Technical Note

Single-Stage Arthroscopy-Assisted Reduction and Internal Fixation (ARIF) of Tibial Rim Fracture With Posterior Cruciate Ligament Reconstruction and Repair of Posterolateral Complex and Meniscal Injury

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Abstract: Multiligament knee injury with periarticular fractures are high-velocity injuries and generally require a staged treatment approach that involves multiple hospitalizations and results in delayed return to activity. We report a single-stage management technique for these injuries with arthroscopy-assisted reduction and internal fixation of a depressed tibial rim fracture with concomitant posterolateral complex repair, medial meniscal repair, and posterior cruciate ligament reconstruction.

Surgical management of multiligament knee injury (MLKI) is a challenging scenario, especially when associated with periarticular fractures.[1] These injuries occur due to high-energy trauma resulting in disruption of the bony architecture and the soft-tissue envelope around the knee. Up to 50% of these injuries may present as a spontaneously reduced knee dislocation and can be grouped under knee dislocation V injury according to Schenck classification.[2-4]

Adequate tibial condylar reduction and restoration of the proximal tibial geometry is important before ligament reconstruction; hence, a staged approach is generally recommended for these injuries. With improvements in arthroscopic instrumentation and availability of innovative techniques, there is a paradigm shift in approaching these injuries, and a single-stage reconstruction can be adopted for ligament injuries with minimally displaced/depressed tibial rim fractures.[5,6] The technical snag of hardware interference during tibial tunnel placement during single-stage reconstruction warrants meticulous planning and approach. Single stage fracture fixation and ligament reconstruction is advantageous to the patient as it avoids multiple hospital admissions and rehabilitation and facilitates earlier return to work. We report a single-stage management technique with arthroscopy-assisted reduction and internal fixation of a depressed tibial rim fracture with concomitant posterolateral complex (PLC) repair, medial meniscal repair, and posterior cruciate ligament (PCL) reconstruction 2 weeks from injury.

Patient Evaluation

MLKI with periarticular fractures presenting acutely requires methodic assessment to rule out neurologic and vascular injury. If the joint is stable through range of motion, antiedema measures along with brace support is advised at least for 10 to 14 days for the soft-tissue swelling to subside, followed by continuous passive motion exercises to achieve at least 90° flexion before planning a single stage fracture fixation and ligament reconstruction. If joint subluxates through range of motion, initial stabilization with an external

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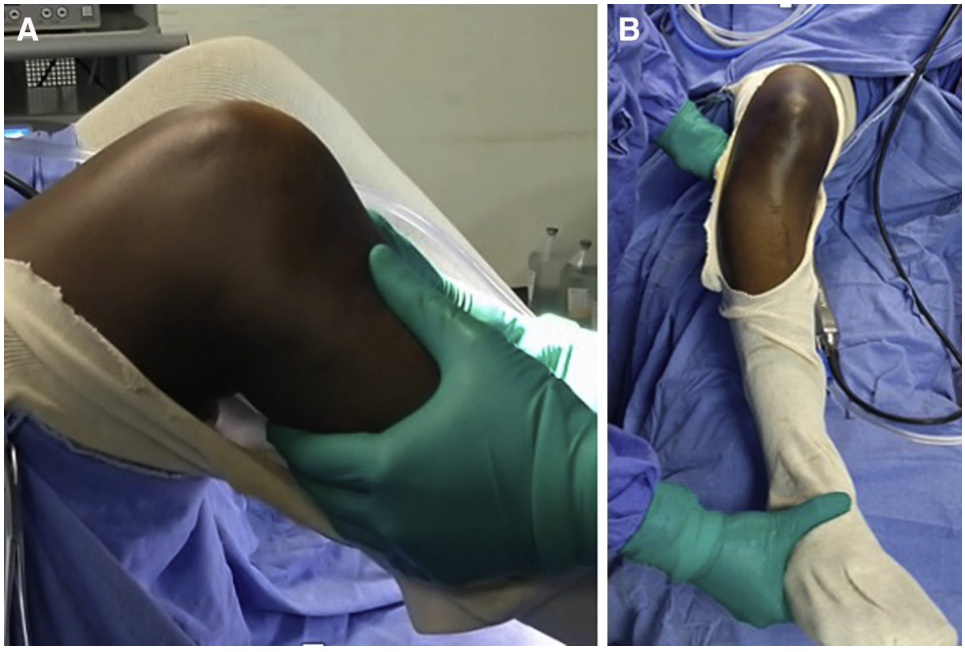

Fig 1. Examination under anesthesia showing (A) a positive posterior drawer indicating a posterior cruciate ligament tear and (B) grade III varus laxity in extension indicating a posterolateral complex injury.

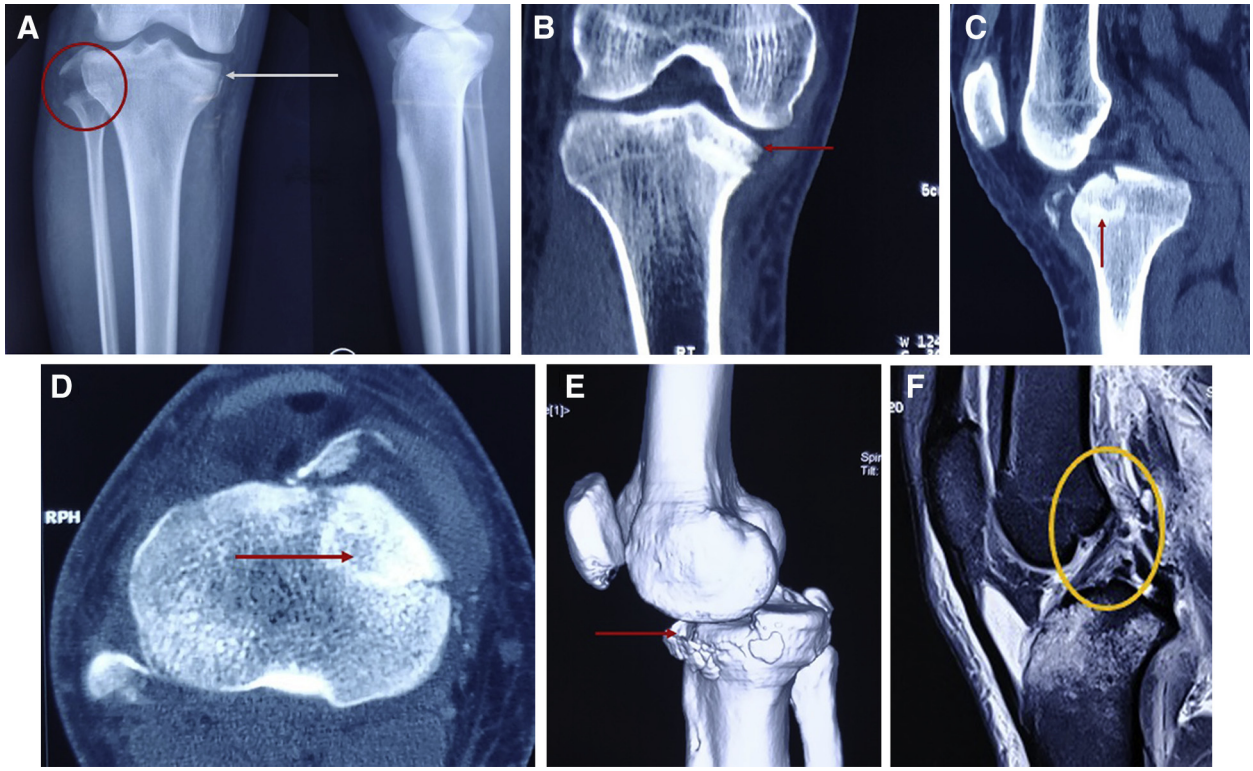

Fig 2. Imaging in MLKI with periarticular fractures. (A) Plain radiograph showing a fibular lateral collateral ligament avulsion (red circle) with a depression fracture of the anteromedial tibia (white arrow). (B-E) Coronal, sagittal, axial, and 3-dimensional—reconstructed computed tomography images showing the anteromedial depressed fracture (red arrows). (F) Sagittal-cut magnetic resonance imaging scan showing the PCL tear (yellow circle).

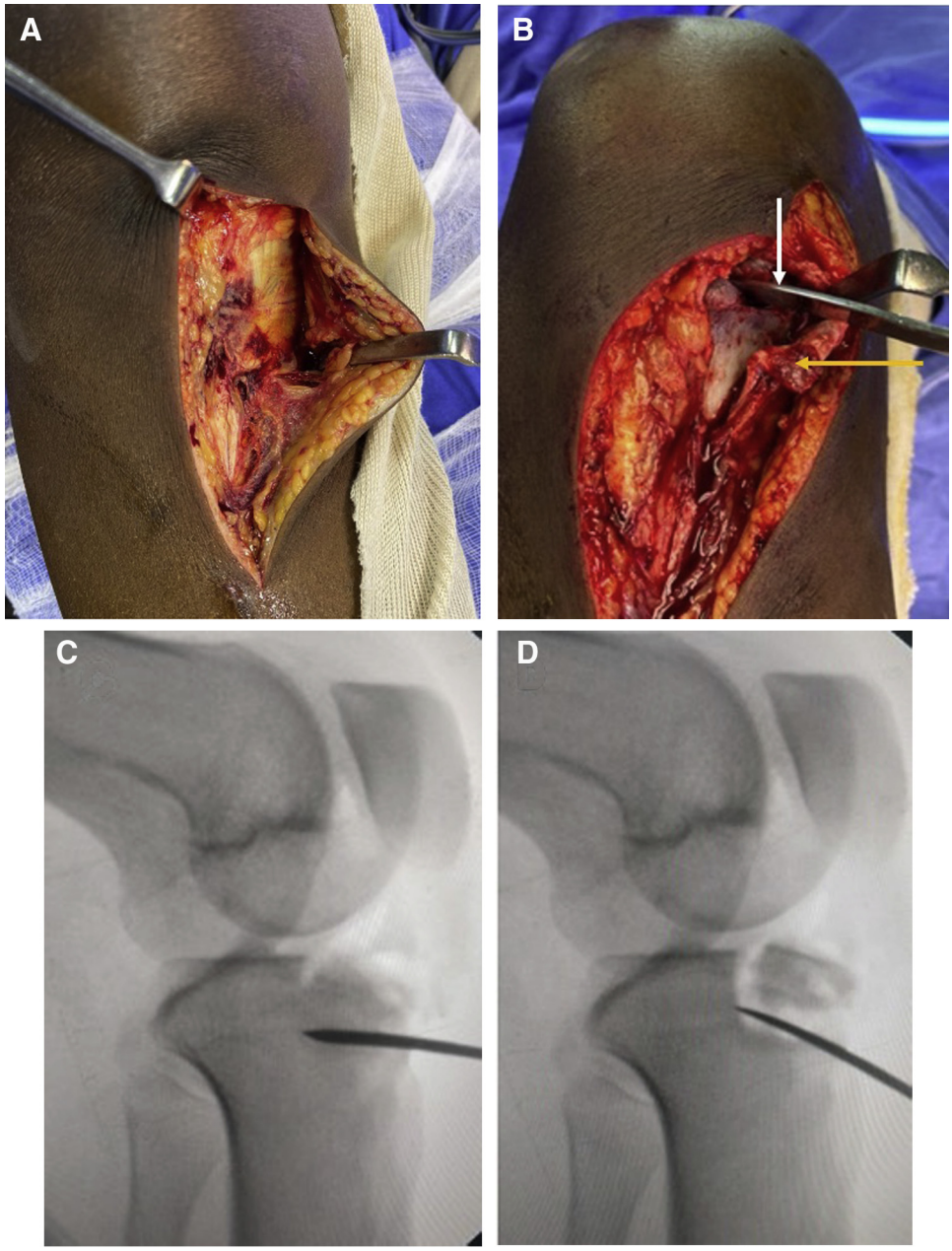

Fig 3. Approaching the anteromedial tibial rim fracture. (A) Linear incision over anteromedial tibia. (B) Periosteum and superficial medial collateral ligament (yellow arrow) is elevated to expose the fracture site and elevation of the depressed fragment is done using osteotome (white arrow). (C) and (D) Fluoroscopy images of intrafocal elevation. (E) and (F) Inserting a contoured bone allograft to maintain the reduction of the elevated anteromedial fragment (white arrow). (G) Arthroscopic evaluation of the intra articular reduction after elevation and bone grafting.

fixator at least for 3 to 4 weeks followed by staged surgery for fracture fixation and ligament reconstruction is advised. Preoperative clinical evaluation for cruciates and collaterals is essential while planning a single stage fracture fixation and ligament reconstruction but at times can be insubstantial due to patient discomfort and guarding due to associated fractures. Hence, examination under anesthesia is most crucial for surgical planning and should include stress testing for cruciate and collateral ligaments (Fig 1).

Imaging

Plain radiographs are essential initial investigations for assessing periarticular fractures and bony ligamentous

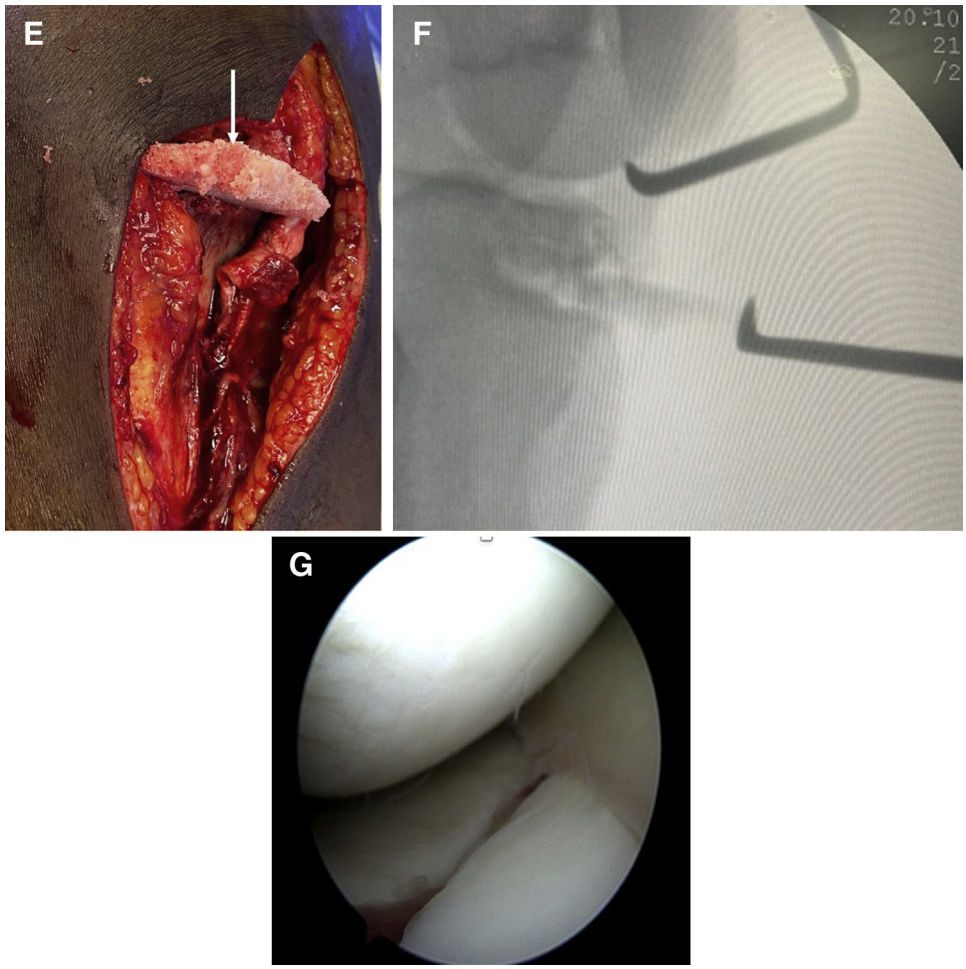

Fig 3. Continued

avulsions while dealing with a MLKI. In addition to these, computed tomography and magnetic resonance imaging are essential to outline the fracture geometry and extent of ligamentous disruption around the knee (Fig 2).

Surgical Indications

This technique is indicated for MLKI associated with tibial rim fractures or minimally displaced tibial condyle fractures. Knee dislocations with displaced tibial condyle fractures represent high-energy injuries, and a staged approach with joint reduction and external fixator application initially and fracture fixation with ligament reconstruction subsequently is a prudent option.[1]

Patient Positioning

The patient is positioned supine on the operating table with 2 supporting posts, one at the lateral side of thigh against a padded tourniquet and latter being a foot roll to maintain 90° knee flexion. A C-arm is stationed on other side of the operating surgeon, which could be easily shuttled across for Intraoperative fluoroscopy.

Equipment

This technique requires thin-profile osteotomes and an impactor for elevation of the tibial rim and bone grafting and a T buttress plate with 3.5-mm screws for buttressing the tibial rim fracture. Fibular head avulsion fixation requires a 4.5-mm cannulated cancellous screw with washer, Kirschner wires, and stainless-steel wires for tension band wiring. Meniscal repair requires all inside- and inside-out meniscal repair devices. PCL reconstruction requires a standard PCL jig and reamers, adjustable loop/fixed loop for femoral PCL fixation, and biocomposite interference screws for PCL tibial fixation.

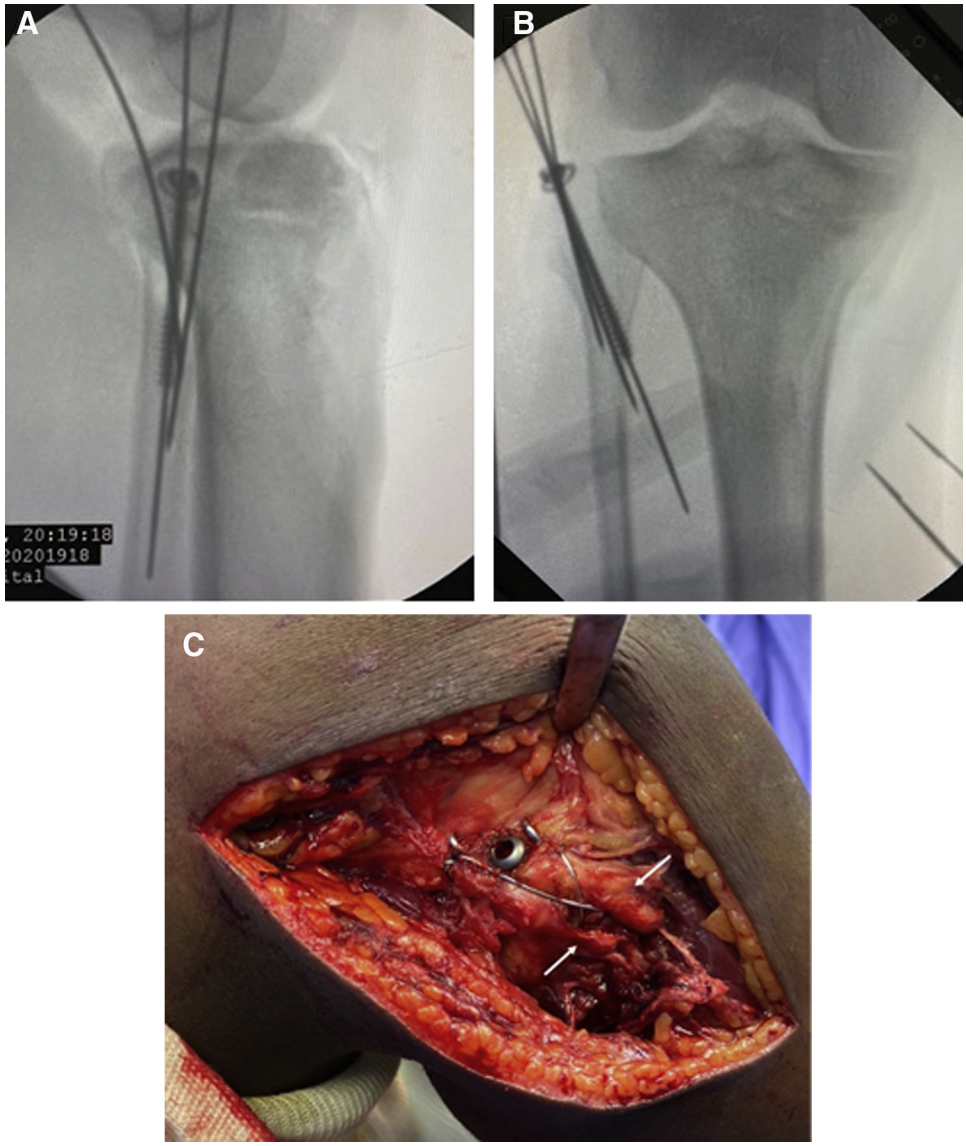

Fig 4. Approaching the fibular head avulsion. (A) and (B) Fluoroscopy images showing fibular head reduction and fixation using 4.5-mm cannulated cancellous screws and K-wires. (C) Intraoperative images showing fibular head fixation. A transverse drill hole (white arrows) is created distal to fracture site to shuttle a stainless-steel wire across the fracture and is tied in a figure-of-8 manner around the K-wires to complete the tension band wiring configuration with knee in 90° flexion. The tips of the K-wires are then bent flush to the bone and impacted to prevent soft-tissue impingement.

Surgical Technique (With Video Illustration)

Step 1: Addressing the Periarticular Fractures

A linear incision is made over the anteromedial aspect of the tibial plateau, and the periosteum is sharply dissected to expose the depressed and impacted anteromedial tibial rim. The fracture line is carefully identified under direct vision confirming the same under C-arm. Using a curved osteotome, a plane is created between the fracture fragment and the rest of the tibial plateau and the fragment is elevated. This elevated fragment is maintained in position using a wedge of bone allograft carefully fashioned to snuggly fit the void after elevation. Arthroscopic evaluation of the elevated fragment is also made using standard anteromedial and anterolateral portals to assess the intra-articular step-off and apposition of the fragment to the rest of the tibial plateau (Fig 3).

A linear incision is given on the lateral side, starting proximal to the lateral joint line along the posterior edge of iliotibial band to proximal third of fibular shaft. The avulsed fibular fragment is carefully dissected and reduced to the rest of fibular head initially and is fixed using two 2-mm K-wires. A guidewire for a 4.5-mm cannulated cancellous screw is inserted across the fracture site, followed by drilling using cannulated drill bit and a 4.5-mm cannulated screw is inserted along with a washer. A transverse drill hole is created distal to fracture site to shuttle a stainless-steel wire across the

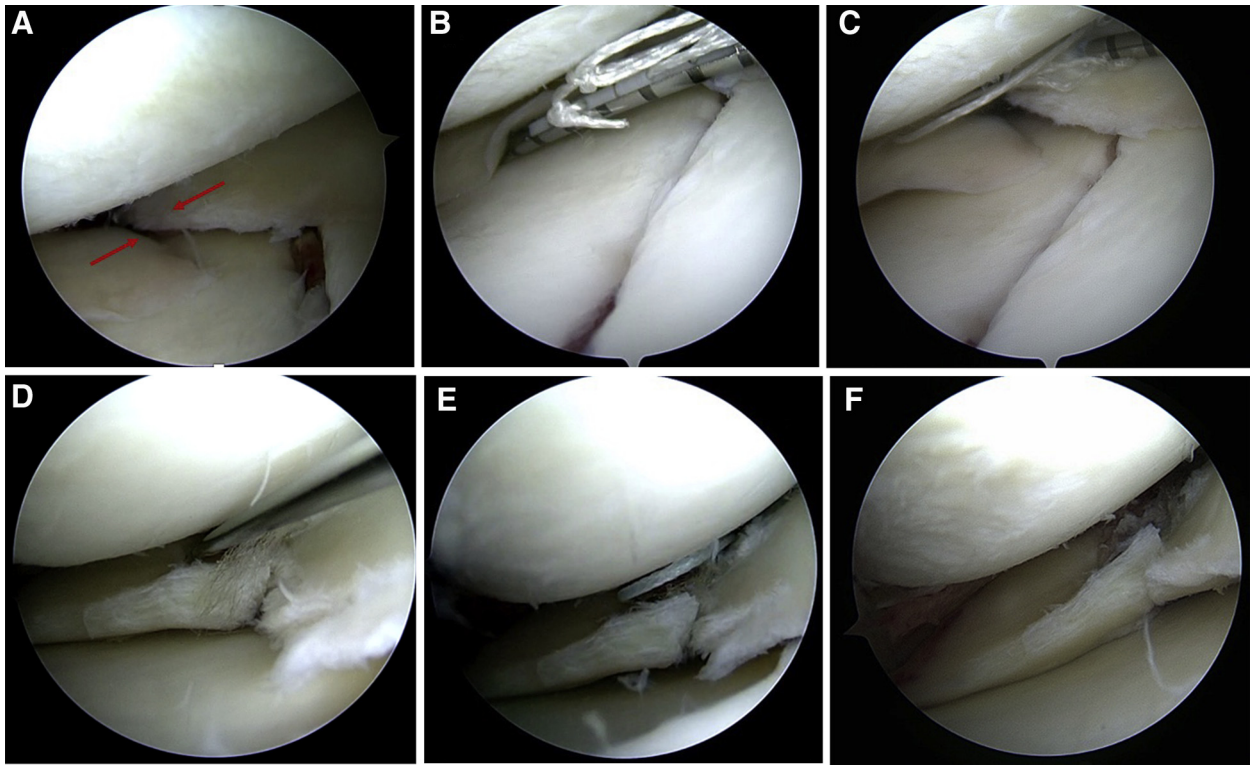

Fig 5. Medial meniscal repair. (A) Complete radial tear of medial meniscus at the junction of body and posterior horn (red arrows). (B) All-inside meniscal repair device at the medial meniscus at one side of the tear (C) All-inside device used across the tear in a horizontal mattress fashion. (D) and (E) Inside-out repair using FiberWire (Arthrex, Largo, FL). (F) Completed all-inside and inside-out repair of the radial tear.

fracture and is tied in a figure-of-8 manner around the K-wires to complete the tension band wiring configuration with knee in 90° flexion. The edges of the K-wires are then bent flush to the bone and impacted to prevent soft-tissue impingement (Fig 4).

Step 2: Addressing the Intra-Articular Injuries

Meniscal Repair. Medial meniscal tears are a common finding in these injuries.[7] Hence, a detailed evaluation of the posterior horn, root, and RAMP lesions is necessary. Radial tears of the posterior horn of medial meniscus are repaired using a combination of inside-out and all-inside techniques (Fig 5) whereas root tears, if encountered in this scenario, can be repaired using suture anchors, all-inside technique, or the suture pull-out technique with meticulous positioning of the tibial tunnel between the elevated rim and the PCL tibial tunnel.[8,9]

PCL Reconstruction. Meniscal repair is followed by single-bundle PCL reconstruction using hamstring graft. Ipsilateral semitendinosus along with gracilis is harvested employing the same incision used for tibial rim elevation along with contralateral semitendinosus. Seven-strand PCL graft is prepared with a diameter of 10 mm for a single-bundle PCL reconstruction. Using an additional posteromedial portal, the tibial footprint of PCL is identified and a 10-mm tibial tunnel is drilled using a standard PCL jig. An accessory anterolateral portal is used for drilling the PCL femoral tunnel. The graft is then shuttled across the tunnels and fixed using adjustable/fixed loop at the femoral end and interference screw at the tibial tunnel (Fig 6).

Step 3: Plate Fixation

The elevated anteromedial tibial rim is fixed using a 3.5-mm T buttress plate in the final step. The position of the PCL tibial tunnel is to be verified under fluoroscopy to avoid screw fixation to the T plate along the PCL tunnel trajectory. This technique of T-plate fixation for anteromedial rim fractures has also been highlighted recently by Liu et al.[10] The final reduction of the fragment after plate fixation is confirmed on fluoroscopy and arthroscopy (Fig 7). The operative steps are explained in Video 1 and summarized in Tables 1 and 2.

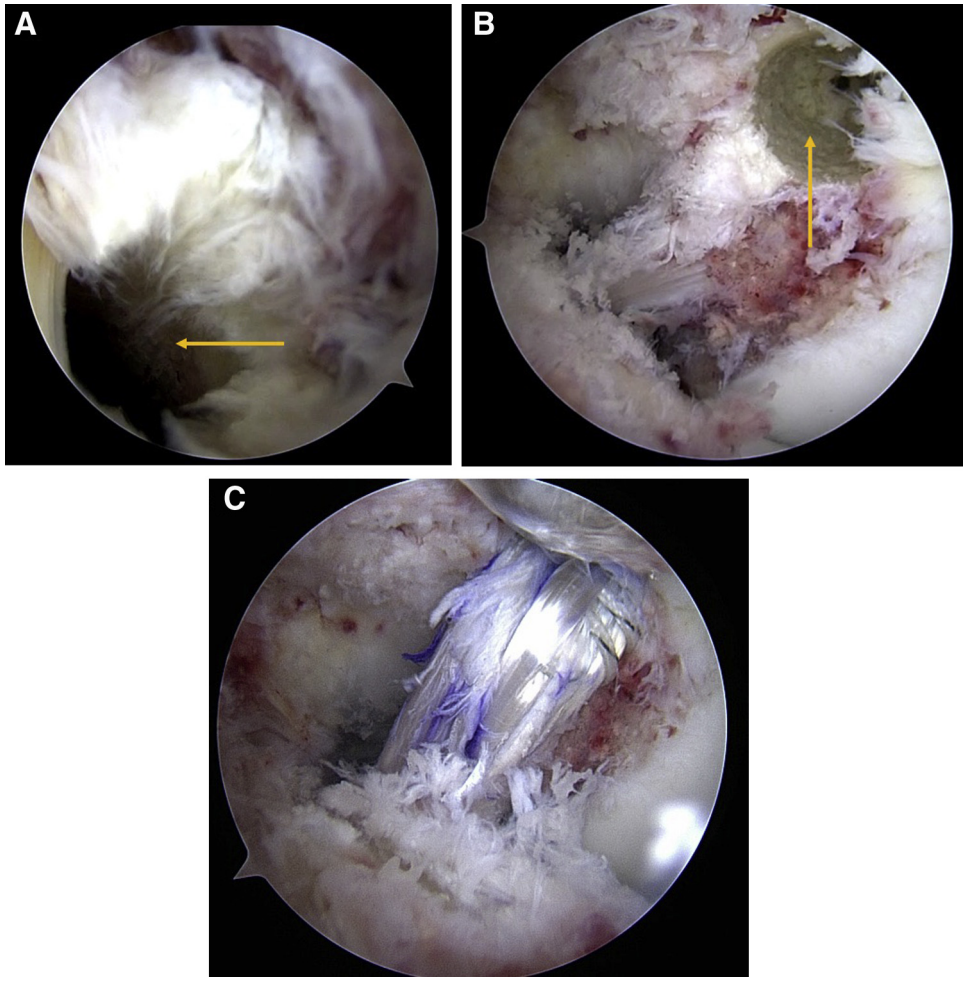

Fig 6. Arthroscopic posterior cruciate ligament (PCL) reconstruction. (A) Tibial PCL tunnel as viewed through the posteromedial portal (yellow arrow). (B) PCL femoral tunnel for single-bundle PCL reconstruction as viewed through the anterolateral portal (yellow arrow). (C) Completed PCL reconstruction with graft in place.

Rehabilitation

The operated knee is supported with a long knee brace with posterior support, and patient is ambulated with non−weight-bearing walker mobilization for first 3 weeks. Prone knee bending is started at 3 weeks. Partial weight-bearing is started at 6 weeks and then progressed to full weight-bearing at 8 weeks. Initial follow-up at regular intervals is emphasized to prevent knee stiffness that can arise as multiple reparative procedures are done in single stage surgery. Weight-resisted exercises are started at 3 months' postsurgery. The patient is advised to start squatting, cross-legged sitting, and recreational sports after 6 months postoperatively.

Discussion

Depressed rim fractures of the anteromedial tibial plateau with MLKI are rarely reported injuries limited to a few case series and reports.[10-14] Although the fracture itself is benign, there can be a marked soft-tissue injury when it is associated with PCL, PLC, and medial meniscal tears.[15] These fractures are classified into 2 types, those that involve more than one-quarter width of the anteroposterior tibial width and those which are lesser than one-quarter width. Interestingly, those that are lesser than one-quarter width are usually associated with PLC and PCL injuries.[14] Hyperextension in combination of varus rotation and significant posterior translation is the proposed mechanism for this combination of injury as suggested by Cohen et al.[11]

Traditionally, although a staged approach is recommended for MLKI associated with periarticular fractures, recent studies have shown that ligament reconstructions can be concurrently performed along with open reduction internal fixation of associated fractures without any difference in outcomes.[16] However, there are no studies/reports that have recommended a specific fixation technique or order for fixation of either depressed anteromedial rim fractures especially when associated with an PLC injury (arcuate fracture) and PCL tear.

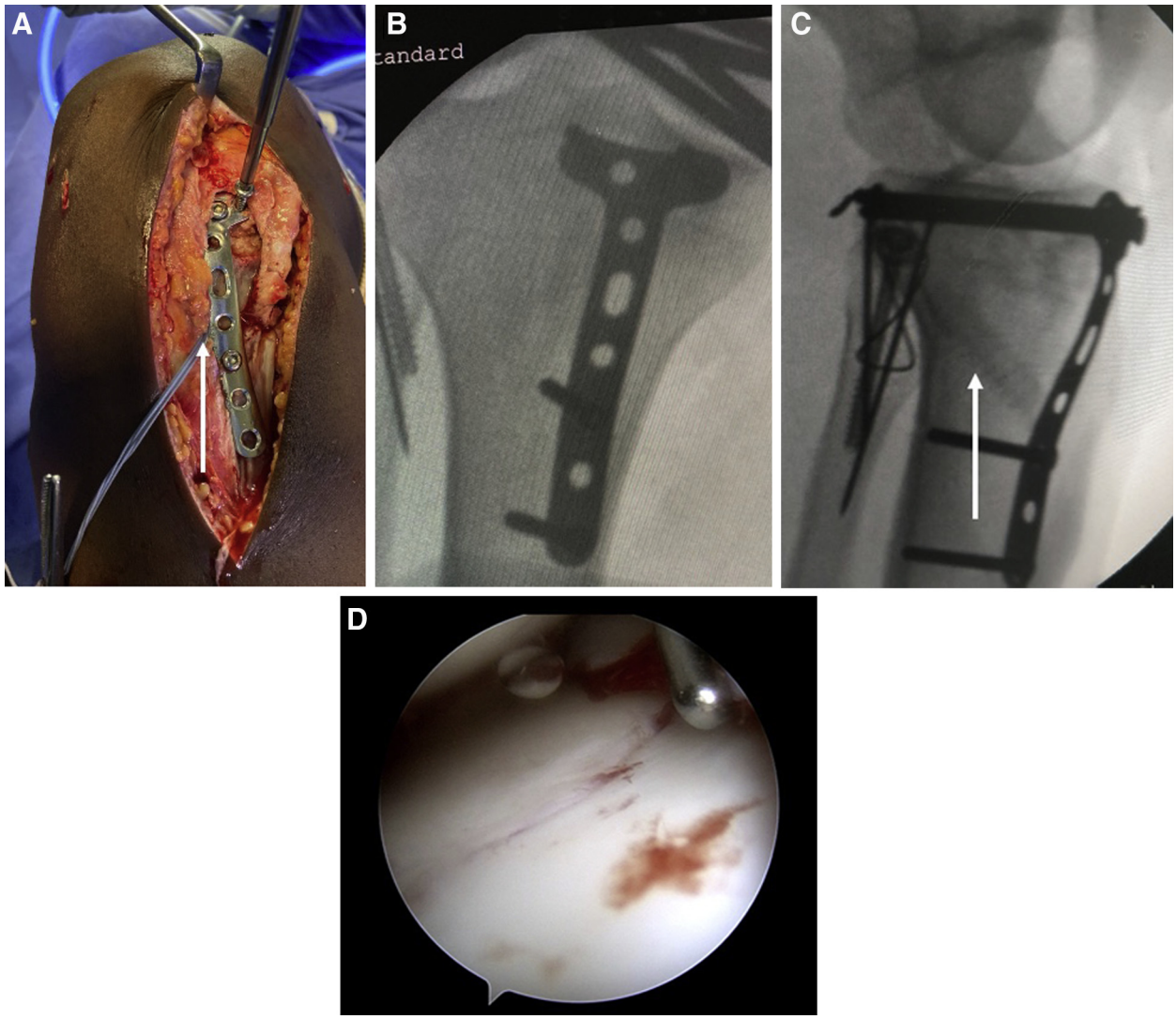

Fig 7. Final construct after buttress plate fixation. (A) Intraoperative photograph of the final fixation using buttress plate avoiding interference screw at the posterior cruciate ligament (PCL) tibial tunnel (white arrow). (B) and (C) Fluoroscopy images of plate fixation maintaining the reduction (white arrow at the PCL tibial tunnel). (D) Arthroscopic evaluation of the final reduction after plate fixation.

Table 1. Summary of the Operative Steps

Step 1: Addressing the periarticular fractures
(a) Addressing the tibial rim fracture:
Elevation of the tibial rim and bone grafting the void
Arthroscopic assessment of the reduction
(b) Tension band wiring of the fibular head avulsion
Step 2: Addressing the intra-articular injuries:
(a) Medial meniscal repair
(b) PCL reconstruction
Step 3: T-plate fixation stabilizing the elevated tibial rim

PCL, posterior cruciate ligament.

Table 2. Surgical Pearls

1. The key step is fracture fixation followed by meniscal repair; ligament reconstruction, and finally buttress plate fixation.
2. Sharp dissection up to the periosteum is necessary to identify the fracture line for elevation.
3. Allografts/tricortical autografts can be used to fill the void after elevation of tibial rim.
4. TBW of the fibular head avulsion in addition to cancellous screw fixation provides a robust fixation.
5. Plate fixation is the final step in the surgery and has to be done after PCL reconstruction. Screw insertion to be avoided at the PCL tunnel trajectory. Plate fixation prevents depression of the elevated rim.

PCL, posterior cruciate ligament; TBW, tension band wiring.

Table 3. Advantages and Limitations of the Technique

Advantages	Limitations
1. Single-stage reconstruction, avoiding multiple hospitalizations and rehabilitation.	1. Prolonged surgical time especially for a less experienced surgeon.
2. Direct visualization of reduction of the fracture	2. Availability of bone allografts.
3. Addressing concomitant intra-articular injuries arthroscopically	

The key is to reduce the fractures initially and then proceed with meniscal repair and PCL reconstruction. Addressing the depressed tibial fracture fragment requires an anteromedial incision to identify the impacted fracture at the anterior cortex, which is elevated and provisionally maintained using an allograft at the void to restore the joint geometry. The buttress plate fixation is performed at the end after fixing the PCL graft at the tibial tunnel. The reduction can be confirmed by using intraoperative fluoroscopy along with direct evaluation using arthroscopy to prevent any articular step-off. Although autografts are considered as gold standard for filling of bone voids at tibial plateau after elevation, prolonged surgical time, especially while attempting a concomitant ligament reconstruction, would still make allograft an ideal option with good incorporation rates.[17] We used a lateral incision with sufficient skin bridge from the anteromedial incision to fix the arcuate fragment of the fibular head to avoid skin necrosis. Although numerous fixation options exist,[18] a cannulated screw with a static tension band wiring at 90° flexion provides a robust fixation for this avulsion fracture .

Advantages, Limitations, and Risks of the Technique

Single-stage reconstruction avoids multiple hospitalizations and rehabilitation and allows earlier return to activity. Another advantage is direct visualization of reduction of the fracture at the articular surface and addressing concomitant intra-articular injuries arthroscopically at the same setting. However, combining fracture fixation with simultaneous meniscal repair and PCL reconstruction can be technically challenging for a surgeon during early phase of the career. Also, simultaneous fixation can result in arthrofibrosis if not rehabilitated promptly. It is important to leave an adequate skin bridge between medial and lateral incision to prevent skin necrosis. As the common peroneal nerve is not explored and dissected separately, there could be a chance of common peroneal nerve palsy if the avulsed fragment/hardware is not handled gently. The advantages, limitations, and risks involved while using this technique are listed in Tables 3 and 4.

Table 4. Risks Involved in the Technique

1. Skin necrosis if adequate skin bridge is not maintained between medial and lateral incisions.
2. Risk of common peroneal nerve palsy as it is not explored and retracted.
3. Greater probability of postoperative knee stiffness if not rehabilitated promptly.

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