



Technical Note

Arthroscopic reduction of posterior cruciate ligament tibial avulsion fracture using two cross-linked pull-out sutures: A surgical technique and case series



Seung Joon Rhee^{a,*}, Jae Hoon Jang^a, Yoon Young Choi^b, Jeung Tak Suh^c

^a Department of Orthopedic Surgery, Biomedical Research Institute, Pusan National University Hospital, Busan, Republic of Korea

^b Department of Radiology, Pusan National University Yangsan Hospital, Yangsan, Republic of Korea

^c Department of Orthopedic Surgery, Busan Medical Center, Busan, Republic of Korea

ARTICLE INFO

Keywords:

PCL
Posterior cruciate ligament
Arthroscopic
Avulsion
Suture fixation

ABSTRACT

Surgical treatment of the posterior cruciate ligament (PCL) tibial avulsion fracture is challenging due to the deep-seated location of the lesion with complex adjacent anatomy and usually with small-sized bone fragment. We introduce a novel arthroscopic reduction technique using two cross-linked pull-out sutures (2XLPOS) through triple bone tunnels in posterior cruciate ligament (PCL) tibial avulsion fracture.

Posterior trans-septal portal was established following the four standard arthroscopic portals. Bilateral margins of the PCL with 1~2 mm margin from the border were penetrated using suture hook. Fiberwire sling tied with a No. 0 PDS knot was introduced anterior to the PCL by the two posteriorly pulled shuttle sutures. Three bone tunnels were drilled in the inferomedial, inferolateral, and apex edge of the avulsed tibial crater. Each end of the Fiberwire was drawn out through the inferomedial and inferolateral bone tunnel, respectively. Two ends of the No. 0 PDS were drawn out through the apex tunnel by the same manner. Fiberwire was tied on the anteromedial aspect of the proximal tibia with one strand of the No. 0 PDS placed underneath the Fiberwire knot. And, the No. 0 PDS loop was tied to complete cross-linking of pull-out construct.

Arthroscopic reduction of PCL tibial insertion avulsion fracture using 2XLPOS technique was performed in eleven patients. Mean range of motion at the first postoperative year was 126.8°. Mean Lysholm score, Tegner activity scale, and IKDC was 69.2, 4.2, and 58.1, respectively. Posterior instability decreased from mean 12.6 mm preoperatively to 3.2 mm at 1-year postoperative follow up. Radiographic union of the fracture site was confirmed in 11 cases. Our new surgical technique yielded good clinical and radiological outcome, and we consider it is unique in utilizing two cross-linked sling type pull-out suture constructs and triple bone tunnels for their passage.

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Introduction

Surgical treatment of the posterior cruciate ligament (PCL) tibial avulsion fracture is challenging due to the deep-seated location of the lesion with complex adjacent anatomy and usually with small-sized bone fragment. Various surgical techniques, from open reduction and internal fixation [1–3] to arthroscopic pull-out suture reduction [4–6] were developed during the evolution of surgical instruments and insight. However, to the best of our knowledge, achieving a stable and firm reduction construct of an avulsed bone fragment while minimising PCL bundle injury has not

yet been accomplished with the most recent arthroscopic reduction techniques. Therefore, we introduce an arthroscopic reduction technique using two cross-linked pull-out sutures (2XLPOS).

The aims of present work were to report a new arthroscopic reduction technique and the clinical results of its application in patients with PCL tibial avulsion fractures.

The cases

From January 2014 to December 2016, arthroscopic 2XLPOS fixation was performed for displaced PCL tibial avulsion fracture in 11 patients (Table 1). Nine male and two female patients were enrolled in this study. The mean age of the patients was 44 years (range, 19–63 years), and the mean

* Corresponding author at: Department of Orthopaedic Surgery, Pusan National University Hospital, 179 Gudeok-ro, Seo-gu, Busan, 602-739, Republic of Korea.
E-mail address: rheefury@naver.com (S.J. Rhee).

Table 1
List of Patients.

Number	Sex	Age	Knee	Cause	OP delay (day)	FU (Mo.)
1	M	45	Left	MVA	6	36
2	M	38	Left	MVA	12	34
3	M	40	Left	MVA	25	29
4	M	75	Left	Fall	22	27
5	M	55	Left	MVA	23	24
6	F	63	Right	Slip	36	20
7	M	23	Right	MVA	17	19
8	M	48	Right	MVA	14	16
9	F	52	Left	Fall	21	16
10	M	19	Left	MVA	7	14
11	M	28	Right	MVA	5	13
Mean		44			17.1	22.6

Cause: cause of injury; OP: operation; FU: follow-up; Mo.: month; MVA: Motor vehicle accident.

follow-up period was 22 months (range, 13–36 months). The cause of injuries were motor vehicle accident, fall from height, slipping down in eight, two, and one patient, respectively. Patients with isolated PCL tibial avulsion fracture with more than 5-mm displacement of the bone fragment were included in this study. Patients with PCL tibial avulsion fracture with less than 5-mm displacement or associated with distal femoral/proximal tibial fracture or older than 70 years were excluded from the surgical indication. Three-dimensional computed tomography (3D CT) and magnetic resonance imaging (MRI) were performed for all patients (Fig. 1). The diagnosis of PCL tibial avulsion fracture was confirmed by an experienced radiologist. The medical record and radiographic images of the patients were retrospectively reviewed. The ethical approval of this study protocol was granted by the Institutional Review Board of the institution. Retrospective consent from the involved patients were acquired during the outpatient visit. Pre- and postoperative functional results were evaluated using Tegner activity scale, Lysholm score, and the International Knee Documentation Committee (IKDC) knee ligament examination form. The knee range of motion (ROM) and instability was evaluated using Telos stress device. Radiographic results were evaluated by the serial true-lateral knee radiography obtained at 1, 3, 6, and 12 postoperative months. Fracture union was confirmed if no remaining fracture line was seen between the avulsed bone fragment and fracture bed in the radiography.

Surgical technique

The patient was placed in supine hemi-lithotomy position using unilateral leg holder in the intact leg with the leg on the lesion side hung in 90° flexed knee position. A thigh tourniquet was used. Standard anterolateral (AL) viewing portal was initially established. Subsequently, anteromedial (AM), posteromedial (PM), and posterolateral (PL) portals were established. The posterior transseptal portal (TS) was established by shaving the posterior septum, which was tented by a switching stick from the PL portal under PM portal visualisation, using a motorized shaver introduced through the AM portal. After opening the passage in the posterior septum, the arthroscope was advanced into the PL compartment, and the shaver was introduced into the PL compartment through the PL portal. The small window of the posterior septum was enlarged using the shaver, and adjacent synovium behind the PCL and fracture site hematoma was shaved to delineate the avulsed PCL fragment. A short crescent-shaped suture hook loaded with No. 1 polydioxanone (PDS) was introduced into the intercondylar notch through the AM portal under AL portal visualisation. The lateral border of the PCL 1–2 mm medial from the lateral edge and right above the avulsed bone fragment was penetrated anteriorly to posteriorly using the suture hook. After changing the viewing portal to PM portal, the PDS suture was advanced out of the suture hook tip and drawn out the PL portal using the suture retriever. Again, the short crescent suture hook loaded with another No. 1 PDS suture was introduced into the intercondylar notch through the AM portal under AL portal visualisation. The medial border of the PCL 1–2 mm lateral from the medial edge and right above the avulsed bone fragment was penetrated, and the PDS suture was advanced under PM portal visualisation (Fig. 2). The second PDS suture was drawn out of the PL portal using the suture retriever. After changing the viewing portal to the AL portal, the anteriorly deployed part of the two PDS sutures were drawn out of the AM portal together using suture retriever to ensure the same passage of the sutures without entangled soft tissue. We recommend using a cannula from the suture hook introducing process to enhance suture hook handling and to avoid soft tissue entangling. Alternatively, the PCL penetration can be performed through the PL working portal-based procedure posteriorly to anteriorly using a curved suture hook if the operator is familiar with the PM portal view of the PCL; however, suture retrieval is difficult because the anterior aspect of the PCL right above the avulsed fragment can be hardly visualised directly. Each PDS suture drawn out of the AM



Fig. 1. Preoperative diagnosis of PCL tibial avulsion fracture is confirmed in plain radiography (A), 3D CT (B), and magnetic resonance image (C).

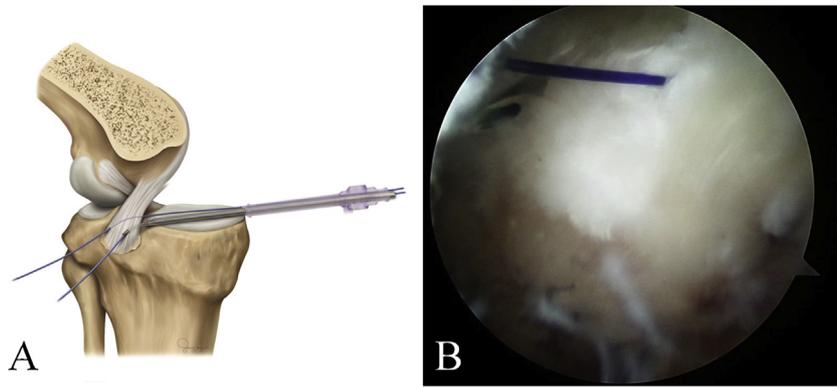


Fig. 2. (A) Illustration showing a short crescent suture hook loaded with a No. 1 polydioxanone (PDS) suture, which is introduced into the intercondylar notch through AM portal cannula. The medial border of the PCL 1–2 mm lateral from the medial edge and right above the avulsed bone fragment is penetrated, and the PDS suture is advancing. Another hook loaded with No. 1 PDS was already located penetrating the lateral border of the PCL 1–2 mm medial from the lateral edge and right above the avulsed bone fragment and drawn out the PL portal. (B) A No. 1 PDS suture has penetrated the medial border of the PCL, and a short crescent suture hook just pierced the lateral border to introduce another No. 1 PDS suture in the arthroscopy.

portal was tied with two other ends of a Fiberwire (Arthrex, Naples, FL, USA) suture as leading sutures. The third PDS suture was tied to the middle of the Fiberwire sling. Subsequently, the two leading sutures were simultaneously drawn out from the PL portal, and a Fiberwire sling tied with PDS was introduced in front of the PCL bundle (Fig. 3). The two crura of Fiberwire were drawn out of the PL portal, and the two crura of the tied PDS remained at the AM portal. The bony crater in the posterior proximal tibia was debrided using a curved shaver while lifting the avulsed bone fragment with Fiberwire sling traction from the PL portal. Subsequently, the PCL tibial tunnelling guide (PCL guide) was introduced into the posterior compartment from the AM portal through the intercondylar notch. A proximal tibia anteromedial accessory skin incision for bone tunnel drilling was made. Two bone tunnels were drilled aiming the inferolateral and inferomedial corners of the crater rim (usually the 4 and 8 o'clock positions) using a PCL-guided 2.4-mm drill bit, and another tunnel was drilled aiming the apex of the crater (Fig. 4). Each Fiberwire strand was pulled into the inferomedial and inferolateral bone tunnel respective of their penetration side in the PCL and drawn out of the tunnel aperture in the anteromedial tibial cortex using a steel Lassowire (Arthrex, Naples, FL, USA). Two PDS strands were pulled into the apex tunnel and drawn out of the tunnel aperture in the anteromedial tibial cortex in the same manner (Fig. 5). The apex tunnel could have variations of a single tunnel (Fig. 6A) or two separate tunnels (Fig. 6B) based on the

fracture pattern and avulsed bone fragment size. The avulsed bone fragment was pulled inferiorly and posteriorly to reduce the fragment in the crater by the Fiberwire traction under PM portal visualisation of the posterior compartment (Fig. 7). Performing passive knee range of motion from 90° flexion to nearly full extension enhanced the reduction process. While maintaining fine reduction under arthroscopic view, the first pull-out suture loop was accomplished by firmly tying the Fiberwire strands intervening a metal button upon the bone bridge and one strand of anteriorly pulled out PDS suture on the anteromedial tibial cortex. Finally, the second pull-out suture loop and cross-linking of the two pull-out suture loops were completed by tying the PDS suture to embrace the Fiberwire knot on the metal button (Fig. 8) (Video 1).

Rehabilitation

Postoperatively, the knee was immobilized in a fully extended position for 3 weeks. Isometric quadriceps strengthening exercise in the knee-extended position was encouraged from the immediate postoperative phase. Passive range of motion in the prone position was allowed from the third postoperative week. Partial weight bearing using crutches was allowed on the sixth postoperative week, and full weight bearing in PCL brace was allowed on the third postoperative month.

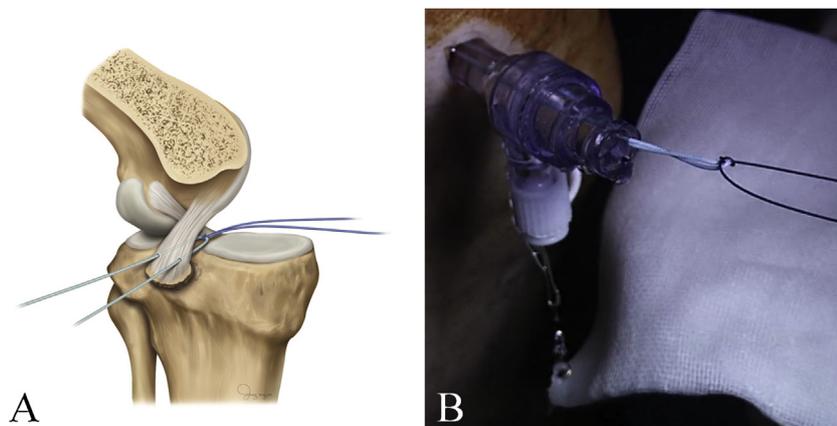


Fig. 3. (A) Illustration showing a Fiberwire sling tied with another No. 1 PDS suture, which is drawn into the joint space by prior two PDS leading sutures to be seated in front of the PCL. (B) Before Fig. 3 (A), the Fiberwire sling was tied with No. 1 PDS suture and was about to be drawn into the AM portal cannula.

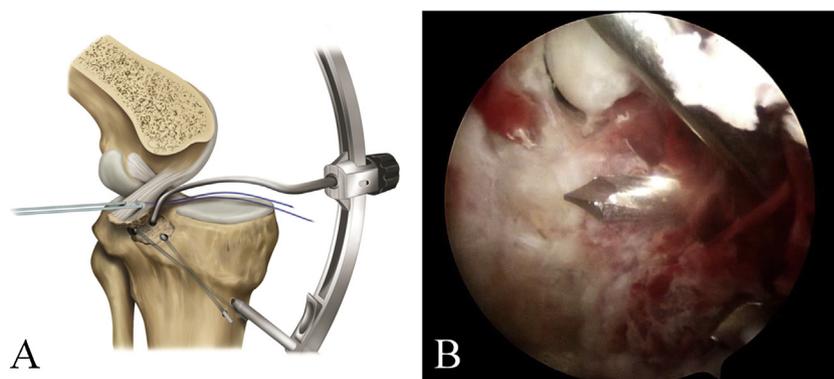


Fig. 4. (A) Illustration showing apex tunnel targeting using PCL tibial guide while the avulsed bone fragment is elevated by Fiberwire sling traction from the PL portal direction. Guidepins are already inserted in inferomedial and inferolateral tunnels. (B) Guidepins for inferomedial and inferolateral tunnels are placed in the relevant positions of fracture bed margin, and the PCL tibial guide is located to drill the apex tunnel in the arthroscopy.

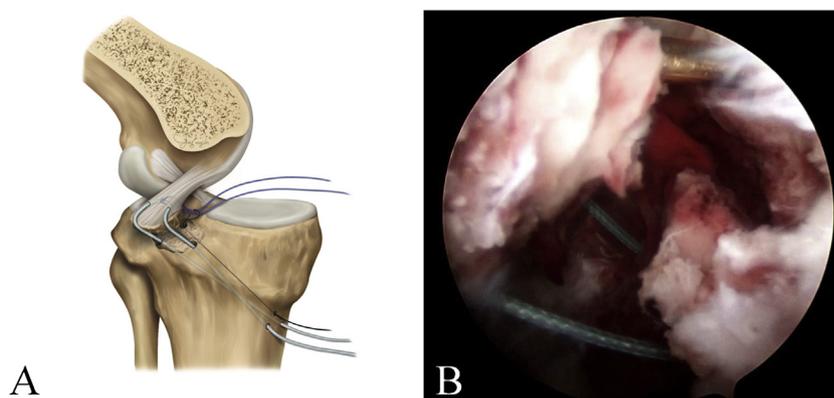


Fig. 5. (A) Illustration showing the pulling out of the sutures. Two crura of a Fiberwire were drawn out through the tunnels of matching direction, and a lassowire is about to pull out the cross-tied No. 1 PDS suture. (B) A small-diameter metal cannula was inserted through the apex tunnel to deliver the lassowire. The inferolaterally and inferomedially pulled out Fiberwire crura are seen underneath.

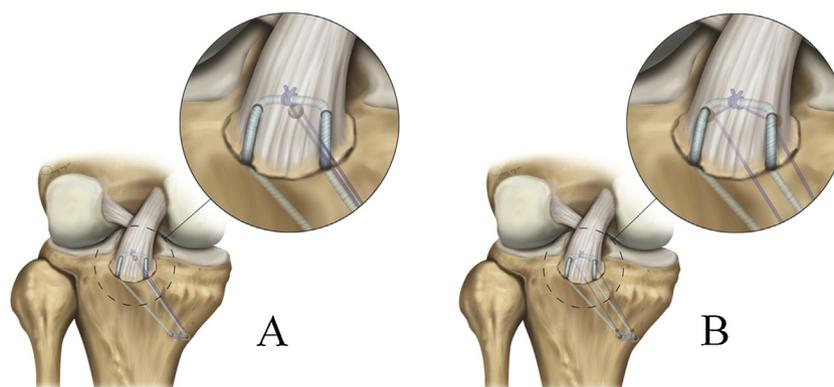


Fig. 6. Illustration showing the different final constructs based on the possible variation in the apex tunnel. (A) Single-apex tunnel, (B) Double-apex tunnel.

Statistical analysis

Statistical analyses were performed using SPSS software version 22.0 (SPSS Inc., Chicago, IL, USA). A p value <0.05 was considered as statistically significant difference. The pre- and postoperative functional results were compared using Wilcoxon test. Intraclass correlation coefficient was calculated to ensure intra- and inter-observer reliabilities in measuring instability (Telos stress test) and radiographic union.

Results

The intraclass correlation coefficient of this study ranged from 0.878 to 0.955 and from 0.803 to 0.897 for intra- and interobserver reliabilities, respectively. The mean knee range of motion increased from 30° (range, 10° – 80°) preoperatively to 126.8° (range, 95° – 145°) postoperatively ($p < 0.05$). The Tegner activity scale score improved from 0.9 (range, 0–2) to 4.2 (range, 2–6) ($p < 0.05$). The Lysholm score was 32.4 (range, 12–47) and 69.2 (range, 52–84).

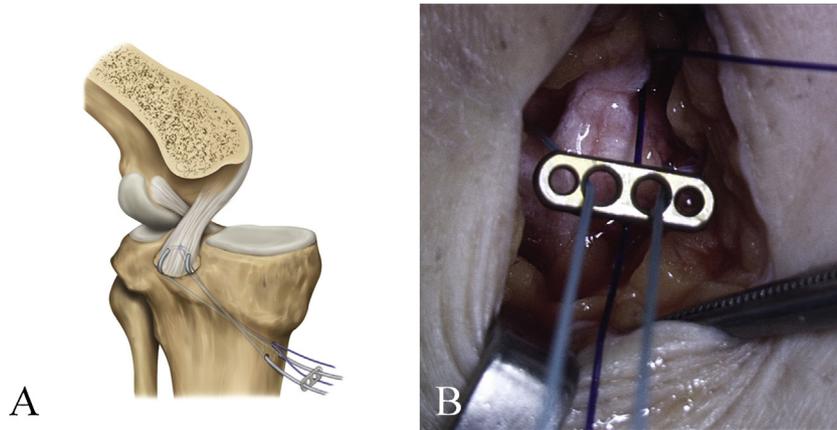


Fig. 7. Illustration (A) and photo (B) showing the deployment of pulled out suture strand in relation with metal button. Fiberwire strands pass through the holes in the button while a strand of No. 1 PDS passes down under the metal button.

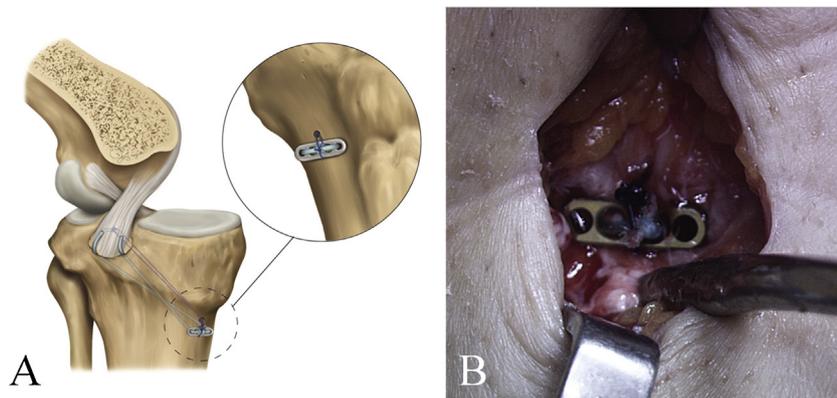


Fig. 8. Illustration (A) and photo (B) showing the construct of the anterior crosslink. The Fiberwire knot is tied intervening the metal button, and the PDS knot is embracing around the Fiberwire knot.

pre- and postoperatively, respectively ($p < 0.05$). The IKDC score was 22.7 (range, 11–37.4) and 58.1 (range, 41.8–74.8) pre- and postoperatively, respectively ($p < 0.05$). Radiological bone union was confirmed in 11 patients (Figs. 9 and 10). The mean side-to-

side difference in posterior stress radiography using Telos device decreased from 12.6 mm (range, 5.1 mm – 18.1 mm) preoperatively to 3.2 mm (range, 0 mm – 7.9 mm) postoperatively ($p < 0.05$) (Table 2). Major complications, including neurovascular injury and infection, were not reported.

Discussion

PCL tibial avulsion fracture is generally known as a relatively rare injury; however, it is common in some regions where high-speed motor vehicles are dominant as modes of transportation [7]. Despite the necessity of prompt surgical reduction in many cases, achieving a satisfactory result for PCL tibial avulsion fracture is still challenging. The complex anatomy of the PCL and adjacent structures, including the popliteal artery, posterior tibial nerve, and posterior femoral condyles, are forming natural obstacles against surgical approach. Moreover, in cases with small-sized avulsed bone fragment, there are few methods to purchase and reduce the fragment in its original position without shattering the fragment or fraying the inserting PCL fibre. Recent advances in arthroscopic surgical technique made the approach through the PM, PL, and TS portals familiar to the knee surgeons, and several studies reported arthroscopic reduction techniques that are far less invasive than open surgical technique [4,5,14–18], [6–13]. Among these, arthroscopic suture reduction techniques are especially advantageous in the treatment of small bone fragment–PCL avulsion fractures. In PCL avulsion fractures with relatively small



Fig. 9. Immediate postoperative plain radiography (A) showing fine reduction of the avulsed bone fragment in the fracture bed. One-year postoperative plain radiography (B) showing complete union of the bone fragment.

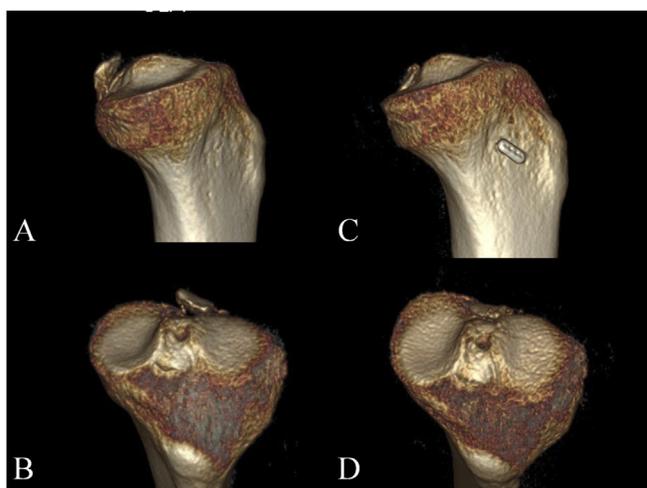


Fig. 10. Fine reduction of the avulsed bone fragment was confirmed by comparing the preoperative sagittal (A) and axial (B) plane 3D CT reconstruction images to the postoperative sagittal (C) and axial (D) plane 3D CT reconstruction images.

Table 2

Results.

Parameter	Preoperative	1-Year Postoperative	P-value
ROM	30° (10°–80°)	126.8° (95°–145°)	<0.05
Lysholm	32.4 (12–47)	69.2 (52–84)	<0.05
Tegner	1 (0–2)	4.2 (2–6)	<0.05
IKDC	22.7 (11–37.4)	58.1 (47.8–74.8)	<0.05
Instability	12.6 mm (5.1 mm–18.1 mm)	3.2 mm (0 mm–7.9 mm)	<0.05

ROM: range of motion.

or thin bone fragment, direct purchase of the fragment is nearly impossible due to the lack of proper fixation device and the risk of shattering the fragment despite several reported techniques [8,9,11,13,17]. Indirect reduction techniques using arthroscopic suture fixation could be alternatives for direct fixation techniques in these circumstances by grabbing and pressing the avulsed bone fragment through multiple traversing sutures [4,5,10,12]. However, some points are questionable in the process of prior suture fixation techniques. First, techniques approaching through a single (mainly the PM) compartment necessitated double PM portals to visualise the fracture site and to handle the instruments simultaneously, and they could not fully visualise the fracture site [6,10]. 2XLPOS technique utilised posterior transseptal approach through the PL and PM portals, which can provide full visualisation of the fracture site landscape while avoiding the crowded double PM portals. Second, multiple suture hook penetrations traversing the PCL

bundle mediolaterally above the tibial insertion often cause substantial injury to the PCL bundle fibre and make the whole operative procedure useless [4,5,10]. Techniques using wrapping-around suture are technically demanding and unreliable because the suture does not directly hold the PCL bundle nor the fragment [12]. Differently from them, in the 2XLPOS technique, the suture hook only pierces the remnant PCL bundle anteroposteriorly at two points, which minimises the risk of PCL bundle transection injury. Moreover, Fiberwire sling, which is introduced in front of the PCL bundle by the shuttle relay of the above PCL piercing PDS sutures, is very efficient in pulling down the avulsed bone fragment. The Fiberwire sling embraces most of the PCL tibial insertion bundle and pulls the whole avulsed fragment anteriorly downward while controlling the sagittal plane rotation of the fragment to align with fracture bed. The Fiberwire strands posteriorly penetrating the PCL cover and push the bone fragment from the backside and firmly settle it into the fracture site similar to the shoulder straps in a backpack. Finally, single or double bone tunnels in the previous pull-out suture techniques cannot resist the flipping or rotational displacement of the bone fragment. Displacement cannot be prevented effectively even with multiple sutures. However, in 2XLPOS technique, triple bone tunnels enable to confer much more rotational stability to the bone fragment and to control (push over) the anterior part of the bone fragment better. To the best of our knowledge, 2XLPOS technique is the first to utilise triple bone tunnels. Additional suture (PDS in this article) tied on the Fiberwire sling is eventually drawn out of the apex tunnel and cross-tied with Fiberwire knot on the anteromedial cortex of the proximal tibia. In this step of the procedure, the knot formed in the middle of the Fiberwire sling in front of the PCL tibial insertion acts as a pressurizer on the bone fragment, and cross-tying on the tibial cortex completely pull-and-push the avulsed bone fragment against the fracture site. Hence, the apex tunnel, which comprises the triple bone tunnel, is an essential part of the 2XLPOS technique (Table 3).

Our study is limited by the small number of cases and non-comparative single-arm reports of surgical results.

Conclusion

In conclusion, arthroscopic reduction of PCL tibial insertion avulsion fracture using 2XLPOS technique yielded good clinical and radiographic outcome. We consider this technique is unique in technique because it utilises sling traction and crosslinking through triple bone tunnels.

Conflict of interest

None.

Table 3

Pearls and pitfalls of 2XLPOS technique.

Pearls	Pitfalls
A strand of Fiberwire provides sufficient tensile strength to maintain the reduction construct unless the outside knot is untied, or abnormal sudden excursion of the PCL occurs.	Cannula should be used from the introduction of short crescentic suture hook to avoid the soft tissue entangling in the Fiberwire sling introduction through the AM portal. Cannula also can help avoid penetrating ACL and to make a subtle change in suture hook piercing point in the PCL insertion.
Try near full extension of the knee to enhance the fine reduction of the avulsed bone fragment while the pull-out traction force is provided.	Pick the PCL piercing points as far as possible from each other. Leave 1–2 mm margin from each border. Points too adjacent to each other rupture the fibre in between, and the procedure fails.
Carefully select the location of the two inferior tunnels to achieve two goals of pulling down the bone fragment while pressing it like shoulder straps.	Use a metal button in the above cortical crosslinking tie to avoid erosive collapse of bone bridge between tunnels, and to avoid crosslinking band rupture due to attrition.

Acknowledgement

None.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.injury.2018.11.022>.

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