Management of Chronic Tibial Subluxation in the Multiple-Ligament Injured Knee

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Abstract: Chronic tibial subluxation is a rare and complicated problem that requires careful evaluation and planning to achieve the desired outcome and patient satisfaction. Reconstruction of catastrophic knee injury requires obtaining a balance in 2 opposing goals: stability and range of motion. Complete understanding of the impact of each of the involved ligamentous structures on knee stability and motion is particularly important, given the absence of ligamentous restraints and landmarks in the multiligamentous knee injury. Three critical operative steps are necessary to produce a desired outcome: (1) complete release and excision of scar tissue, (2) recreation of the central knee axis through anterior cruciate ligament and posterior cruciate ligament allograft reconstruction, and (3) maintenance of postoperative stability and functional motion with an external hinge fixator or functional knee brace. Careful postoperative clinical and radiographic follow-up completes the process toward an excellent result in this difficult clinical scenario.

Key Words: multiligamentous knee injury, chronic knee dislocation, ligament reconstruction, tibial subluxation, instability

(*Sports Med Arthrosc Rev* 2011;19:147–152)

Chronic tibial subluxation has been documented after single-ligament and multiligamentous knee injury, and after subsequent repair or reconstruction. The direction and subsequent clinical impact of chronic tibial subluxation on knee stability and kinematics is directly dependent on the constellation of ligamentous injury including the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posterolateral corner (PLC), and posteromedial corner in each specific patient.

This study will outline the impact of chronic tibial subluxation as it pertains to each individual ligament injury, the respective evaluation and management for each injury, and finally, the compilation of these evaluation strategies and management options in the knee with multi-ligamentous injury.

ANTERIOR CRUCIATE LIGAMENT

Overview

The ACL is the primary stabilizing structure to resisting anterior translation of the tibia on the femur. The intact ACL provides 86% of the total resistance to anterior translation of the tibia relative to the femur.[1] In addition, the ACL aids to restrict internal and external rotation in the extended knee and limits varus and valgus stress in the setting of injury to the medial collateral ligament (MCL) or lateral collateral ligament (LCL).[2] Many studies have documented improved anteroposterior tibial laxity after ACL reconstruction.[3,4] However, data exist showing that ACL reconstruction may not restore the native tibiofemoral relationship; this abnormal relationship has been linked with an irreducible fixed anterior subluxation of the tibia relative to the femur.[5]

Evaluation of Tibial Subluxation in the ACL-deficient Knee

Earlier studies have shown chronic, fixed anterior subluxation after ACL injury and reconstruction, and have postulated that this subluxation may affect the normal knee kinematics by altering the physiologic rolling motion of the tibiofemoral joint and, thereby, increase the risk for development of osteoarthritis.[5,6] ACL-deficient knees with irreducible anterior tibial subluxation have also been noted to have significantly increased osteoarthritic changes compared with a lack of arthrosis in ACL-deficient knees without fixed anterior tibial subluxation.[6] Thus, elimination of fixed anterior tibial subluxation may reduce the progression of knee arthrosis in the ACL-deficient or reconstructed knee, although no data exist in this regard.

POSTERIOR CRUCIATE LIGAMENT

Overview

The primary function of the PCL is the primary restraint to posterior tibial translation at flexion angles above 30 degrees and a secondary restraint to external rotation.[7,8] Sectioning studies of the PCL have shown increased posterior translation of the knee under a posterior tibial load in the PCL-deficient knee. This translation is greatest at 90 degrees of flexion and is decreased with full extension.[1,9] Posterior tibial subluxation may occur after PCL injury, especially in the severely injured knee.[10] Reconstruction of the PCL aids to reduce this subluxation; however, the effects of gravity and hamstring forces increase the risk for permanent posterior tibial sag even in the presence of the reconstructed PCL.[11,12]

Posterior subluxation of the tibia has been documented to increase the knee articular surface pressure and reduce the load-sharing on the menisci.[13] This increased articular pressure has been correlated with changes in knee kinematics after chronic PCL rupture and may lead to increased risk for knee arthrosis, specifically in the patellofemoral and medial compartments.[14–16]

Evaluation of Tibial Subluxation in the PCL-deficient Knee

Fixed posterior subluxation in PCL-deficient knees has been documented in multiple earlier studies and has been

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defined as a condition in which posterior sag, or posterior tibial displacement greater than 3 mm, could not be reduced to a neutral position with an anteriorly directed force. These patients commonly present with absent or minimal increased anteroposterior laxity in combination with pain, as opposed to instability. On examination, posterior sagging may be visualized and confirmed with fixed posterior tibial subluxation present on lateral radiographs with posterior and anterior stress obtained with the knee in 90 degrees of flexion.[17] The difference in tibial translation between these 2 radiographs aids in quantifying the degree of fixed posterior tibial subluxation (Fig. 1). Earlier data have shown a mean difference in anteroposterior laxity of 7.4 mm in patients with fixed posterior tibial subluxation in the PCL-deficient knee compared with 13.46 mm in a control group of PCL-deficient knees without fixed subluxation.[17]

Strobel et al[17] divided fixed posterior subluxation into 3 grades: grade I, 3 to 5 mm; grade II, 6 to 10 mm; and grade III, greater than 10 mm. In this study, 248 patients were assessed for PCL insufficiency and 109 (44%) were noted to have fixed posterior subluxation of the tibia. These 109 patients noted to have significant risk factors for posterior tibial subluxation including a history of earlier PCL operation, use of patellar tendon graft at the index reconstruction, male sex, and long-standing history of PCL insufficiency.

These investigators postulated that if a posterior tibial subluxation is irreducible intraoperatively in the presence of a reconstructed PCL, it is likely that the index PCL graft was pretensioned and fixed in a subluxated position and, thus, may be counteracting normal physiologic motion and should likely be revised at the time of surgery. If, however, the fixed posterior tibial subluxation is reducible intraoperatively, it is likely that the surrounding active soft tissue resistance may be the counteracting force producing the subluxation.

Harner and Hoher[10] and other investigators have recommended nonoperative treatment for isolated injury to the PCL (grades I to III) and early surgical intervention within the first 2 weeks for combined injuries. This recommendation was based on the natural history of this injury, likely because of the presence of intact secondary restraints and potentially intact portions of the PCL. Acute grade III injuries were recommended to proceed with immobilization in full extension for 2 to 4 weeks to reduce the posterior tibial sag. In addition, initiation of quadriceps strengthening at 1 month was also suggested, as earlier studies have suggested that this may minimize posterior tibial subluxation.[12] Chronic grade III PCL injuries, in contrast, may have concomitant injury to the PLC and, thus, surgical reconstruction may be indicated in certain cases.[10]

In the presence of fixed posterior tibial subluxation, bracing with a posterior tibial support brace at night, which locks the knee in full extension with a posterior support present at the calf region which directs a passive anterior force to limit posterior sag.[17] Daytime bracing with a functional PCL brace should also be used to allow motion and limit stiffness.

Treatment of these patients with a posterior tibial support brace produced a mean reduction of posterior subluxation to 2.58 mm over 180 days. Application of the posterior tibial support brace effectively reduced 78.4% and 70.1% of grade I and II subluxations, respectively. However, only 32% of grade III subluxations were reduced. In these cases, operative intervention should be considered.

POSTEROLATERAL CORNER

Overview

Cadaveric studies have shown that the PLC complex, comprised of the LCL, arcuate complex, popliteal tendon, and popliteal-fibular ligament functions as the primary restraint to posterior tibial translation at flexion angles less than 30 degrees.[7,8,18] Moreover, the PLC is the primary restraint to varus stress and posterolateral rotation.

Biomechanical studies have also shown that although only minimal rotatory and varus/valgus laxity is produced with isolated PCL injury, PCL injury combined with injury to the PLC results in a significantly increased posterior laxity, greater than injury to either individual structure.[7,8]

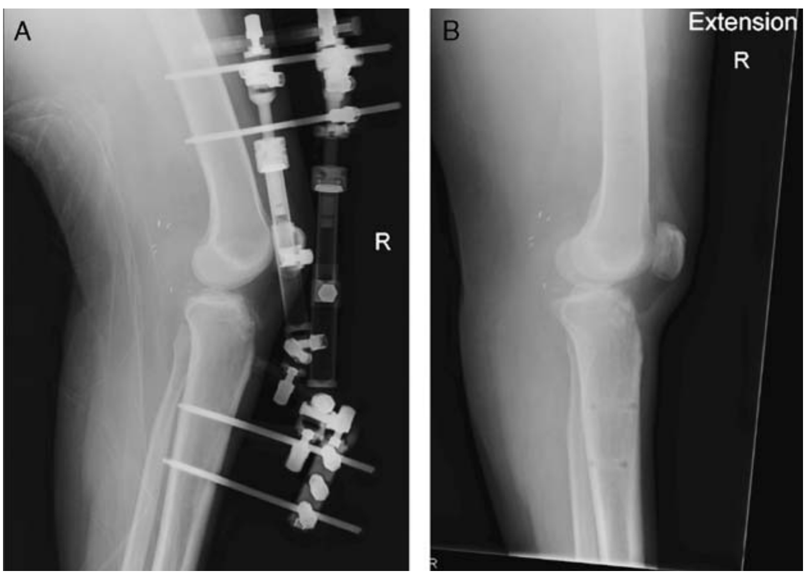

FIGURE 1. Posterior tibial subluxations present (A) before and (B) increased after removal of the external fixator.

Recreation of PLC is crucial to maintenance of rotational and translational stability. Many studies have documented improved outcomes with early surgical intervention for PLC injuries[19,20]; however, controversy still exists with regard to repair or reconstruction of the collateral ligaments.[21] In the setting of chronic injury and tibial subluxation, early intervention is no longer an option and, thus, reconstruction is recommended for recreation of lateral stability, especially in the multiligamentous injured knee.[21]

Evaluation of Tibial Subluxation in the PLC-deficient Knee

Strauss et al[22] biomechanically evaluated the effect of tibial positioning on posterolateral rotatory instability in the PCL-deficient knee in human cadaveric knees. This data documented significant increase in tibial external rotation with sequential sectioning of the PCL, popliteus, and popliteofibular ligament and LCL. Moreover, an anteriorly directed force produced significant 9-degree and 12-degree rotational increase with each sectioning test compared with neutral and posteriorly directed forces, respectively.

MULTILIGAMENTOUS INJURY

Overview

Very little data is available on the clinical and radiologic long-term outcomes after treatment of multiple-ligament knee injuries, given the rarity of this injury in developed countries.[23] Earlier studies consist of retrospective review with a heterogeneous patient population.[15,24,25] Historically, treatment of multiligamentous knee injuries has been a subject of significant controversy. Treatment has ranged from cast immobilization to early ligamentous repair to reconstruction. To date, no consensus on optimal treatment has been reached. In addition, despite extensive research and advanced reconstructive techniques, residual knee stiffness or laxity continues to present a significant problem to the treating surgeon.[5,17,26–30]

Evaluation of Tibial Subluxation in the Multiligamentous Knee

Earlier data from repair and reconstruction of multiligamentous injuries have documented fixed posterior displacement on follow-up examination despite normal Lachman tests and firm endpoints at the time of the index reconstructive procedure (Fig. 2).[29] Contributing causes for this phenomenon have been related to difficulty in both reestablishing the exact neutral position of the tibia on the femur[31] and the correct pretensioning of the grafts[32] at the time of reconstruction. Minimal data exist with regard to treatment of the chronic traumatic knee dislocation. Sisto and Warren[33] documented loss of anterior and posterior reduction in patients that were immobilized in the position of dislocation and, thus, recommended postoperative immobilization in the position opposite that of the dislocation. Henshaw et al[34] described a single case report regarding a chronic traumatically dislocated knee with fixed posterior dislocation with gross deformity and inability to ambulate. Clinical evaluation showed posterior sag, laxity to varus stress, and a firm endpoint on Lachman testing. An S-shaped deformity was noted on gross observation of the knee, signifying chronic posterior tibial dislocation relative to the femur. Simonian et al[28] documented 2 cases of chronic knee dislocations managed with open reduction, ligament reconstruction, and external hinge fixation. Excellent stability was achieved and a range of motion from −5 to 120 degrees at 6-month follow-up. Full, stable weight bearing was achieved in both cases.

Management options of this rare situation range from primary knee arthrodesis[35] to ligament reconstruction.[28,34] Knee arthrodesis has been associated with excellent pain relief and adequate joint stability[36,37]; however, long-term follow-up studies have documented increased rates of chronic hip and back pain, patient dissatisfaction, disability, and significant lifestyle changes.[38,39] In contrast, follow-up data from reconstructive studies have shown good to excellent results in joint stability, patient satisfaction, pain control, and school participation.[34] Although the knee range of motion from 5 to 40 degrees was documented as poor, the motion remained greater than that which would have been possible with arthrodesis.

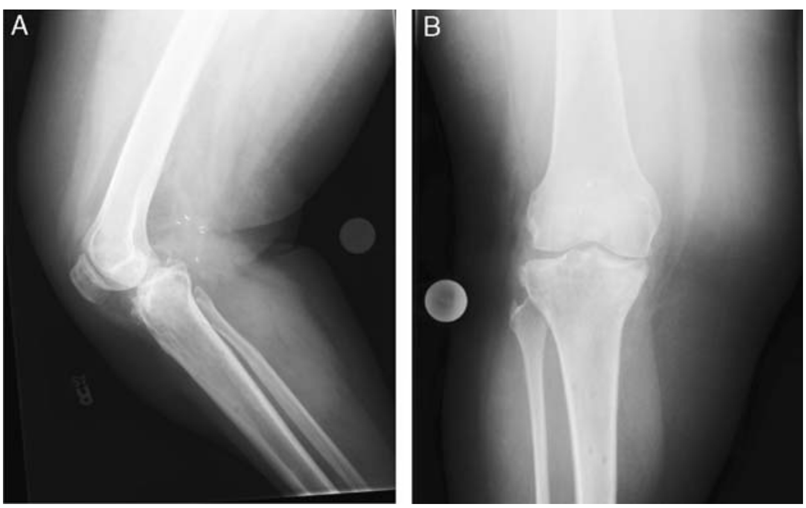

FIGURE 2. A, Anteroposterior and lateral (B) radiographic evidence of chronic, fixed posterior dislocation.

FIGURE 3. Sagittal magnetic resonance imaging showing (A) posterior tibial subluxation with anterior cruciate ligament laxity and (B) chronic posterior cruciate ligament rupture from the femoral footprint.

As mentioned previously, small fixed anterior or posterior tibial subluxations may be treated nonoperatively with knee bracing in a reduced position. However, large anterior or posterior tibial subluxations or dislocations require open surgical intervention to achieve adequate reduction and reliable stabilization (Fig. 3).

Surgical Technique

The key components to operative management of the fixed, chronically subluxated or dislocated knee include: (1) knee reduction, (2) achieve stability through a balanced reduction, and (3) protect the reconstruction while maintaining a functional knee range of motion.

Initial approach to a patient should be achieved through an anteromedial parapatellar arthrotomy. Development of a chronic traumatic dislocation produces significant scarring of the injured capsular and ligamentous structures in the malreduced position. To achieve an adequate, anatomic reduction of the subluxated or dislocated knee joint, the significant scarring must be extensively released and removed. These releases are particularly crucial in the posterior, lateral, and intercondylar regions.

Posterolateral instability should then be addressed after ACL and PCL reconstruction. Isometric positioning of this reconstruction may be obtained by evaluating the length change of suture positioned at the desired fixation points. Minimal suture length change identifies the isometric positions for graft fixation. Note that this technique relies upon earlier recreation of the central axis of the knee through ACL and PCL reconstruction.

Finally, medial instability should be addressed at the final stage of the reconstruction. Isometric positioning of this reconstruction may be obtained in a manner similar to that of the PLC.

Lastly, protection of the aforementioned reconstruction while allowing controlled functional motion is crucial to maintaining joint stability while reducing the inherent risk of arthrofibrosis and subsequent loss of range of motion. Both bracing and external hinge fixation are reasonable options in this regard. External hinge fixation use incurs, the potential risk of increased infection and poor patient tolerance. Nevertheless, this technique has been effectively used earlier.[28] If this protective option is selected, as mentioned previously, significant care should be taken during placement of the centering pin. This pin establishes the knee center of rotation and, thus, provides the foundation upon which the reconstruction protection and functional motion occurs.

Excision of the remains of the ACL and PCL should then be conducted. Attention can then be directed to the lateral and posterolateral regions in which a careful neurolysis of the peroneal nerve should be conducted to ensure accurate identification and protection of this crucial structure throughout the remainder of the procedure. Excision of the LCL and popliteal tendon remnants can be then conducted. Significant scarring between the distal anterior femur and the extensor mechanism may be present and should be released as well. This release will also provide improved mobilization and visualization. Failure to excise scarring between the extensor mechanism and the femur can significantly limit knee flexion. The medial and lateral menisci should then be evaluated, and if repair or debridement is required this should be performed before reconstruction.

Balanced reduction and stabilization must begin by recreating the central axis of the knee through ACL and PCL reconstruction. The authors prefer to perform both ACL and PCL reconstruction with allograft as this has reproducibly enabled excellent fixation while minimizing donor morbidity associated with autograft harvest. The PCL should be reconstructed before ACL to ensure ease of visualization to the posterior aspect of the tibia; thereby, allowing accurate placement of the tibial PCL aperture. A transtibial and femoral single drill hole technique is used during PCL reconstruction. The PCL graft is anchored in the tibial tunnel and the ACL graft is anchored in the femoral tunnel before tensioning. Final tensioning and fixation of the PCL and ACL occur with tension placed and held on both grafts with fixation of the PCL and ACL at 90 and 30 degrees of flexion, respectively. Notably, the central axis of the knee should be confirmed radiographically after tensioning and fixation of the PCL and ACL before proceeding with further reconstructive steps.

The PLC should then be reconstructed after the central knee axis has been recreated through cruciate reconstruction. The authors recommend reconstruction of the popliteus tendon and the LCL with an Achilles tendon allograft.[40] The PLC reconstruction should be tensioned and fixed with the knee in 30 degrees of flexion and internal rotation.

If required, the MCL reconstruction should take place as the last component of the case with Achilles tendon allograft. A guide pin should be inserted 3 to 5 mm proximal and 3 to 5 mm posterior to the medial femoral epicondyle parallel to the joint line in the coronal plane and 15 degrees anteriorly to avoid the intercondylar notch. A suture loop should then be used to confirm isometry from the previously placed guidepin to the tibial insertion immediately posterior to the pes anserinus. This tibial insertion should be modified to ensure isometry of the graft as required. A 9 × 18 mm bone plug is created for reconstruction and this is inserted into the femoral bone tunnel, which is drilled over the previously placed guidepin. Finally, the authors prefer to secure the tendinous portion of the graft to the tibia with a spiked screw and washer. Final tensioning and tibial fixation of the MCL graft should occur in 20 degrees of flexion with light varus stress.

In this manner, the PCL, ACL, PLC, and MCL reconstruction should be performed. Patellar tracking should then be assessed and the lateral retinaculum should not be closed if maltracking is identified with attempted closure. An anterior compartment release should also be performed to reduce the risk of postoperative compartment syndrome, given the extensive dissection.

Finally, if the decision is made that application of an external compass hinge fixator is necessary for protection of the aforementioned reconstruction, this should be performed at this time. Use of mobile skeletal fixation in this setting is dependent upon the intraoperative stability of the knee after reconstruction and may not be indicated in every case. Postoperative immobilization in a hinged knee brace may also be sufficient if postreconstruction knee stability is determined to be sufficient. If the compass hinge option is selected, extreme care should be used during placement of the centering pin. This pin establishes the knee axis of rotation and will function as the foundation upon which stability and functional motion is based. Centering pin placement should occur at the isometric point on both the medial and lateral femoral condyles. To identify the isometric point, temporary pins should be placed 3 cm distal to the joint line in the middle of the medial and lateral collateral insertions on the tibia and the fibula, respectively. Sutures can then be tied to each pin and then placed proximally on the medial and lateral femoral condyles at the perceived isometric point. The knee should then be placed through a range of motion, and the isometric point on the femoral condyles can be confirmed when the aforementioned sutures do not change in length during motion. It is at these lateral and medial isometric positions that the centering pin should enter and exit, respectively.

After centering pin placement, the centering pinholes on the hinge fixator can then be placed over the centering pin to ensure optimal placement of the hinge based on the previously placed centering pin. At this point, the knee should be placed in extension and two 5.0-mm Schanz pins should be placed in the femur and the tibia through the semicircular rings on the hinge fixator. Placement of these pins will provide secure osseous fixation of the hinge fixator. The semicircular rings provide multiple options for positioning of the Schanz pins. In this manner, the surgeon should avoid pin placement through the quadriceps muscle and extensor mechanism.

Note that hinge placement should always occur with the knee in full extension. The authors have found that in vivo placement of the hinge fixator is most reproducible with the knee in full extension.

Fluoroscopy should be used throughout this procedure to confirm the adequacy of reduction of the knee throughout a range of motion from 0 to 90 degrees. This confirmation should occur after PCL and ACL reconstruction and after PLC reconstruction and placement of the hinge fixator.

Postoperative Protocol

The authors suggest that a continuous passive motion machine be used immediately postoperatively with the hinge fixator in place. The patient should remain nonweight bearing for 4 to 6 weeks. The hinge fixator can then be removed at 6 weeks postoperatively. An examination under anesthesia should be conducted after removal of the hinge fixator but before removal of the Schanz pins or centering pin. If adequate stability and range of motion are confirmed, then the remainder of the pins should be removed. After hinge removal, the patient may begin progressive weight bearing in a prefabricated functional ACL brace. Close clinical and radiographic follow-up should be conducted, including comparison of contralateral lateral radiographs with ensure symmetric centering of the tibia on the femur at 90 degrees of flexion.

CONCLUSIONS

Evaluation and treatment of the multiligamentous knee with chronic tibial subluxation or dislocation is difficult and requires careful patient evaluation including full history and physical examination, complete radiographic evaluation including stress radiographs if indicated, meticulous preoperative planning, and close postoperative follow-up. Although earlier suggestion that knee arthrodesis may be the preferred intervention for the chronic traumatic knee subluxation or dislocation, open reduction and reconstruction have been shown to produce improved stability and range of motion. It is for this reason that the authors prefer open reduction and reconstruction to arthrodesis. Common pitfalls encountered during treatment of this rare, difficult situation include recreation of the central axis of the knee during ACL and PCL reconstruction, accurate ligament tensioning, and isometric centralizing pin placement, if an external compass hinge fixator is required for postoperative stability. Nevertheless, despite these pitfalls, excellent patient satisfaction, knee stability, and range of motion can be attained with this management algorithm.

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