Hinged-Knee External Fixator Used to Reduce and Maintain Subacute Tibiofemoral Coronal Subluxation

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Abstract

Dislocation of the knee is a rare phenomenon that is becoming increasingly recognized with the expansion of its definition to include knees presenting with multiligament compromise. Hinged external fixators are now considered a viable supplementary treatment option in the management of acute ligament repair or reconstruction but their use in the management of subacute or chronic tibiofemoral dislocations or subluxations is less well defined.

We report a case of a hinged-knee external fixator used to facilitate and maintain reduction of a chronic coronal tibial subluxation that presented after repair of an acute knee dislocation with lateral ligament injury secondary to a motor vehicle accident. At 5-year follow-up, the patient treated with hinged external fixation had a stable joint, was able to tolerate regular aerobic exercise, was minimally symptomatic, and did not require more extensive ligament reconstruction.

Although there are reports on postoperative use of hinged external fixation to maintain the reduction of chronic or subacute knee dislocations in the sagittal plane after cruciate ligament repair, there are no reports on management of subacute tibiofemoral subluxation in the coronal plane.

Dislocation of the knee is a severe injury that usually results from high-energy blunt trauma.[1] Recognition of knee dislocations has increased with expansion of the definition beyond radiographically confirmed loss of tibiofemoral articulation to include injury of multiple knee ligaments with multidirectional joint instability, or the rupture of the anterior and posterior cruciate ligaments (ACL, PCL) when no gross dislocation can be identified[2] (though knee dislocations without rupture of either ligament have been reported[3,4]). Knee dislocations account for 0.02% to 0.2% of orthopedic injuries.[5] These multiligamentous injuries are rare, but their clinical outcomes are often complicated by arthrofibrosis, pain, and instability, as surgeons contend with the competing interests of long-term joint stability and range of motion (ROM).[6-9]

Whereas treatment standards for acute knee dislocations are becoming clearer, treatment of subacute and chronic tibiofemoral dislocations and subluxations is less defined.[5] Success with articulated external fixation originally across the ankle and elbow inspired interest in its use for the knee.[10-12] Richter and Lobenhoffer[13] and Simonian and colleagues[14] were the first to report on the postoperative use of a hinged external fixation device to help maintain the reduction of chronic fixed posterior knee dislocations. The literature has even supported nonoperative reduction of small fixed anterior or posterior (sagittal) subluxations with knee bracing alone.[15,16] However, there are no reports on treatment of chronic tibial subluxation in the coronal plane.

We report a case of a hinged-knee external fixator (HEF) used alone to reduce a chronic medial tibia subluxation that presented after initial repair of a knee dislocation sustained in a motor vehicle accident. The patient provided written informed consent for print and electronic publication of this case report.

Case Report

A 51-year-old healthy woman who was traveling out of state sustained multiple orthopedic injuries

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Figure 1. Initial injury. (A) Coronal fast spin echo T2-weighted fat-saturated magnetic resonance imaging showing edema of medial femoral condyle and intercondylar eminence of tibia suggests subluxation in response to varus force. Lateral ligament complex has sustained substantial injury. (B) Sagittal T2-weighted magnetic resonance imaging shows intact posterior cruciate ligament.

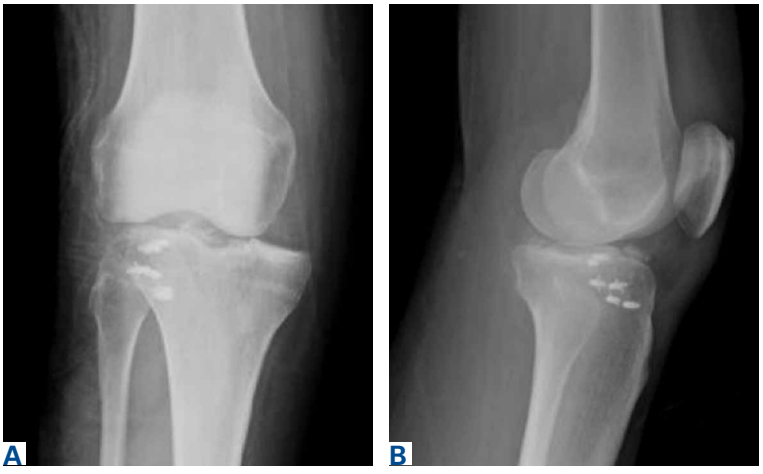

Figure 2. First presentation. (A) Anteroposterior and (B) lateral radiographs show substantial tibial subluxation in coronal plane but not sagittal plane.

in a motor vehicle accident. She had a pelvic fracture, a contralateral femoral shaft fracture, significant multiligamentous damage to the right knee, and a cavitary impaction fracture of the tibial eminence with resultant coronal tibial subluxation. Initial magnetic resonance imaging (MRI) showed the tibia injury likely was the result of varus translation, as the medial femoral condyle impacted the tibial spine, disrupting the ACL (**Figures 1A, 1B**). The patient also had disruption of the posterolateral corner (PLC), including a lateral collateral ligament (LCL) fibular avulsion, an iliotibial band avulsion, and a popliteus myotendinous junction tear with an intact biceps femoris tendon. Three weeks after the accident and after the associated polytrauma injuries were stabilized, the patient underwent "en masse" repair of the PLC, at an outside institution, as described by Shelbourne and colleagues[17] with tibial spine and ACL débridement.

On initial presentation to our clinic 5 weeks after injury, x-rays showed progressive medial subluxation of the tibia in relation to the femur with translation of about a third of the tibial width medially (**Figures 2A, 2B**). The central tibial defect nearly apposed the medial femoral condyle, consistent with the initial impaction injury with translation in the coronal rather than anteroposterior plane. Additional MRI and computed tomography were performed to better define the bony and ligamentous anatomy (**Figures 3A-3C**). They showed an intact en masse lateral repair, an intact superficial medial collateral ligament, a bucket-handle lateral meniscus tear, and absence of the ACL and tibial eminence.

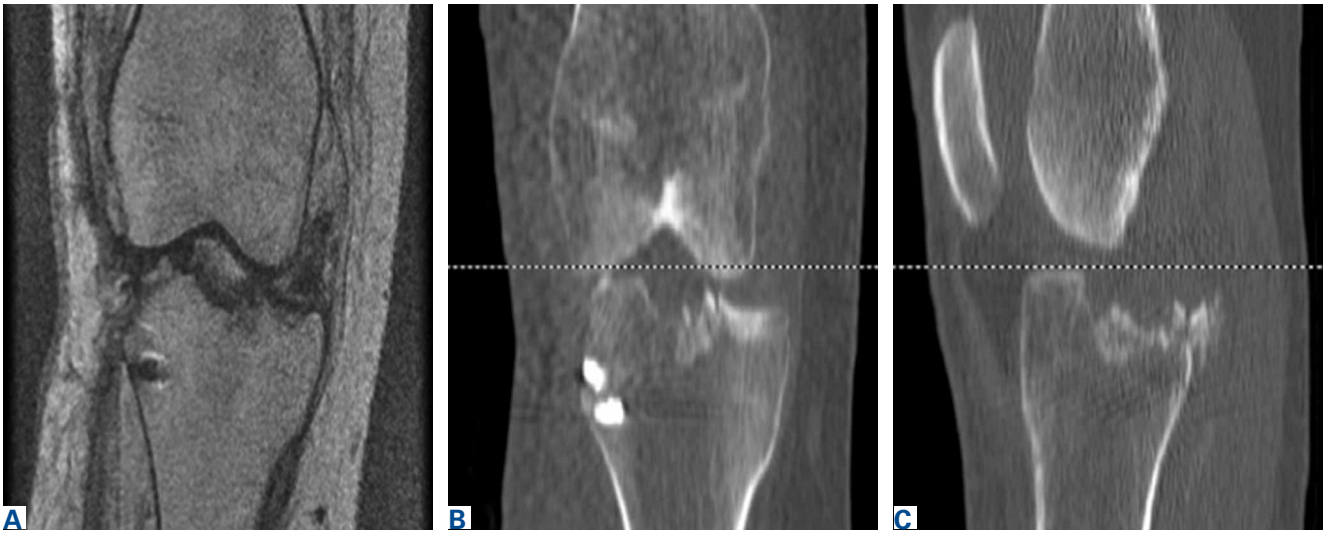

Figure 3. First presentation. (A) Coronal T1-weighted magnetic resonance imaging, (B) coronal computed tomography, and (C) sagittal computed tomography show intact "en masse" lateral repair, anterolateral tibial plateau fracture, and central defect in posterior tibia

Figure 4. Postoperative radiograph shows application of hinged-knee external fixator after tibiofemoral reduction.

Figure 5. (A) Anteroposterior and (B) lateral radiographs obtained on removal of hinged-knee external fixator 6 weeks after application show tibiofemoral alignment.

Given the worsening tibial subluxation and resultant instability, the patient was taken to the operating room for examination under anesthesia, and planned closed reduction and spanning external fixation. Fluoroscopy of the lateral translation and external rotation of the tibia allowed us to reduce the joint, with the lateral tibial plateau and lateral femoral condyle relatively but not completely concentric. A rigid spanning multiplanar external fixator was then placed to maintain the knee joint in a more reduced position.

A week later, the patient was taken back to the operating room for arthroscopic evaluation of the knee joint. At the time of her index operation at the outside institution, she had undergone arthroscopic débridement of intra-articular loose bodies and lateral meniscus repair. Now it was found that the meniscus was not healed but had displaced. A bucket-handle lateral meniscus tear appeared to be blocking lateral translation of the tibia, thus impeding complete reduction.

Given the meniscus deformity that resulted from the chronicity of the injury and the resultant subluxation, a sub-total lateral meniscectomy was performed. As the patient was now noted to have an intact medial collateral ligament and an intact en masse lateral repair, we converted the spanning external fixator to a Compass Universal Hinge (Smith & Nephew) to maintain reduction without further ligamentous reconstruction (**Figure 4**). As we were able to maintain reduction, we thought bone grafting for stability augmentation was not needed, despite the central tibial defect (analogous to an engaging Hill-Sachs defect in shoulder instability). The HEF allowed knee flexion while maintaining coronal alignment.

After HEF placement, the patient spent a short time recovering at an inpatient rehabilitation facility before starting aggressive twice-a-week outpatient physical therapy. Initially after HEF placement, she could not actively flex the knee to about 40° or fully extend it concentrically. Given these limitations and concern about interval development of arthrofibrosis, manipulation under anesthesia was performed, 3 weeks after surgery, and 90° of flexion was obtained. When the HEF was removed, 6 weeks after placement, fluoroscopy and radiographs showed maintained tibiofemoral alignment (**Figures 5A, 5B**).

Six weeks after HEF removal, the patient was ambulating well with a cane, pain was minimal, and knee ROM was up to 110° of flexion. Tibiofemoral stability remained constant—no change in medial or lateral joint space opening. Full-extension radiographs showed medial translation of about 5 mm, which decreased to 1 mm on Rosenberg view. This represents marked improvement over the severe subluxation on initial presentation.

Follow-up over the next months revealed continued improvement in the right lower extremity strength, increased tolerance for physical activity, and stable right medial tibial translation. A year after HEF removal, imaging showed adequate tibiofemoral alignment (**Figures 6A-6C**). There was mild to moderate joint space narrowing, lateral more than medial.

At 5-year follow-up, the patient was asymptomatic, had continued coronal and sagittal stability, and was tolerating regular aerobic exercise, including hiking, weight training, and cycling. Physical

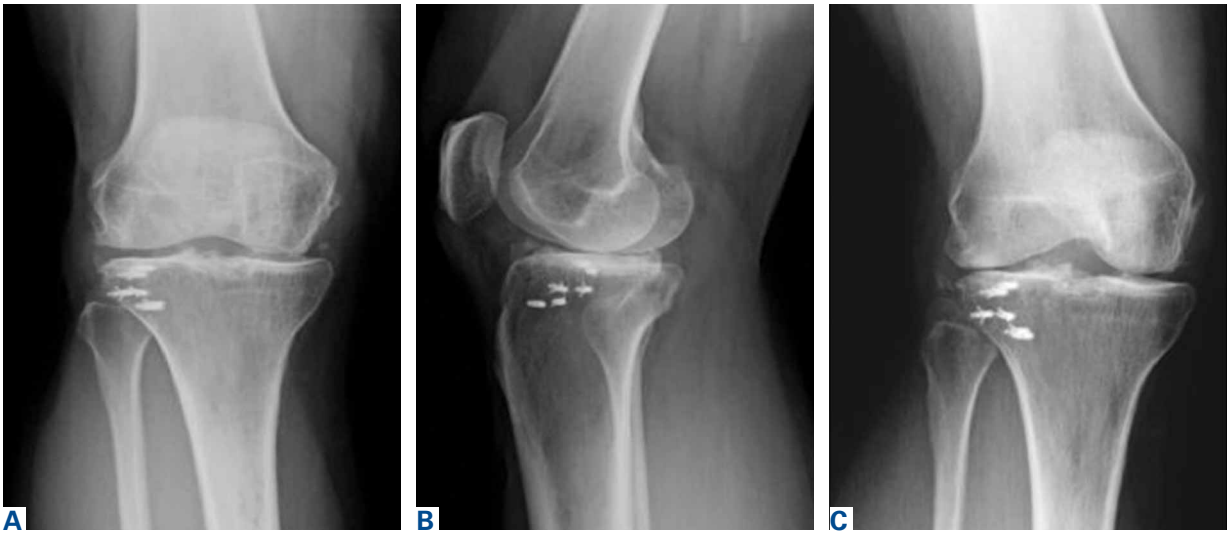

Figure 6. (A) Anteroposterior, (B) lateral, and (C) Rosenberg radiographs obtained 1 year after removal of hinged-knee external fixator show stable, minor coronal translation of tibia in coronal plane with lateral more than medial joint space narrowing.

Figure 7. (A) Anteroposterior, (B) lateral, and (C) Rosenberg radiographs obtained 5 years after removal of hinged-knee external fixator show stable tibial translation medially, associated with joint space narrowing (lateral more than medial).

examination revealed grade 1B Lachman, grade 0 pivot shift, and grade 0 posterior drawer. There was 3 mm increased lateral compartment opening in full extension, which increased to about 6 mm at 30° with endpoint. Radiographs (**Figures 7A-7C**) showed stable 2-mm coronal translation and asymptomatic though severe lateral compartment arthritis, likely secondary to the multiligament knee injury and the sub–total lateral meniscectomy performed on top of previous lateral compartment arthritis. Final International Knee Documentation Committee (IKDC) score was 78.2, final Tegner Lysholm Knee Score was 94 ("excellent"), Modified Cincinnati Rating System score was 80 ("excellent"), and Knee Injury and Osteoarthritis Outcome Score was 87.5.

Discussion

Although knee dislocations with multiligamentous involvement are rare, their outcomes can be poor. Fortunately, the principles of managing these complex injuries in the acute stage are becoming clearer. In a systematic review, Levy and colleagues[18] found that operative treatment of a dislocated knee within 3 weeks after injury, compared with nonoperative or delayed treatment, resulted in improved functional outcomes. Ligament repair and reconstruction yielded similar outcomes, though

repair of the posterolateral corner had a comparatively higher rate of failure. For associated lateral injuries, Shelbourne and colleagues[17] advocated en masse repair in which the healing tissue complex is reattached to the tibia nonanatomically, without dissecting individual structures—a technique used in the original repair of our patient's injuries.

Originally designed for other joints, hinged external fixators are now occasionally used for rehabilitation after traumatic knee injury. Stannard and colleagues[9] recently confirmed the utility of the HEF as a supplement to ligament reconstruction for recovery from acute knee dislocation.[9] Compared with postoperative use of a hinged-knee brace, HEF use resulted in fewer failed ligament reconstructions as well as equivalent joint ROM and Lysholm and IKDC scores at final follow-up. This clinical outcome is supported by results of kinematic studies of these hinged devices, which are capable of rigid fixation in all planes except sagittal and can reduce stress on intra-articular and periarticular ligaments when placed on the appropriate flexion-extension axis of the knee.[19,20]

Unfortunately, the situation is more complicated for subacute or chronic tibial subluxation than for acute subluxation. Maak and colleagues[16] described 3 operative steps that are crucial in obtaining desired outcomes in this setting: complete release of scar tissue, re-creation of knee axis through ACL and PCL reconstruction, and postoperative application of a HEF or knee brace. These recommendations mimic the management course described by Richter and Lobenhoffer[13] and Simonian and colleagues,[14] who treated chronic fixed posterior tibial subluxations with arthrolysis, ligament reconstruction, and use of HEFs for 6 weeks, supporting postoperative rehabilitation. All cases maintained reduction at follow-up after fixator removal.

It is also possible for small fixed anterior or posterior tibial subluxations to be managed nonoperatively. Strobel and colleagues[15] described a series of 109 patients with fixed posterior subluxations treated at night with posterior tibial support braces. Mean subluxation was reduced from 6.93 mm to 2.58 mm after an average treatment period of 180 days. Although 60% of all subluxations were completely reduced, reductions were significantly more successful for those displaced <10 mm.

Management of subacute or chronic fixed coronal tibial subluxations is yet to be described. In this article, we have reported on acceptable reduction of a subacute medial tibial subluxation with use of a HEF for 6 weeks after arthroscopic débridement of a deformed subacute bucket-handle lateral meniscus tear. Our case report is unique in that it describes use of a HEF alone for the reduction of a subacute tibial subluxation in any plane without the need for more extensive ligament reconstruction.

The injury here was primarily a lateral ligamentous injury. In the nonanatomical repair that was performed, the LCL and the iliotibial band were reattached to the proximal-lateral tibia. Had we started treating this injury from the time of the patient's accident, then, depending on repair integrity, we might have considered acute augmentation of the anatomical repair of LCL with Larson-type reconstruction of the LCL and the popliteofibular ligament. Alternatively, acute reconstruction of the LCL and popliteus would be considered if the lateral structures were either irreparable or of very poor quality. In addition, had we initially seen the coronal instability/translation, we might have acutely considered either a staged procedure of a multiplanar external fixator or a HEF.

Given the narrowed lateral joint space, the débridement of the lateral meniscus, and the risk of developing posttraumatic arthritis, our patient will probably need total knee arthroplasty (TKA) at some point. We informed her that she had advanced lateral compartment joint space narrowing and arthritic progression and that she would eventually need TKA based on pain or dysfunction. We think the longevity of that TKA will be predictable and good, as she now had improved tibiofemoral alignment and stability of the collateral ligamentous structures. If she had been allowed to maintain the coronally subluxed position, it would have led to medial ligamentous attenuation and would have compromised the success and longevity of the TKA. In essence, a crucial part of the utility of the HEF was improved coronal tibiofemoral alignment and, therefore, decreased abnormal forces on both the repaired lateral ligaments and the native medial ligamentous structures. Although temporary external fixation issues related to infection risk and patient discomfort are recognized,[21-23] use of HEF alone can be part of the treatment considerations for fixed tibial subluxations in any plane when they present after treatment for multiligamentous injury.

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References

1. Stannard JP, Sheils TM, McGwin G, Volgas DA, Alonso JE. Use of a hinged external knee fixator after surgery for knee dislocation. *Arthroscopy*. 2003;19(6):626-631.
2. Yeh WL, Tu YK, Su JY, Hsu RW. Knee dislocation: treatment of high-velocity knee dislocation. *J Trauma*. 1999;46(4):693-701.
3. Bellabarba C, Bush-Joseph CA, Bach BR Jr. Knee dislocation without anterior cruciate ligament disruption. A report of three cases. *Am J Knee Surg*. 1996;9(4):167-170.
4. Cooper DE, Speer KP, Wickiewicz TL, Warren RF. Complete knee dislocation without posterior cruciate ligament disruption. A report of four cases and review of the literature. *Clin Orthop Relat Res*. 1992;(284):228-233.
5. Howells NR, Brunton LR, Robinson J, Porteus AJ, Eldridge JD, Murray JR. Acute knee dislocation: an evidence based approach to the management of the multiligament injured knee. *Injury*. 2011;42(11):1198-1204.
6. Magit D, Wolff A, Sutton K, Medvecky MJ. Arthrofibrosis of the knee. *J Am Acad Orthop Surg*. 2007;15(11):682-694.
7. Medvecky MJ, Zazulak BT, Hewett TE. A multidisciplinary approach to the evaluation, reconstruction and rehabilitation of the multi-ligament injured athlete. *Sports Med*. 2007;37(2):169-187.
8. Noyes FR, Barber-Westin SD. Reconstruction of the anterior and posterior cruciate ligaments after knee dislocation. Use of early protected postoperative motion to decrease arthrofibrosis. *Am J Sports Med*. 1997;25(6):769-778.
9. Stannard JP, Nuelle CW, McGwin G, Volgas DA. Hinged external fixation in the treatment of knee dislocations: a prospective randomized study. *J Bone Joint Surg Am*. 2014;96(3):184-191.
10. Bottlang M, Marsh JL, Brown TD. Articulated external fixation of the ankle: minimizing motion resistance by accurate axis alignment. *J Biomech*. 1999;32(1):63-70.
11. Madey SM, Bottlang M, Steyers CM, Marsh JL, Brown TD. Hinged external fixation of the elbow: optimal axis alignment to minimize motion resistance. *J Orthop Trauma*. 2000;14(1):41-47.
12. Jupiter JB, Ring D. Treatment of unreduced elbow dislocations with hinged external fixation. *J Bone Joint Surg Am*. 2002;84(9):1630-1635.
13. Richter M, Lobenhoffer P. Chronic posterior knee dislocation: treatment with arthrolysis, posterior cruciate ligament reconstruction and hinged external fixation device. *Injury*. 1998;29(7):546-549.
14. Simonian PT, Wickiewicz TL, Hotchkiss RN, Warren RF. Chronic knee dislocation: reduction, reconstruction, and application of a skeletally fixed knee hinge. A report of two cases. *Am J Sports Med*. 1998;26(4):591-596.
15. Strobel MJ, Weiler A, Schulz MS, Russe K, Eichhorn HJ. Fixed posterior subluxation in posterior cruciate ligament-deficient knees: diagnosis and treatment of a new clinical sign. *Am J Sports Med*. 2002;30(1):32-38.
16. Maak TG, Marx RG, Wickiewicz TL. Management of chronic tibial subluxation in the multiple-ligament injured knee. *Sports Med Arthrosc Rev*. 2011;19(2):147-152.
17. Shelbourne KD, Haro MS, Gray T. Knee dislocation with lateral side injury: results of an en masse surgical repair technique of the lateral side. *Am J Sports Med*. 2007;35(7):1105-1116.
18. Levy BA, Fanelli GC, Whelan DB, et al. Controversies in the treatment of knee dislocations and multiligament reconstruction. *J Am Acad Orthop Surg*. 2009;17(4):197-206.
19. Fitzpatrick DC, Sommers MB, Kam BC, Marsh JL, Bottlang M. Knee stability after articulated external fixation. *Am J Sports Med*. 2005;33(11):1735-1741.
20. Sommers MB, Fitzpatrick DC, Kahn KM, Marsh JL, Bottlang M. Hinged external fixation of the knee: intrinsic factors influencing passive joint motion. *J Orthop Trauma*. 2004;18(3):163-169.
21. Anglen JO, Aleto T. Temporary transarticular external fixation of the knee and ankle. *J Orthop Trauma*. 1998;12(6):431-434.
22. Behrens F. General theory and principles of external fixation. *Clin Orthop Relat Res*. 1989;(241):15-23.
23. Haidukewych GJ. Temporary external fixation for the management of complex intra- and periarticular fractures of the lower extremity. *J Orthop Trauma*. 2002;16(9):678-685.

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