# Arthroscopy Mini-plate Fixation with the Posterior Trans-septal Portal for Treating Posterior Cruciate Ligament Tibial Avulsion Fractures

**Chunlei Wang**
Central Hospital of Cangzhou
**Haisen Zhang**
Central Hospital of Cangzhou
**Longjie Li**
Central Hospital of Cangzhou
**Si Chen**
Central Hospital of Cangzhou
**Chang Liu** (ydyxlc123@126.com)
Central Hospital of Cangzhou

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**Research article**

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## Abstract

**Background** Posterior cruciate ligament (PCL) avulsion fractures are rare and difficult to treat. The present work aimed to examine the effect of an innovative arthroscopy method for the treatment of PCL tibial avulsion fractures using mini-plate reduction and fixation through two tibial tunnels and the posterior trans-septal portal.

**Methods** Totally 19 patients (median age, 33 years; range, 23–43 years) with PCL tibial avulsion fractures who underwent treatment with an arthroscopic suture bridge method were retrospectively assessed. Knee function pre-operation and at last follow up was assessed via Lysholm and Tegner scores. A KT-2000 arthrometer was employed for determining knee stability, the range of motion (ROM), and side-to-side differences. Plain radiography and International Knee Documentation Committee (IKDC) exams were performed for patient evaluation.

**Results** No patient was switched to conventional open surgery due to difficult intraoperative procedures. Mean post-surgical Lysholm and Tegner scores ($P < 0.001$) were significantly improved in comparison with presurgical values. KT-2000 examination revealed markedly reduced side-to-side differences at last follow-up than observed preoperatively ($1.2 \pm 0.6$ VS. $9.3 \pm 2.2$; $P < 0.001$). Radiography at the final follow up revealed solid union at the fracture site in the totality of 19 cases.

**Conclusions** This new arthroscopy mini-plate fixation and posterior trans-septal method for posterior cruciate ligament tibial avulsion fractures resulted in good clinico-radiological outcomes, with adequate stability and fracture site healing. It could be employed to repair avulsion fragments of various sizes.

Level of evidence IV

## Introduction

Tibial avulsions of the posterior cruciate ligament (PCL) occur in the youth, and often result from high-energy trauma. They commonly damage the knee and ipsilateral limbs. Motor vehicle accidents are major causes of such fractures, especially motorcycle-related injuries. When a backward force pressures the proximal tibia with a bent knee, the instrument panel is injured. The second most common cause is sport-related trauma, in which the mechanism involves knee hyperextension[1].

Greatly displaced avulsed fractures of the PCL tibial attachment point are traditionally managed mostly by open reduction and hollow screw internal fixation[2]. Even in case of minimal displacement, the risk of nonunion or malunion causes multiple surgeons to consider surgery[3, 4]. However, the traditional operative procedure for PCL tibial avulsion fractures remains difficult because of the deep lesion localization and complex adjacent anatomical structures, with most of them involving small bone fragments. In case of small and seriously comminuted avulsion fracture fragments, which may not be reliably fixed with screws, suture fixation is required[5, 6]. This is because the relatively benign appearance of these small fragments may not only cause more serious potential damage to the main stable structure of the joint, but also result in secondary fractures of the small fragments[7].

With the advancement of arthroscopy technology and instruments, PCL tibial avulsion fractures are currently more often treated by arthroscopic procedures rather than an open approach[7–9]. Biomechanical evidence suggests no significant differences in maximum load and stiffness in cases with PCL tibial avulsion fractures administered suture and screw fixation [4, 10].

However, to the best of our knowledge, there is currently no arthroscopic suture fixation technology that not only minimizes PCL bundle injury, but also achieves stable and firm reduction of avulsion bone fragments. Therefore, we developed a new arthroscopy reduction technique, which achieved satisfactory clinical and radiological results, especially for small avulsion fracture fragments.

# Patients And Methods

The present trial had approval from the Institutional Review Board of Cangzhou central Hospital. From May 2014 to December 2016, 19 patients with displaced PCL tibial avulsion fractures underwent posterior trans-septal approach with arthroscopic mini-plate fixation. Medical records and radiologic findings were retrospectively assessed. Inclusion criteria were: (1) displaced PCL tibial avulsion fractures with > 5-mm displacement; (2) meniscal injury or not. Exclusion criteria were: (1) PCL tibial avulsion fractures with < 5-mm displacement or accompanied by distal femoral/proximal tibial fracture; (2) other ligament tear requiring surgery; (3) > 60 years old. Radiography and magnetic resonance imaging (MRI) were carried out in each patient (Fig. 1abc). Bone fragments in presurgical radiographs were used for normalization. The small or comminuted fragments were measured during arthroscopy with 5-mm vertical probe tips.

The study included 19 individuals (13 men and 6 women), averaging 33 years (22–43 years) of age. The mean time from injury to surgical treatment was 4 days (2–9 days). Most of the patients acquired the injury in a motorcycle accident (11 cases), in a traffic accident (5 cases) and a self-fall (3 cases). Follow up was performed for 25 months in average (ranging from 24 to 29 months). The mean estimated fragmentation size was 12 × 7 × 6 mm (range, 8 × 5 × 3 mm to 18 × 12 × 11 mm).

Pre- and post-surgical functional data were assessed via Tegner activity scale and Lysholm scores. The IKDC systems assesses both symptoms and signs. Knees were categorized in the IKDC checklist as follows: normal, Grade A; near normal, Grade B; abnormal, Grade C; seriously abnormal, Grade D[11]. A KT-2000 arthrometer was utilized for assessing knee stability, the range of motion (ROM), and side-to-side differences. The patients were submitted anteroposterior and lateral radiography of the knee right after the operation, and at 3, 6, and 12 postoperative months, respectively. Fracture union was confirmed with invisible line and/or clinical stability.

### Surgical approach

The supine patient was submitted to lumbar epidural anesthesia. No tourniquet on the operation side was used. The routine parapatellar anterolateral (AL) and anteromedial (AM) portals were generated. Arthroscopy was carried out for menisci, cartilage and ligament assessment. After PCL identification, the knee was placed in 70° of flexion. The arthroscope was advanced from the posterior angle between the medial femoral condyle and the PCL to reach the popliteal recess. Posteromedial (PM) and posterolateral (PL) portals were generated using percutaneous guide needles, beside the PM and PL femoral condyles and approximately 2 cm above the joint line (Fig. 2a).

The posterior transseptal (TS) portal was generated via posterior septum shaving, upon closing with a switching stick, from the PL portal under PM portal visualization, with a shaver advanced via the AM portal. Upon posterior septum opening, the arthroscope was introduced into the PL as well as the shaver. This was followed by enlargement of the posterior septum's window with the shaver; neighboring synovium anterior to the PCL and the fracture site's hematoma were removed to outline avulsed PCL fragments. The fracture fragments were assessed comparatively to the probe's vertical tip (5 mm). The PCL guide was employed for manipulating and anatomically reducing displaced fracture fragments by direct visualization (Fig.2b). An about 1.5-cm incision was performed about 2 cm distal to the tibial tubercle on the anteromedial lower leg, with deepening until subperiosteal exposure of the tibial metaphysis. Upon PCL guide introduction posteriorly at 45°to 50°, the guide's tip was placed at the tibial fracture bed's medial and lateral boundaries at approximately the 4:00 and 8:00 o'clock positions, respectively. The PCL guide with additional two 2.0-mm Kirschner pins was employed for establishing 2 (medial and lateral) bone tunnels (Fig.2c). Then, two 0.5-mm wire loops underwent insertion into the knee joint via the abovementioned tunnels (Fig.2d). Maintaining the arthroscope in the anterolateral portal, the PCL guide was advanced to traverse the anteromedial portal and positioned on avulsion fragments (Fig.2e). Next, the arthroscope was advanced to the PL portal for controlling fragment reduction and verifying that the guide wire was in, which prevents popliteal neurovascular bundle damage. Finally, the loops wire was pulled out of the PM portal using the wire grabber. Two non-absorbable (no. 5) ultra-braid sutures (high-molecular weight polyethylene fibers) were passed over the mini-plate (Titanium alloy material, 12 mm×3.75 mm×1.5 mm) and connected to the loop wires *in vitro*. The loops wire was pulled out from the tibia anteriorly, and the mini-plate was pulled into the knee posteriorly and on top of the avulsed tibial bony fragment (Fig.2f) (Fig.3). Using a probe for adjusting fragment orientation through the PM portal, both suture ends were tightened, and the plate was pressed to fix the avulsion fracture to achieve anatomical reduction and tied over the tibial cortex between both tunnel openings. In order to achieve a good anatomical reduction when knotting and fixing, the PCL guide was still required. After the fixation, the arthroscopy was re-explored, and fracture reduction and microplate fixation were satisfactory. The same surgeon carried out the totality of operations.

## Postoperative Recovery

Post-surgically, knee bandaging was performed. The limb was positioned in a long-leg hinged brace in full extension for three weeks after surgery. Isometric quadriceps-strengthening exercises in the knee-extended position were encouraged right after the operation. Weight-bearing was forbidden for the initial three postoperative weeks. Afterwards, passive ROM exercises were initiated, and walking with partial weight-bearing and the use of crutches was allowed. The brace remained in full extension during walking. At six postsurgical weeks, brace unlocking was carried out to allow motion, and full weight-bearing was allowed. At eight postoperative weeks, brace removal was performed, with patients encouraged to increase activity gradually. At 6 months, physical activity could be fully resumed.

### Statistical analysis

SPSS 20 (SPSS, USA) was utilized for statistical analysis. Paired Student's t test was performed for comparing pre- and post-operative Lysholm and Tegner scores, as well as mean side-to-side differences on KT-2000 scans. The chi-squared test was performed for comparing IKDC score changes in groups A plus B versus groups C plus D (normal/nearly normal v abnormal/seriously abnormal) before the operation and at final follow up. $P < 0.05$ indicated statistical significance.

## Results

No patient was switched to conventional open surgery due to difficult intraoperative procedures. No major complications were reported in this study, including neurovascular injury and infection. During the operation, three cases showed combined meniscal injury, involving lateral ($n = 1$) and medial ($n = 2$) menisci, and partial meniscectomy was performed.

The study included 19 cases, with 13 men and 6 women, averaging 33 years old (range, 22–43 years). Follow up averaged 14 months (range, 12–18 months). The mean knee ROM (0°preoperatively) was improved to $154.5 \pm 6.3°$at the last follow-up($P < 0.001$). Tegner score improvement after operation in the 36 patients was statistically significant ($1.5 \pm 0.9$ VS. $7.3 \pm 1.1$, $P < 0.001$). Lysholm scores were significantly higher postoperatively than preoperatively ($89.2 \pm 5.3$ VS. $30.1 \pm 3.6$, $P < 0.001$). At the last follow up, IKDC was classified as A (normal) in 18 patients (94.7%) and B (near normal) in 1 patient (5.3%). Therefore, the level of activity after surgery was significantly improved compared with preoperative values ($P < 0.001$). KT-2000 evaluation revealed significantly reduced side-to-side differences at the final follow up in comparison with preoperative values ($1.2 \pm 0.6$ VS. $9.3 \pm 2.2$, $P < 0.001$). Radiography at the final follow up indicated solid union at the fracture site in all 19 cases (Fig. 4).

## Discussion

With increasing studies assessing the anatomy, physiological function and biomechanics of PCL, growing attention has been paid to PCL injury[12]. Avulsion fractures at the PCL's distal insertion represents a special PCL injury. PCL tibial avulsion fractures are relatively scarce but commonly occur in regions with high-speed motor vehicles as major transportation means[1]. Although prompt operative reduction is usually required, it remains a challenge to achieve satisfactory results due to the specific location of PCL tibial avulsion fractures.

Surgical treatment options for PCL tibial avulsion fractures comprise arthroscopic repair and open reduction plus internal fixation. Although the traditional open reduction plus fixation is effective, it is invasive and difficult to handle. For instance, screws may induce bone splitting of avulsion fragments. In addition, recovery is prolonged, with high risk of postsurgical adhesions. Moreover, due to the complex anatomical structures bordering the PCL such as the popliteal artery, such fractures may cause severe soft tissue injury and neurovascular damage. Previous reports have described arthroscopy reduction and hollow screw internal fixation as the recommended method, particularly for large fracture fragments[10]. However, the risk of screw incisions, bone fragmentation and screws penetrating the joint is always high[13]. In addition, for small-size avulsion bone fragments, there are few ways to restore the bone fragments to their original positions without crushing the fragments or wearing out the inserting PCL fiber.

With the advancement of arthroscopy technology and instruments, the recent progress in arthroscopic surgery has familiarize the approach via PM, PL and TS portals, and evidence indicates that arthroscopic suture reduction is particularly beneficial in treating small bone fragment-PCL avulsion fractures[1, 8, 14–16]. Biomechanical studies have shown that for individuals with PCL tibial avulsion fractures with suture and screw fixation, maximum load and stiffness are comparable[17, 18]. Previous studies[19, 20] have indicated that suture fixation is satisfactory for small or crushed fragments. Kim and collaborators[21] claimed that multiple suture fixation is only adequate in cases with small or comminuted fragments. For fracture fragments that are relatively small or thin, indirect reduction methods utilizing arthroscopic suture fixation can be used as an alternative to direct fixation approaches[14–16].

However, there are problems that need to be noticed in the previous suture fixation technology. First of all, the anterior and posterior portals to the operative field cannot clearly show the fracture part, resulting in incomplete debridement, fracture nonunion and/or operation failure[8, 22]. Secondly, multiple use of the suturing hook to penetrate the PCL bundle on avulsed tibial fracture block seriously damages PCL bundle fibers and may lead to the failure of the whole operation[8, 16]. Finally, in the previous suture technology, the suture cannot directly fix the fracture fragments, but acts through the traction of fracture fragments, compression reduction and fixation. This suture technique may lead to uneven force, displacement, and failure to reduce the fracture mass during the pulling process. Such suture fixation type is similar to point fixation; the contact area is small and there is a risk of being cut and injured, which eventually leads to the failure of the operation. Therefore, the previous suture technology could be referred to as the “band-to-face fixation” technology. Unlike the previous reports, this study introduced a novel arthroscopic surgical technique for PCL tibial avulsion fractures, which uses double tibial tunnels, mini-fixation plate with a line, and posterior trans-septal formation. The novel technique had good clinico-radiological outcomes, without complications. The surgical approach is via the posterior trans-septal portal, which can clearly show fracture location and the size of the fracture mass, and could clear the soft tissue and congestion in the fracture line.

Different from the previous suture technique, the suture wraps the PCL bundle without the need for suture hooks to penetrate the PCL bundle, which is protected from damage. Meanwhile, the PCL guide is used for fracture reduction, which not only stabilizes the reduced fracture fragments, but also establishes a tibial tunnel based on the guide at this time, avoiding cutting injury to the suture during the processes of pulling, compression and reduction. It is worth noting that the innovation of this technology lies in the reduction and fixation of fracture fragments with a wire micro-steel plate. This way, the previous "band-to-face fixation" was changed to "face-to-face fixation", and even comminuted fractures can be readily reduced and fixed. With the development of this technology, fragment size is no longer the decisive parameter in determining the method of internal fixation.

The suspensory fixation utilized here had multiple advantages. First, it has well-described biomechanical features and is easily handled thanks to its small size. In addition, this method is simple, with no requirement of many sutures and bony tunnels. Moreover, it can be employed for fragments of any size. For extremely small fragments, uniform compression could be achieved indirectly via broad PCL tibial insertion. In this study, patients with distinct fragment sizes (ranging 8 × 5 × 3 mm to 18 × 12 × 11 mm) were treated by arthroscopy-assisted reduction with mini-plate for fixation. As a result, radiologic osseous or stable fibrous union was obtained, with knee joint stabilization, early ROM, low morbidity and remarkable activity level improvement.

The arthroscopic posterior mediastinal portal has many advantages compared with previous methods. Indeed, the posterior trans-septal portal can directly reach the fracture area, clearly reveal fracture location and size, thoroughly debride and clear the congestion, and promote the healing of the fracture after surgery. It was recently suggested that limited release of the posterior capsule through the posterior trans-septal portal under arthroscopy provides sufficient arthroscopic working space, and keeps the knee flexion at 90° or more for posteriorly shifting the popliteal neurovascular bundle [23]. Therefore, the operation using this approach is relatively safe, and nerve and blood vessel injuries may rarely occur.

There are some considerations for establishing the posterior trans-septal portal.  Surgical position: the knee joint is placed at 90° flexion. At this time, the popliteal artery is relatively far from the posterior capsule, and nerves and muscles slide to the back of the posterior knee compartment, thereby reducing the risk of injury.  Puncture direction: the direction should be from outside to inside when passing through the posterior trans-septal, because the popliteal artery is located outside of the posterior artery, and the medial side of the posterior knee space is larger than the lateral side.  Penetration site: it is best to be located at the posterior margin of the posterior cruciate ligament and the middle of the posterior trans-septal. This can reduce the proprioceptive damage and avoid the popliteal artery behind the cruciate ligament tibial junction.

This study had limitations that need to be addressed. First, the sample size was small. In addition, the current method was not compared with existing treatment approaches, including screw fixation. Since PCL tibial avulsion fractures are rarely diagnosed, randomized controlled trials that compare many fixation approaches for treatment are nearly impossible to design and execute. Moreover, different skills are needed while using the posterior trans-septal portal compared with the common anteromedial and anterolateral portals, and experienced arthroscopic surgeons may be required.

# Conclusion

This new arthroscopy mini-plate fixation and posterior trans-septal approach for posterior cruciate ligament tibial avulsion fractures showed good clinico-radiological outcomes, with adequate stability and fracture site healing. The novel method provides enough compression, restoring PCL length, and could be employed for fixing avulsion fragments of various sizes.

# Abbreviations

PCL: Posterior cruciate ligament ; ROM: range of motion ; IKDC: International Knee Documentation Committee; MRI: magnetic resonance imaging; AL: anterolateral: AM: anteromedial; PM: Posteromedial; PL: posterolateral; TS: transseptal

# Declarations

# Conflict of interest

The authors have declared no conflict of interest.

# Ethical approval

The study was approved by the Institutional Review Board of the Cangzhou central of Hospital.

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None declared.

# Acknowledgements

None.

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# Tables

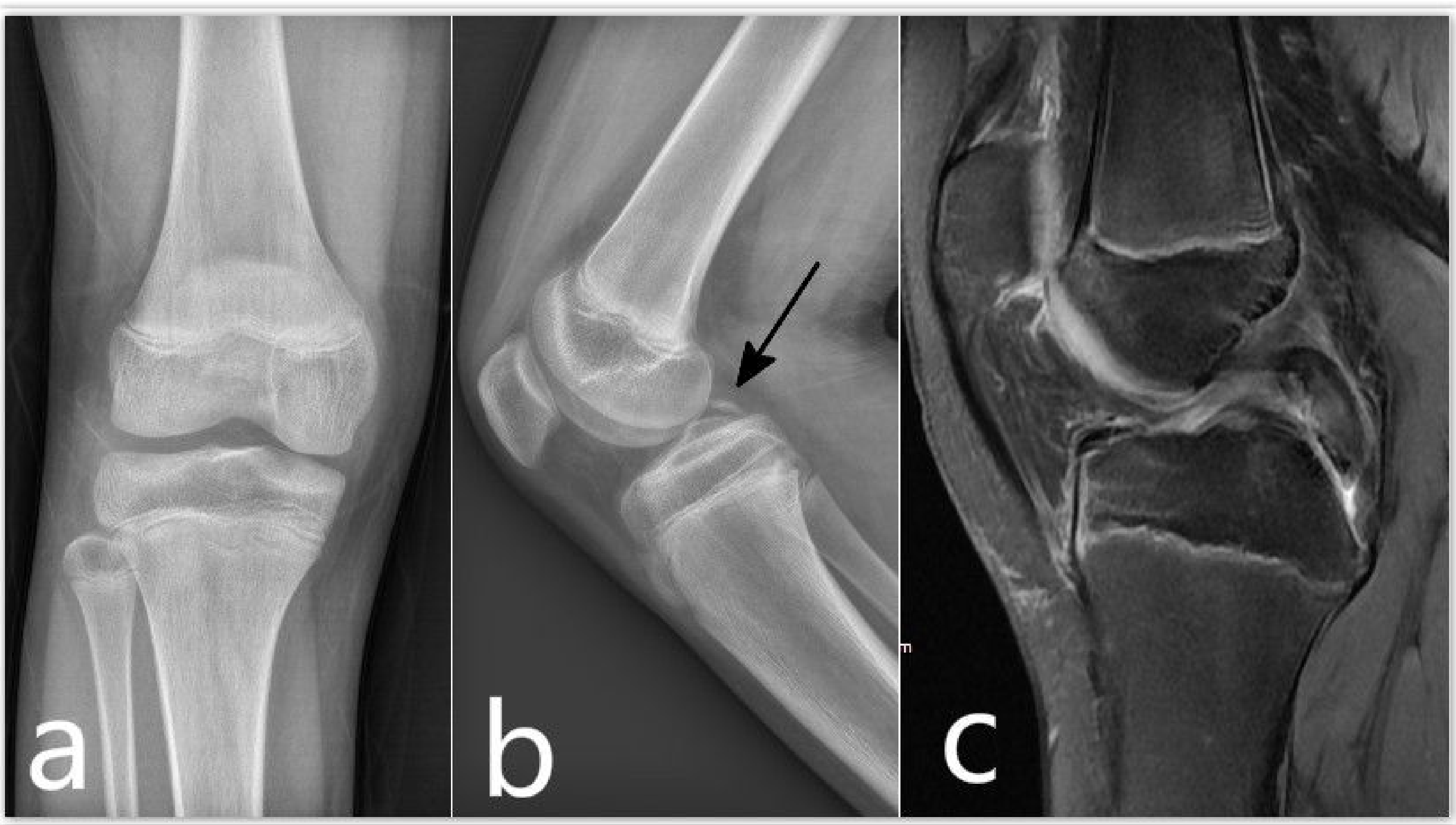
Table 1
Summary of anthropometric patient characteristics

| **Paramtere** | |
|---|---|
| Male:Female(n) | 13:6 |
| Age (years) | 33.2 ± 6.1 |
| Body mass index(Kg/m2) | 23.8 ± 3.2 |
| Interval from injury to surgery(days) | 4.5 ± 1.7 |

Table 2
Comparison of preoperative and final follow-up

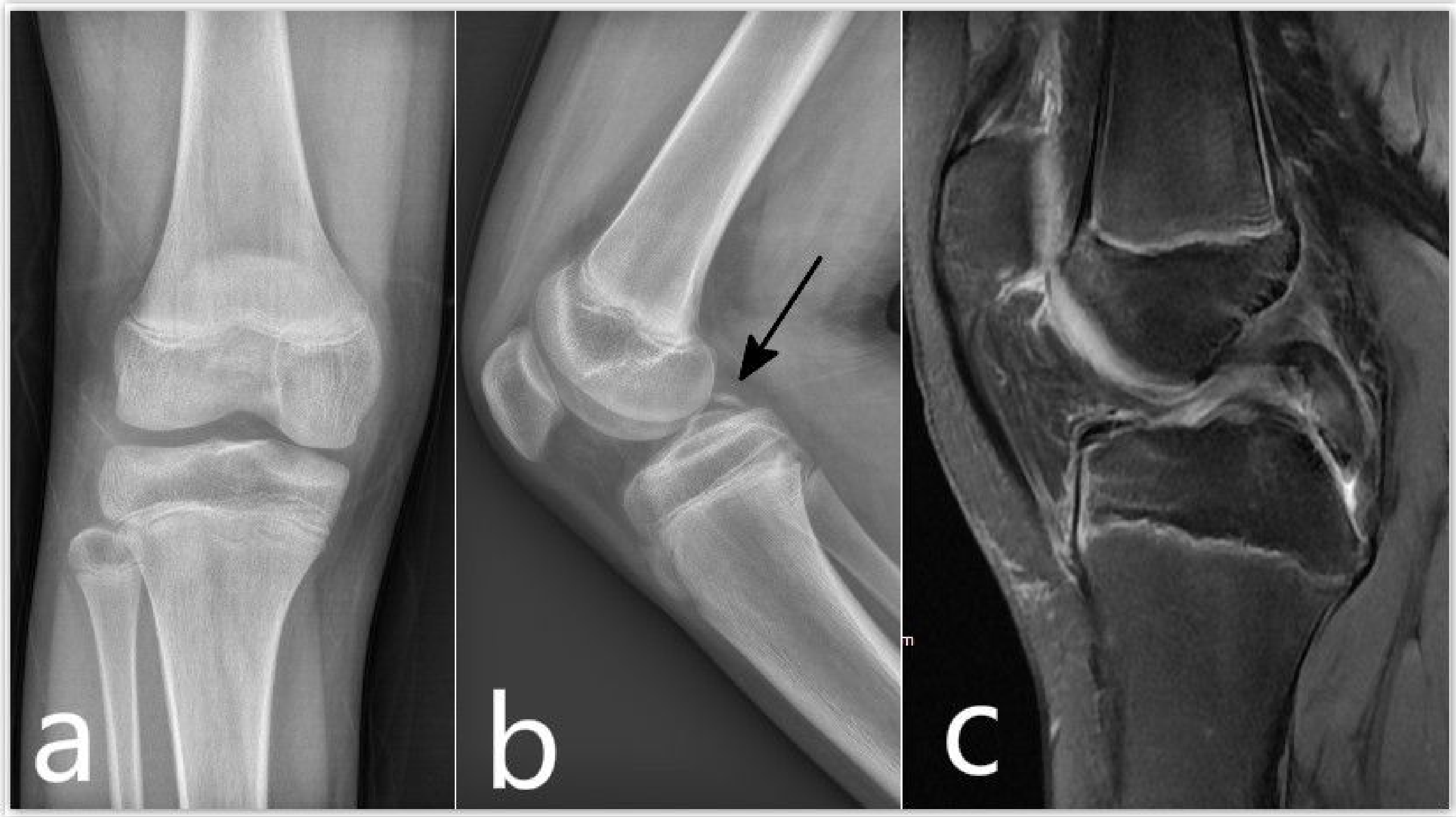
| | Pre-operative | Final follow-up | P-value |
|---|---|---|---|
| ROM | 0 | 154.5 ± 6.3 | 0.001* |
| Tegner score | 1.5 ± 0.9 | 7.3 ± 1.1 | 0.001* |
| Lysholm score | 30.1 ± 3.6 | 89.2 ± 5.3 | 0.001* |
| KT-2000 examination | 9.3 ± 2.2 | 1.2 ± 0.6 | 0.001* |
| IKDC | | | 0.001* |
| A(normal) | 0 | 18 | |
| B(nearly normal) | 0 | 1 | |
| C(abnormal) | 10 | 0 | |
| D(severely abnormal) | 9 | 0 | |
| * P < 0.05 | | | |
| ROM: Range of motion, IKDC: International Keen Documentation | | | |

## Figures



## Figure 1

Pre-operative anteroposterior(a) and lateral(b) radiographs and sagittal MRI(c) showing a posterior cruciate ligament tibial avulsion fracture (indicated by the arrows).

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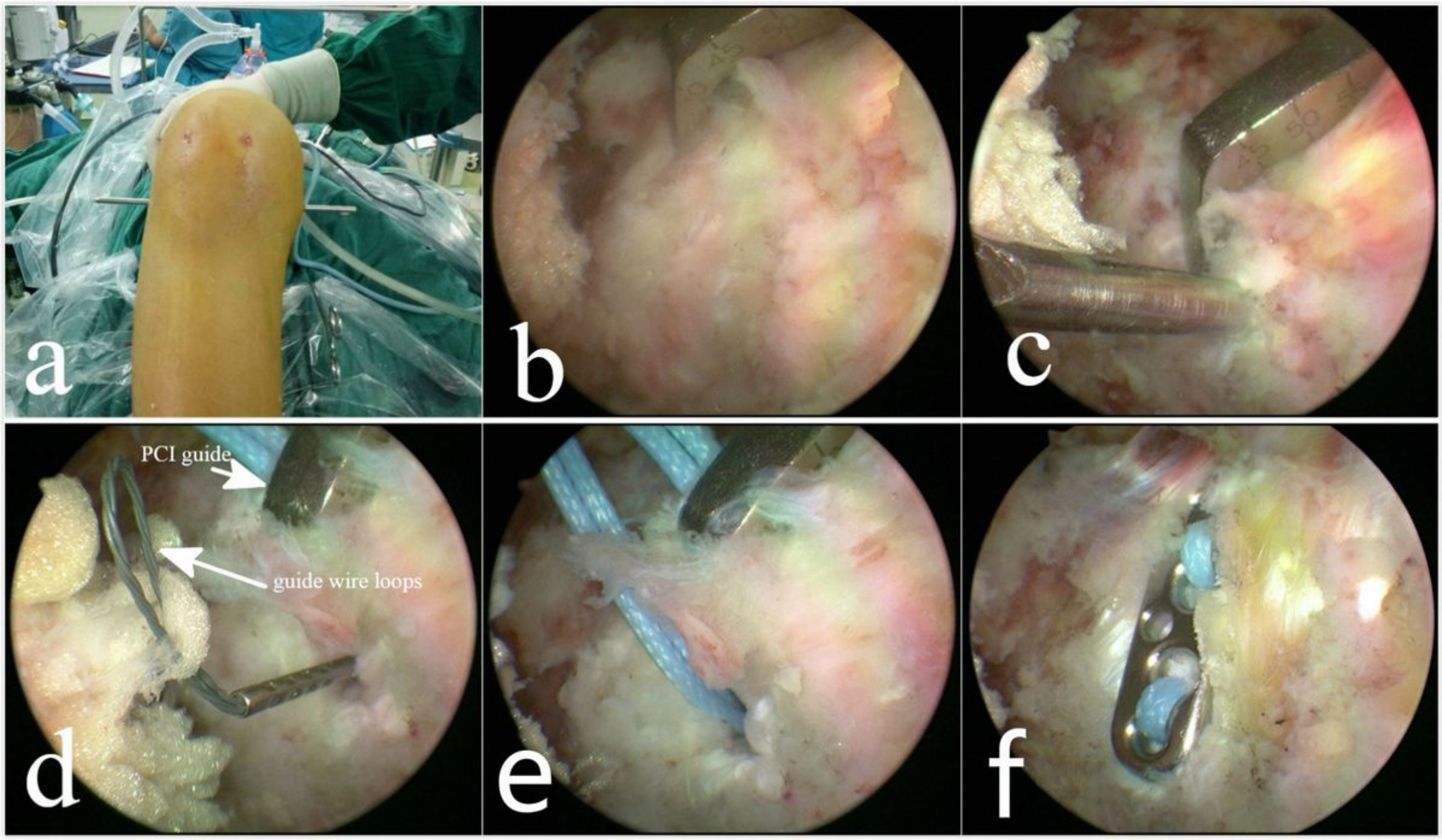
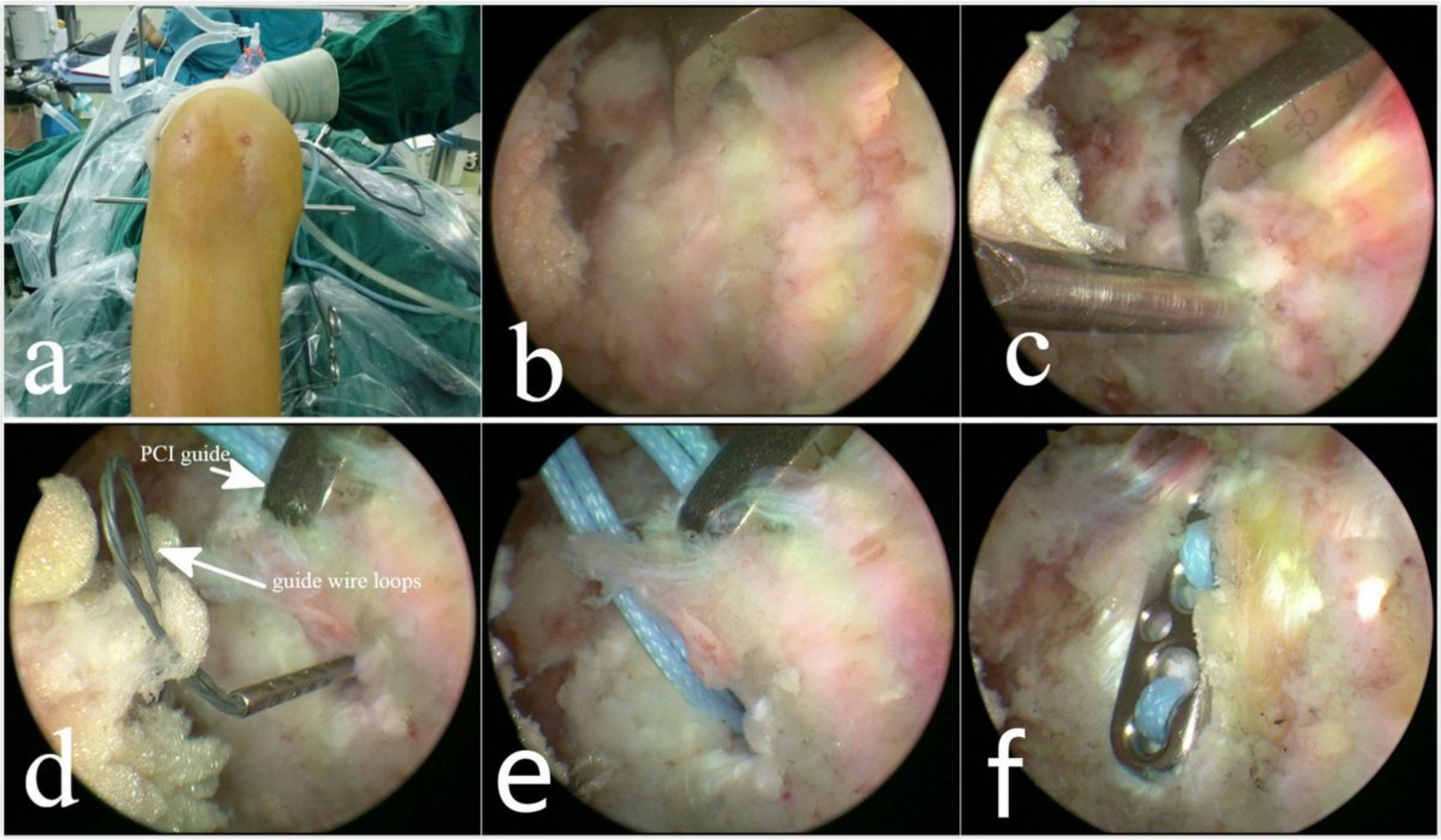



**Figure 2**

Arthoscopic images showing (a) after the switching stick is established the posterior trans-septal portal, (b) fracture fragments of anatomical reduction fixed by PCL guide tip, (c) use the PCL guide to establish two tibial tunnels at or across the fracture fragment, (d) the guide wire loops is passed through the tibial tunnel and brought out through the postero-medial door, (e) sutures with miniature steel plates pulled out through the tibial tunnel, (f) miniature steel plate is located above the fracture fragments, and the fracture fragments are compressed and fixed for anatomical reduction.

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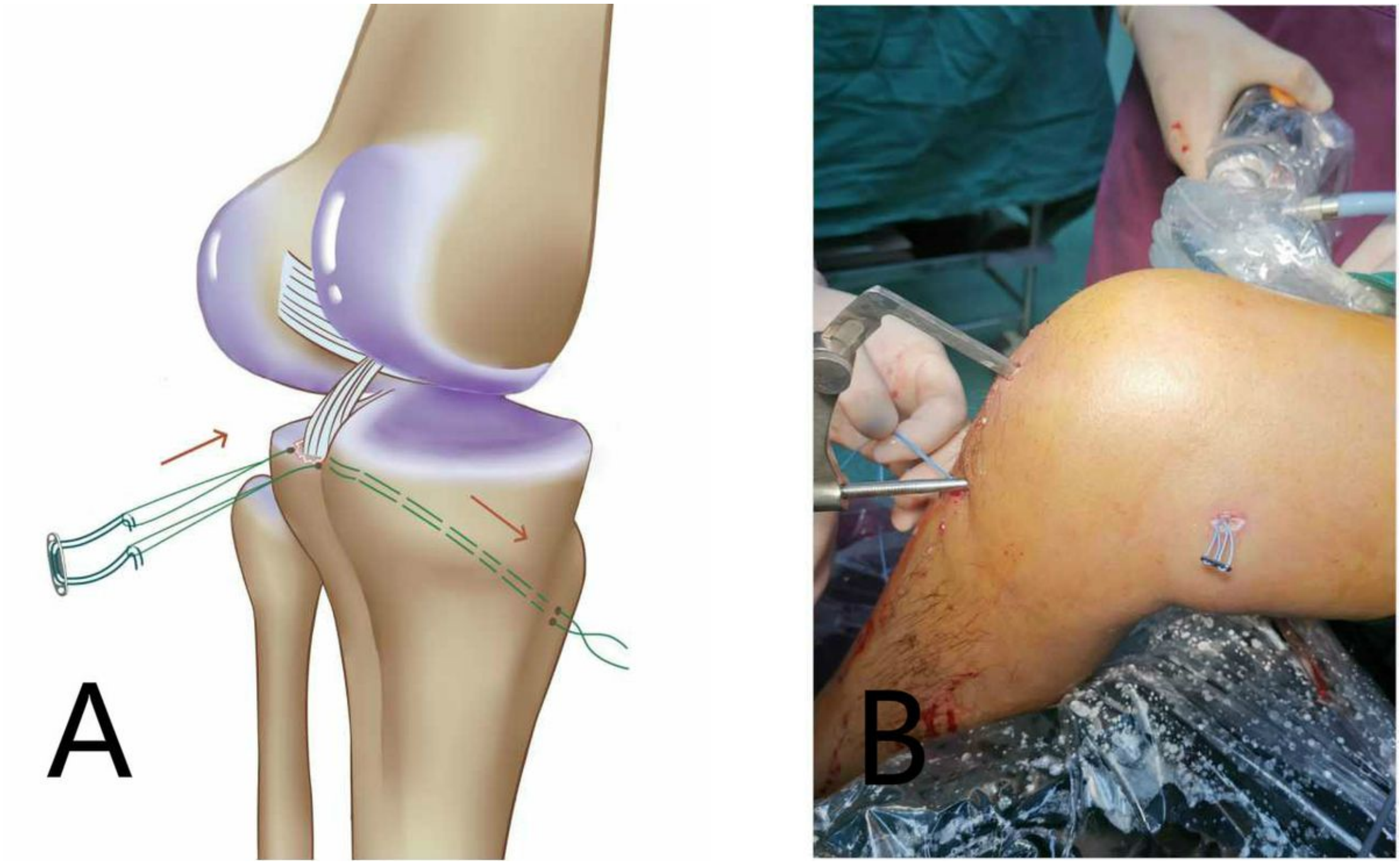


**Figure 3**

(A) Illustration shows the drawing of a miniature steel plate through the posterior medial portal. (B) Pull the suture through the tibial tunnel, tighten and pass the mini-plate through the posteromedial portal into the posterior compartment of the joint.

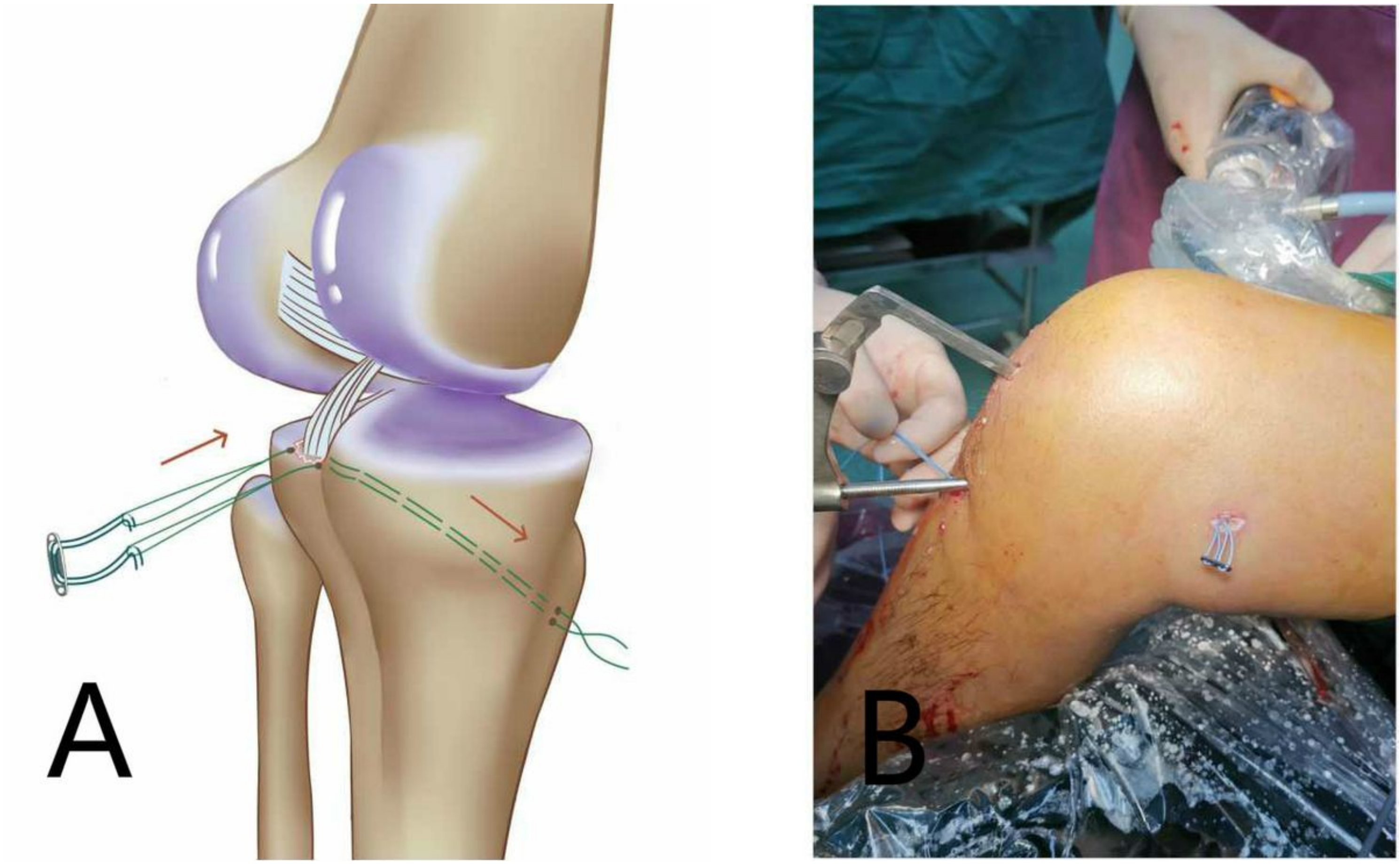


**Figure 3**

(A) Illustration shows the drawing of a miniature steel plate through the posterior medial portal. (B) Pull the suture through the tibial tunnel, tighten and pass the mini-plate through the posteromedial portal into the posterior compartment of the joint.


## Figure 4

Post-operative anteroposterior and lateral radiographs showing good avulsion fracture reduction at the distal insertion of the posterior cruciate ligament at the 24-month follow-up


## Figure 4

Post-operative anteroposterior and lateral radiographs showing good avulsion fracture reduction at the distal insertion of the posterior cruciate ligament at the 24-month follow-up