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An Overview on Posterior Cruciate Ligament (PCL) Avulsion Fractures

Mahmoud Ibrahim El-Desoky Mohamed, Adel Mohamed Salama, Hossam Fathy Mahmoud And Sameh Mohamed Holyl

Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt

*Corresponding author: Mahmoud Ibrahim El-Desoky Mohamed

Abstract:

Background: Posterior cruciate ligament (PCL) avulsion fractures are uncommon knee injuries that typically occur following high-energy trauma such as dashboard injuries or sports-related mechanisms. Despite their relatively low incidence, these injuries are clinically significant due to their association with posterior knee instability and long-term functional impairment if not properly managed. The aim of the review Was to provide a comprehensive overview of the current evidence regarding the etiology, classification, clinical presentation, diagnostic approaches, management strategies, and rehabilitation protocols of PCL avulsion fractures.PCL avulsion fractures most commonly affect young, active individuals and are frequently associated with high-energy trauma. Imaging modalities, particularly CT and MRI, play a crucial role in accurate diagnosis and treatment planning. While conservative management may be appropriate for minimally displaced fractures, surgical fixation remains the preferred approach for displaced injuries. Recent advances in arthroscopic and minimally invasive techniques have demonstrated improved functional outcomes, reduced morbidity, and faster recovery compared to traditional open methods. Early diagnosis and appropriate management are essential to achieve optimal outcomes in PCL avulsion fractures. Surgical intervention, especially using arthroscopic techniques, is considered the standard of care for displaced fractures. Structured postoperative rehabilitation is crucial for restoring knee stability and function while minimizing complications.

Keywords: Posterior cruciate ligament; PCL avulsion fracture; Knee injury; Arthroscopy; Internal fixation; Rehabilitation.

Introduction:

PCL injuries are far less frequent compared to anterior cruciate ligament (ACL) injuries, representing approximately 3–38% of all acute knee injuries, with avulsion fractures comprising an even smaller subset (**Katsman et al., 2018**).

The most common mechanism involves a direct blow to the proximal tibia when the knee is flexed, such as a dashboard injury during motor vehicle accidents. This force drives the tibia posteriorly, resulting in avulsion of the PCL at its tibial attachment. Additionally, hyperflexion or hyperextension injuries sustained during sports or falls from heights are notable causes (**Katsman et al., 2018**). The injury predominates in young, active males, reflecting the demographic's higher exposure to high-energy trauma scenarios.

Classification of Avulsed Pcl Fracture

Meyers and McKeever classification (Modified for PCL Avulsion)

- **Type I**

Minimally displaced or nondisplaced fracture

- **Type II**

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Partially displaced

Anterior elevation of the fragment with posterior hinge intact

- **Type III**

Completely displaced fragment

No bony contact with tibial attachment

- **Type IV (Zaricznyj modification)**

Comminuted avulsion fragment

Clinical Presentation

Patients with PCL avulsion fractures commonly present with acute onset of posterior knee pain, swelling, and difficulty bearing weight. Clinical evaluation may reveal joint effusion, tenderness over the popliteal area, and restricted range of motion due to pain and swelling. Key diagnostic tests include the posterior drawer test and the posterior sag sign, which may reveal posterior laxity of the tibia relative to the femur (**Katsman et al., 2018**).

Due to the nature of the trauma, it is not uncommon for these injuries to be associated with other intra-articular injuries such as meniscal tears (reported in up to 16.8% of cases) and concurrent ligamentous disruptions, particularly to the medial collateral ligament or posterolateral corner (**Katsman et al., 2018**).

Imaging & Diagnosis

Accurate diagnosis of PCL avulsion fractures requires a combination of imaging modalities. Lateral view radiographs of the knee may reveal the presence of a bone fragment avulsed from the posterior aspect of the tibia. However, plain radiography can sometimes underestimate the extent of the injury, especially in cases of small or minimally displaced fragments. Computed tomography (CT) provides superior evaluation of the fragment's size, displacement, and comminution, aiding in surgical planning (**Katsman et al., 2018**). Magnetic resonance imaging (MRI) is invaluable for assessing the integrity of the PCL fibers, evaluating for associated soft tissue injuries such as meniscal tears or cartilage lesions, and excluding other ligamentous injuries (**Katsman et al., 2018**).

Figure 1: There is an acute PCL avulsion fracture at the posteromedian articular surface of the upper tibia. The avulsed fracture fragment is displaced superiorly by approximately 2.3 cm and rotated anteriorly. A large trilevel lipohaemarthrosis is present. (Katsman et al., 2018)

Management Strategies

Nonoperative Treatment

Nonoperative management is generally reserved for minimally displaced (Type I) fractures where the risk of posterior instability is low and neurovascular intact. This typically involves knee immobilization in full extension using a brace or cast for a period of 4 to 6 weeks, followed by a structured rehabilitation program aimed at restoring range of motion and quadriceps strength. However, nonoperative management has been associated with inferior outcomes compared to surgical treatment, including lower rates of fracture union (approximately 87%) and increased posterior tibial translation post-treatment (**Gopinath et al., 2023**).

Surgical Treatment

Surgical intervention is considered the gold standard for managing displaced (Type II–IV) avulsion fractures, in cases where conservative treatment fails or neurovascular affected. Open reduction and internal fixation (ORIF) using screws or suture anchors has been the traditional approach, allowing direct visualization and anatomical reduction. However, the advent of arthroscopic-assisted fixation techniques has transformed the management paradigm, offering the benefits of minimally invasive surgery with lower soft tissue morbidity, faster recovery, and the ability to address concomitant intra-articular injuries simultaneously. Arthroscopic fixation has been shown to result in significantly lower postoperative posterior tibial translation (average 0.6–3.2 mm) compared to open surgery (1.7–3.1 mm) (**Gopinath et al., 2023**).

Recent Advances

Minimally invasive posterior-medial approaches for PCL avulsion fixation have gained popularity, providing a balance between visualization and reduced surgical trauma. A study by **Guo et al. (2023)** demonstrated excellent clinical outcomes using this technique, with mean Lysholm and IKDC scores exceeding 90 and restored range of motion averaging 137°. Furthermore, innovative fixation techniques combining cannulated screws with suture augmentation have shown promising results. **Ghoti et al., 2024** reported that all patients treated with this method achieved complete radiological healing, with significant improvements in functional scores and knee flexion (**Ghoti et al., 2024**).

Prognosis

When diagnosed and treated appropriately, PCL avulsion fractures have a favorable prognosis, with restoration of knee stability, high rates of fracture healing, and return to pre-injury activity levels. Conversely, delayed diagnosis, nonunion, or inadequate fixation can result in chronic posterior instability, functional impairment, and progression to early osteoarthritis. Early surgical intervention iscrucial to optimize outcomes and prevent long-term complications (**Gopinath et al., 2023**).

Clinical Recommendations

A high index of suspicion is essential when evaluating patients with posterior knee pain following trauma, particularly in dashboard injuries or sports-related hyperflexion. MRI should be employed as the imaging modality of choice for comprehensive evaluation. For displaced avulsion fractures, surgical fixation—preferably via arthroscopic or minimally invasive approaches—remains the standard of care, offering excellent outcomes with lower complication rates. Postoperative rehabilitation focusing on early range of motion and strengthening is vital to ensure optimal functional recovery (**Gopinath et al., 2023; Guo et al., 2023**).

Complications

Neurovascular Injury and Posterior Fossa Morbidity

Neurovascular injury—specifically popliteal artery or posterior tibial nerve damage—remains exceptionally rare (<1%) with contemporary surgical approaches, contrasting with historical concerns about posterior dissection. This favorable safety profile reflects: (1) understanding of neurovascular anatomy, (2) judicious use of retraction, and (3) increased adoption of arthroscopic and minimally invasive techniques. **(Katsman et al., 2018).**

arthrofibrosis and Motion Restrictions

Arthrofibrosis (knee stiffness/motion deficit) remains the most commonly reported complication, occurring in 2.7% of patients overall (33/1,225 patients). However, reported prevalence varies considerably by surgical approach: arthroscopic techniques report 0–36% incidence compared to 0–25% for open approaches. This apparent paradox reflects heterogeneous definitions of "clinically significant" stiffness and variable postoperative rehabilitation protocols rather than inherent technical superiority of either approach. **(Katsman et al., 2018).**

The most commonly reported complication is **arthrofibrosis**, which occurs more frequently in arthroscopic repairs (0–36%) than in open repairs (0–25%) (**Sabat et al., 2016**). Contributing factors include delays in surgery or range of motion initiation (**Nicandri et al., 2008; Khatri et al., 2015**). Achieving stable fixation is essential to facilitate early mobilization—particularly challenging in comminuted avulsions, where suture techniques may be necessary. Hardware-related symptoms requiring removal have also been documented (**Sabat et al., 2016; Yang et al., 2003**). **Nonunion and infection rates** appear to be similar across both techniques (**Sabat et al., 2016**).

Nonunion Complications

True nonunion (failure of osseous consolidation by 24 weeks) remains exceptionally rare (<1%) with temporary surgical techniques, reflecting improved fixation stability compared to historical screw-only approaches. When nonunion does occur, it typically associates with: (1) severely comminuted fragments, (2) delayed presentation with capsular contracture impeding reduction, or (3) inadequate compression with non-bridging fixation methods. Treatment requires revision ORIF with improved anatomic reduction or PCL reconstruction for functionally significant instability. **(Katsman et al., 2018).**

Hardware-Related Complications

Cannulated screw fixation, historically the most common technique, encounters symptomatic screw head retraction in 5–15% of cases and screw loosening requiring removal in 10–20% of open series. Contributing factors include: (1) poor initial purchase in small bone fragments, (2) tapping soft cancellous bone without adequate thread engagement, and (3) cyclic loading causing thread stripping. Recent data comparing fixation methods demonstrate screw loosening in 10% of cases versus malunion in 10% with suture bridge technique. **(Pu et al., 2025).**

Surgical Site Infections

Overall infection rate is<1% across combined series. Superficial incisional infections occur in<0.5% of cases, while deep intra-articular infections remain exceptionally rare (<0.2%). Prophylactic broad-spectrum antibiotics administered within 60 minutes of incision and continued for 24 hours postoperatively, combined with careful hemostasis and drainage, account for these favorable infection rates **(Katsman et al., 2018).**

Rehabilitation After PCL Avulsion Fixation:

Phase I: Immediate Post-Op (0–2 Weeks)

- Goals
- Protect fixation
- Control pain&swelling
- Achieve full knee extension
- Quadriceps activation

- Protocol
- Brace: Hinged knee brace locked in extension

Phase II: Early Rehab (2–6 Weeks)

- Goals
- Gradually increase ROM
- Improve quad strength
- Protocol
- Gradual ROM to 90°–110°
- Continue brace (may unlock gradually)
- Closed chain quadriceps exercises (0–45°)
- Avoid resisted hamstrings
- Stationary cycling (low resistance, high seat)

Phase III: Intermediate Phase (6–12 Weeks)

- Goals
- Full ROM
- Improve strength
- Improve neuromuscular control
- Protocol
- Progress weight bearing to full
- Leg press (0–60°)
- Step-ups
- Proprioception training
- Begin light hamstring strengthening after 8–10 weeks

Phase IV: Advanced Strengthening (3–6 Months)

- Goals
- Restore muscle balance
- Improve dynamic stability
- Protocol
- Progressive resistance training
- Balance board exercises
- Light jogging (usually after 4–5 months).

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