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Research Article

Reduction Technique of Atypical Irreducible Posterolateral Quadrant Dislocation in Proximal Tibial Fracture with Entrapment of the Popliteal Tendon

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Summary

Treatment of proximal tibia fractures with involvement of the posterolateral quadrant remains challenging due to the difficulty in achieving adequate reduction and fixation. We describe a rare but special fracture pattern with an irreducible Posterolateral Quadrant Dislocation (PLQD) in proximal tibial fractures with entrapment of the popliteal tendon. In our case series, we present four cases with a PLQD treated in a level one trauma center. All patients were treated using an extended lateral transfibular approach to attain anatomical reduction and fixation of the posterolateral fragment was performed with rim plates or posterolateral buttress plates. All patients showed a good to excellent clinical outcome in the follow up and all fractures healed uneventfully with no signs of instability. In conclusion, we strongly recommend an extended lateral approach for direct visualization of the posterolateral corner and for adequate manipulation of the fragment and the popliteal tendon.

Keywords: Entrapment popliteal tendon; internal fixation; open reduction; Proximal tibial fracture; posterolateral quadrant dislocation.

Introduction

Proximal tibia fractures are frequent injuries requiring treatment at specialized trauma centers. Up to 15% have fracture involvement of the posterolateral tibial plateau [1,2]. Often, tibial plateau fractures are described based on their fit in the "Arbeitsgemeinschaft Osteosynthesefragen" (AO/OTA) [3], Schatzker [4], or Moore [5] classification systems. The first two classification systems describe frequent unicondylar and bicondylar patterns. Moore's classification describes patterns specific to fracture-dislocations. While each classification includes patterns with lateral condylar involvement, there is no established classification focusing on Posterolateral Quadrant Dislocations (PLQD). Fracture-dislocations occur after high energy trauma and are often combined with severe soft tissue damage [5]. Prior studies report entrapment of tendons in dislocated fragments after high energy trauma in other anatomical regions such as pilon, calcaneal or distal radius fractures [6-8]. To our knowledge, there is no prior report of entrapment of the popliteal tendon causing a PLQD in proximal tibial fractures.

Generally, sufficient anatomical articular reduction and stable fixation of proximal tibial fractures lend more stability [9] and better functional outcome [10,11]. This is especially true in

posterolateral fracture fragments [12]. However, it can be more difficult to achieve these goals if there is clinically significant posterolateral plateau involvement. This is because of anatomic constraints imposed by cover by the fibular head, neurovascular bundle and posterolateral ligamentous structures in the corner region. However, in some studies direct visualization and manipulation using an extended lateral approach lead to better reduction, fragment specific stabilization, and improved clinical and functional outcomes [13]. In this study, we present a rare but not previously described fracture pattern with an irreducible PLQD due to interposition of the popliteal tendon into the fracture zone. Based on this experience, the extended lateral approach is recommended in PLQD fracture patterns due to the possibility of an entrapped popliteal tendon. Furthermore, we want to illustrate the technique of direct visualization and manipulation of the posterolateral quadrant in this fracture pattern using an extended lateral approach.

Methods

A retrospective cohort study at a level one trauma center was performed. All patients who were operated on a proximal tibial fracture between January 2009 and December 2019 were eligible for inclusion. Exclusion criteria were mal- or non-union and absence of written informed consent. The study was in accordance with the ethical guidelines (BASEC-Nr. 2021-00928). Patients were identified using our prospective trauma database. Baseline characteristics (patient age, gender, trauma mechanism, type of fracture including concomitant injuries, treatment, and complications) were retrieved from the electronic hospital patient files. Fractures were classified according to the official AO/OTA classification system. [14]The primary outcome parameter was anatomical reduction of the PLQD. Secondary outcome parameters were non-union of the tibial head and clinical outcome scores using Rasmussen's functional score [15], Lysholm-Score [16] and the Tegner activity Score [17]. A minimum of 12 months follow-up was required.

Technique

Due to the high energy nature of this special fracture pattern an external fixator should be applied first as part of a two-staged procedure. Computed tomography (CT) examination should ideally be carried out after the joint-bridging external fixator has been applied (span-scan-plan) [18]. Definitive stabilization should only be performed when the edema has subsided and the skin starts to wrinkle (positive wrinkling sign).

Patient positioning: The external fixator was removed under general anesthesia. Depending on the fracture pattern, patients were positioned either supine or lateral if a concurrent medial approach was needed eventually. A pneumatic inflatable was placed underneath the operative knee during the posterolateral approach to induce varus opening of the lateral joint line with gravity. The leg was prepared circumferentially from toes to midthigh and draped free. The image intensifier was placed on the side of the uninjured leg and rotated for antero-posterior and lateral views.

Surgical Approach: Using a pneumatic tourniquet, a lateral extended approach was performed. A longitudinal incision was made just above the biceps tendon contour and the fibular head. Full-thickness subcutaneous tissue flaps were raised until the iliotibial band was exposed and incised above the peroneal nerve which was normally already shining through. The peroneal nerve was mobilized and the peroneus longus muscle was detached from the fibula to gain access to the fibular head. In two cases the fibular neck was osteotomized obliquely under visual control of the peroneal nerve and the fibular head was reflected proximally with the biceps tendon and the lateral collateral ligament complex after releasing the capsule of the tibiofibular joint. In two cases we used a concomitant fibular neck fracture instead of an osteotomy. Intraarticular visualization of the posterolateral quadrant follows elevation of the tibialis anterior muscle from the anterolateral aspect of the tibia and a submeniscal arthrotomy. The entrapment of the popliteal tendon between the dislocated posterolateral fragment and the tibial plateau could be directly visualized at this step.

Reduction Strategy: After application of traction on the popliteal tendon, either manually, with an elevator or using a vessel loop, the displaced posterolateral fragment could be reduced beneath the tendon ventral to the tibial shaft. Through this extended lateral approach, an anatomical reduction of the PLQD could be achieved under visual control. The posterolateral fragment was then preliminarily transfixed by K-wires. Intraoperative orthogonal imaging with fluoroscopy verified the anatomical reduction.

Plate positioning and fixation: Internal fixation of the posterolateral fragment was with either one third 3.5 mm tubular plates or 2.4 mm variable-angle locking compression (VA-LCP) plates in a rim plate function. The plates were contoured according to the size and shape of the posterolateral plateau using bending devices while trying to avoid hole deformation. The plate was positioned closest to the joint line. The size and length of the rim plate was defined for the placement of ideally >2 screws directed through the posterolateral fragment preventing collapse and rotational stability [19]. In one case the posterolateral fragment was stabilized using a 3.5 mm T-shaped-LCP which was contoured according to the fragment size. The plate was fixed with a conventional screw to the tibial shaft and two locking head screws were inserted into the fragment.After the posterolateral fragment was sufficiently stabilized, the remainder lateral plateau fracture was also treated with a buttress plate (3.5 mm LCP in double

plating technique lateral and medial, 4.5 mm LCP in single plating technique solely lateral). The fibular head was finally reduced and fixed with a 3.5 mm intramedullary lag screw and a fibulotibial 3.5mm screw in three cases and with a tension band fixation in one case. The wound was closed in layers with drains left intraarticular and subfascial. Depending on the fracture pattern with concomitant fracture medially, the extended lateral approach can be combined with an anteromedial or posteromedial approach and subsequent plate fixation. **Postoperative Management:** After two days of bed rest with leg elevation, ambulation was started with toe-touch weight bearing (10-15 kg) using two crutches. The patients received a hinged knee brace with allowed range of motion from terminal extension to flexion of 90°. After six weeks, depending on the radiological follow up, the brace was removed and weight bearing was increased rapidly with full loading 10-12 weeks after initial surgery. Thrombosis prophylaxis (low-molecular-weight heparin) was recommended until full weight bearing was feasible. Routine follow-up took place at six, 12 weeks and one year after surgery in outpatients and was extended with further visits years after the index surgery. Conventional radiographs were taken at every outpatient visit. Implant removal was not performed routinely. Patients All patients were operated on by the same surgeon (C. S., chief of trauma). For clarifity, the surgical strategy and technique is explained with illustrations and case details to validate its feasibility. Two cases were selected out of four cases.

Case 1

A 52-year-old woman was involved in a skiing accident and sustained a multifragmentary, partial articular proximal tibial fracture with a PLQD (AO/OTA 41-B3, Schatzker II) and a concomitant proximal fibula fracture (Figure 1). After primary stabilization using a knee-bridging external fixator a CT scan was performed and showed the entrapped popliteal tendon (Figure 2). As soon as the soft tissue swelling subsided definitive surgery could be done on the fourth posttraumatic day. The patient was positioned lateral with a foamed tunnel device underneath on a radiolucent operating table. A non-sterilized pneumatic tourniquet was used and the leg was prepared circumferentially from toes to midthigh and draped free. An extended lateral approach through the concomitant fibular fracture was used for better visualization and accessibility of the PLQD. The popliteal tendon showed a clear barrier between the posterolateral fragment and the tibial plateau (Figure 3). Anatomical reduction was achieved by manual tension on the popliteal tendon and manipulation of the posterolateral fragment beneath the popliteal tendon. The posterolateral quadrant was stabilized using an anatomically bent 2.4 mm LCP rim plate which could be positioned close to the joint line starting from a central-posterior position. Anterolateral stabilization was done using an anatomically bent 3.5 mm T-shaped LCP with a buttress function. The fibula fracture was stabilized using a 3.5 mm interfragmentary screw and a 3.5 mm cortex screw with fixation of the fibular head to the tibial shaft. Bone union was achieved within 12 weeks. After 12 months the x-rays demonstrated complete remodeling of the tibial fracture zones with a non-union of the fibula head, which was clinically asymptomatic (Figure 4). The patient had an excellent clinical outcome and range of motion at 6 and 12 months postoperatively (Figure 4).


Figure 1: Case No.1: (A/B) Preoperative x-rays show the PLQD in a proximal tibial fracture (AO41-B3). (C/D) Postoperative x-rays after definitive stabilization through an extended lateral approach show anatomical reduction of the joint line.
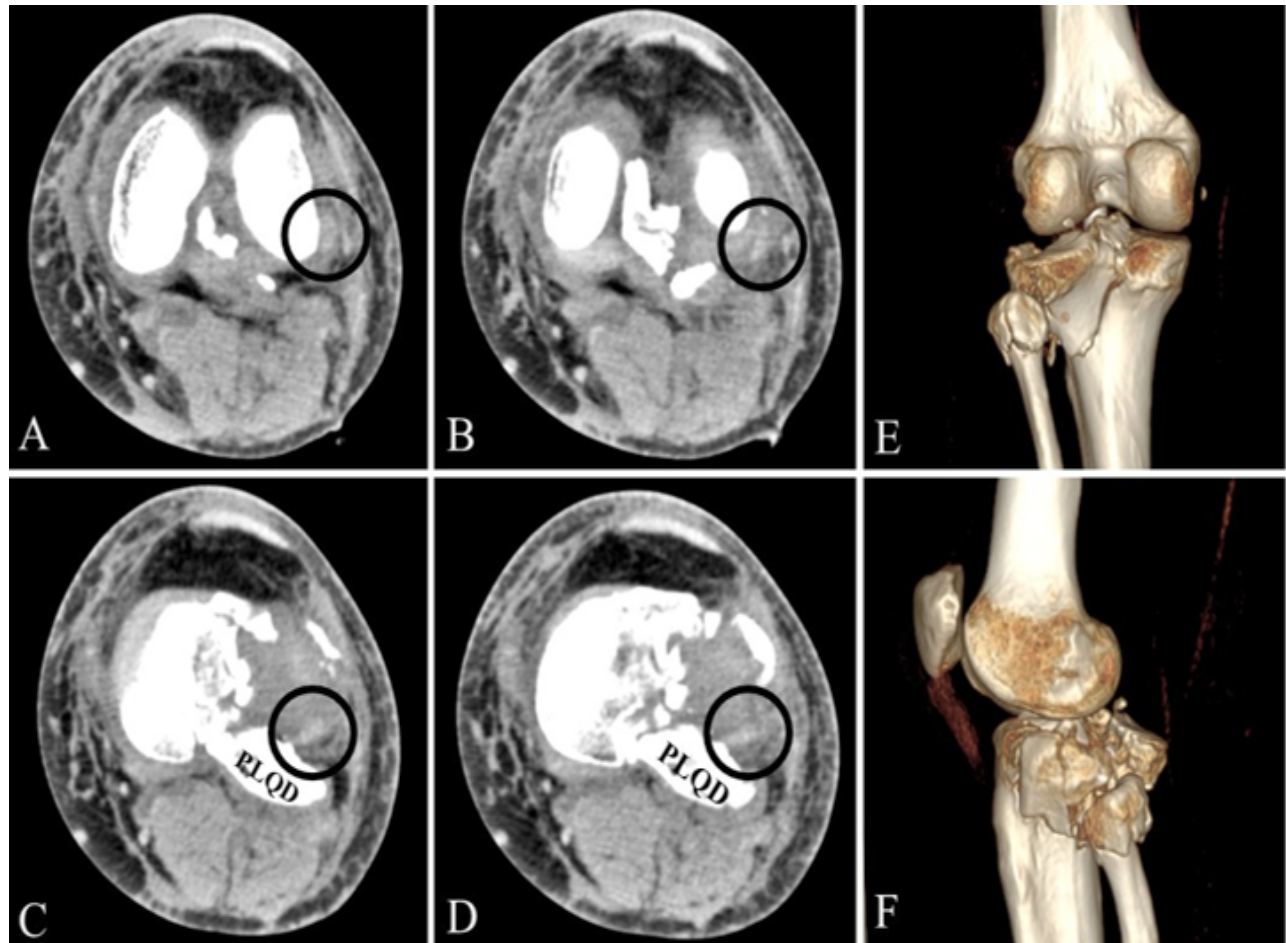
Figure 2: Case No. 1: (A-D) Axial CT-scans in soft tissue windows showing the entrapment of the popliteal tendon (black circle) beneath the disclocated posterolateral quadrant. (E/F) 3D computed tomography scan reconstruction
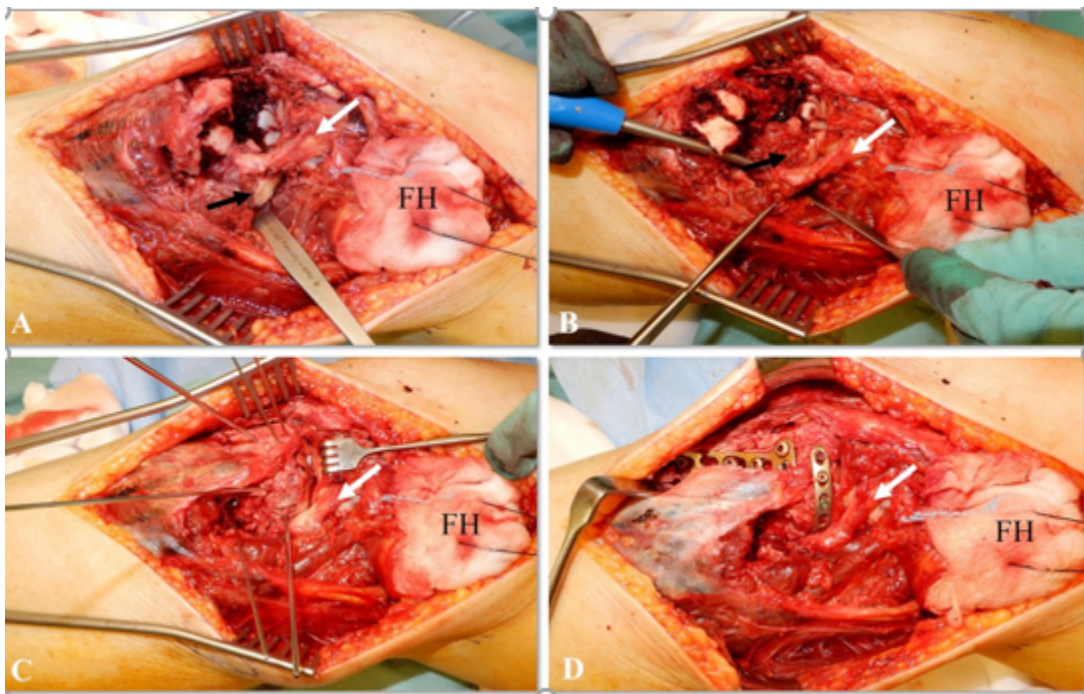
Figure 3: Case No.1: Extended lateral approach with good visualization of the posterolateral quadrant. The fibular head (FH) is reflected proximally. (A) The posterolateral fragment (black arrow) is dislocated. The popliteal tendon (white arrow) is entrapped building a barrier for anatomical reduction. (B) The posterolateral fragment can be reduced easily beneath the popliteal tendon. (C) Anatomical reduction and temporally fixation with k-wires. (D) Definitive stabilization using a 2.4mm LCP rim plate and anterolateral 3.5mm T-LCP buttress plate.

Figure 4: Case No.1: (A/B) Showing a satisfactory range of motion (E/F 0-0-140) 6 months postoperatively. (C/D) X-rays showing the healed tibial fracture with no significant step-off after 12 months postoperatively.

Case 2

A 49-year-old patient injured his right knee in a ski accident and sustained a proximal complete intraarticular tibial head fracture with a PLQD (AO/OTA 41-C3, Schatzker VI). Initial care was performed at an outside hospital prior to referral for a posterolateral fragment malreduction. At the peripheral hospital, accompanying compartment syndrome was treated with medial and lateral fasciotomies of all four compartments and a knee-bridging external fixator was applied. Definitive stabilization using a medial and lateral 3.5 mm LCP buttress plate was performed on day 14 after the initial trauma through an extended ventral approach (Figure 5). Postoperatively, an unacceptable malalignment of the PLQD was found and the patient was referred to our trauma center. During revision surgery, after implant removal, an extended lateral approach using a fibular osteotomy was performed by extending the preexisting skin incision of the lateral fasciotomy and the entrapped posterolateral fragment could be visualized. The displaced posterolateral fragment could be reduced anatomically beneath the entrapped popliteal tendon. Stabilization was achieved by using a bent one third 3.5 mm tubular plate in a rim plate function. Further stabilization was done by lateral and medial 3.5 mm LCP buttress plates. The fibular neck osteotomy was reduced and fixed with two 3.5 mm interfragmentary lag screws (Figure 5). Bone union was achieved within 12 weeks and complete remodeling could be demonstrated at 12 months postoperatively on standard x-rays (Figure 6).

Figure 5: Case No. 2: (A/B) X-rays show the definitive stabilization through an extended ventral approach with an inacceptable malreduction of the PLQD. (C/D) X-rays after revision surgery was done using an extended lateral approach. After releasing the entrapped popliteal tendon, anatomical reduction of the PLQD and fixation with a rim plate was achieved

Figure 6: Case No. 2: (A/B) X-rays show the 12 months follow up

Results

From January 2009 to December 2019, we treated 555 proximal tibial fractures (AO 41) in our level one trauma center. There were four cases (0.7%) with a PLQD with entrapment of the popliteal tendon. Patient demographics, fracture classification and intraoperative information are shown in Table 1. Mean age was 52.5 years (range 49 – 58). All injuries resulted from high-velocity trauma with three cases of skiing falls and one case of fall from high altitude. The fractures were classified according to the classification of AO/OTA[3] and Schatzker [4].In all four cases a two-staged procedure with primary stabilization using a knee-spanning external fixator and delayed definitive fixation after 3 – 8 days (mean 5.2 days) was achieved. Compartment syndrome of the lower limb occurred in one patient and was immediately treated surgically with medial and lateral fasciotomy of all four compartments. Intraoperative details and findings are presented in Table 2. In all four cases, an extended lateral approach was performed as presented above. In two a fibular osteotomy was done and the other two the associated proximal fibular fracture was used. In all cases sufficient reduction and fixation of the posterolateral fragment was achieved with rim plates and/or posterolateral buttress plates.

Case No.	Sex	Age	Mechanism of injury	Additional injuries	Classification	
					AO/OTA	Schatzker
1	W	52	Skiing	Monotrauma	AO 41-B3	II
2	M	49	Skiing	Monotrauma	AO 41-C3	VI
3	M	58	Fall from 100 meters	Polytrauma	AO 41-C3	VI
4	W	51	Skiing	Monotrauma	AO 41-B3	II
M: male, F: female						

Table 1: Demographic details and fracture patterns

Case No.	two staged procedure	Surgical Approach	Fixation of the tibial plateau	Associated knee injuries
1	Yes	Extended lateral approach (PFF)	2.4 mm LCP rim plate + anterolateral 3.5 mm T-LCP buttress plate	PFF, MCLR, LMT
2	Yes	Extended lateral approach (FO)	one third tubular 3.5 mm rim plate + 3.5 mm LCP lateral and medial buttress plates	Compartment syndrome
3	Yes	Extended lateral approach (PFF)	One third tubular 3.5 mm rim plate + cortical screws 3.5mm + lateral 4.5/5.0mm LCP buttress plate	Epineural hematoma CPN, III° open tibial shaft fracture
4	Yes	Extended lateral approach (FO)	Posterolateral 3.5 mm T-LCP buttress plate + anterolateral 3.5 mm LCP buttress plate + 3x anteroposterior 3.5 mm lag screw	LMT
CPN: Common peroneal nerve, FO: Fibular osteotomy, PFF: Proximal fibula fracture, MCLR: Medial collateral ligament rupture, LMT: lateral meniscus tear				

Table 2: Details of Surgery.

Case No.	Rasmussen Functional Score*	Lysholm Score Classificiation†	Range of Motion (degrees)
1	30 (excellent)	95 (excellent)	0-0-140
2	26 (good)	90 (good)	0-0-130
3	28 (excellent)	99 (excellent)	0-0-140
4	Lost to follow up		
* 30-27=excellent, 26-20=good, 19-10=fair, <10=poor			
† 95-100=excellent, 84-94=good, 65-83=fair, <65=poor			

Table 3: Clinical and radiological follow up at least 12 months postoperative.

Postoperative follow-up findings are summarized in Table 3. Articular reduction was evaluated intraoperatively by direct visual control and fluoroscopy and immediately postoperatively with plain x-rays. Anatomical reduction was achieved in all four cases. Three patients were available for long term follow-up; however, one patient was lost to follow up due to foreign residence. The mean follow up was 4 years (range 3-6). All followed-up patients showed a "good" to "excellent" clinical outcome using Rasmussen's und Lysholm Score [15,16] and good Range of Motion (ROM). All wounds healed uneventfully and no signs of lateral or posterolateral instability could be demonstrated clinically, even with long-term follow-up. There was one non-union of the fibula head which was clinically asymptomatic and no non-union of the tibia. There were no common-peroneal nerve related symptoms.

Discussion

In a retrospective analysis over a period of 10 years we present four cases of proximal tibial fractures with a dislocated posterolateral fragment due to interposition of the popliteal tendon. Compared to all surgically treated proximal tibial fractures in our department, the prevalence of 0.7% indicates a rare injury variation. All cases were treated surgically using an extended lateral transfibular approach showing good clinical outcomes and sufficient fracture healing. In all our cases the PLQD did not occur as an isolated fracture pattern but was associated with concomitant fractures of the tibial plateau or ligamentous injuries. Furthermore, all patients presented following high energy trauma (e.g. skiing accident). It is known that skiing mechanisms are associated with complex proximal tibia fracture variations [20,21]. Skiing combines valgus stress with axial compression in knee flexion that is associated with posterolateral fractures. Based on this, we assume these biomechanical forces in high energy trauma are risk factors for a PLQD [22,23]. As in any other complex fracture pattern we strongly recommend the "span – scan - plan" algorithm. Particularly, we suggest preoperative computed tomography (CT) scans when PLQD is suspected on initial x-ray imaging. It is important to highlight that CT scans can show the entrapped popliteal tendon within the fracture gap. While there

is no study focusing on the diagnosis of an entrapped popliteal tendon in CT scans, we do have data concerning the occurrence of posteromedial structure entrapment in pilon fractures. Fokin et al. describe at least a rate of diagnosis of 50% based on CT-findings [6]. Knowledge of an entrapped popliteal tendon in a PLQD based on the preoperative CT should influence the surgeon's decisions and choice of surgical approach.

The ideal approach addressing the posterolateral corner is controversial. Many authors have previously introduced different approach options. Traditionally, proximal lateral tibial fractures are addressed using an anterolateral approach [24]. The drawback of this standard approach is inadequate visualization and direct fracture manipulation of the posterolateral corner [12,25.] In case of a PLQD with an entrapped popliteal tendon, reduction and fixation of the dislocated fragment with an anterolateral approach in isolation is, in our view, impossible. This could be demonstrated very clearly in Case 2 where a PLQD was treated unsuccessfully through an anterolateral standard approach and required reoperation with an extended lateral approach. In this study all cases were treated using an extended lateral approach with mobilization of the fibular head either by a concomitant fibular head/neck fracture or creation of a fibular neck osteotomy. This approach was initially described by Lobenhoffer et al. [26] and modified by Solomon et al. [27]. An advantage of this extended approach is an ideal overview and accessibility of the posterolateral region with the possibility of direct manipulation of the posterolateral fragment(s) and the popliteal tendon. Furthermore, posterolateral implant positioning for definitive fracture fixation is feasible. Nevertheless, the extended lateral approach is associated with potential destruction of the proximal tibiofibular joint and a risk of peroneal nerve injuries. However, our cohort showed no iatrogenic nerve injury or tibiofibular joint instability. While not used in this case series, more recent studies suggest alternate methods to address posterolateral plateau variant injuries. These include a posterolateral approach without fibular osteotomy [28] or using a femoral lateral epicondylar osteotomy [29]. These approaches could possibly be useful for the treatment of a PLQD with an entrapped popliteal tendon but have to be evaluated regarding their own drawbacks (e.g. creating an iatrogenic bucket handle meniscus lesion). Regardless, this study also alerts treating surgeons to a rare but clinically significant tendon interposition that should be considered when developing a treatment algorithm.

Conclusion

Here, we describe a rare but clinically significant case series with entrapment of the popliteal tendon in tibial plateau fractures posterolateral quadrant dislocation. A PLQD with interposition of the popliteal tendon must be recognized by the treating surgeon

and can be anticipated by scrutiny of the preoperative CT scan. In case of a PLQD, we strongly recommend an extended lateral approach for direct visualization of the posterolateral corner and for adequate manipulation of the fragment and the popliteal tendon. Thereby, the entrapped popliteal tendon can be released easily and anatomical reduction of the PLQD can be achieved.

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