing First Hospital. Written informed consent was obtained from all patients.

Ethical Review Committee Statement

All participants provided written informed consent as approved by The Nanjing Medical University Ethical Review Committee.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Conception and design of the research: Yiqiu Jiang and Jianchao Gui; Acquisition of data: Tianqi Tao and Wengbo Yang; Analysis and interpretation of data: Xing Tao; Statistical analysis: Yang Li and Kaibin Zhang; Drafting the manuscript: Tianqi Tao; Revision of manuscript for important intellectual content: Tianqi Tao and Yiqiu Jiang. All authors read and approved the final manuscript.

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