Repair and Augmentation with Internal Brace in the Multiligament Injured Knee

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KEYWORDS

• Ligament augmentation • Internal brace • Ligament reinforcement
• Multiligament knee injury • Ligament repair

KEY POINTS

- Multiligament knee injuries are part of a complex spectrum of knee injuries. It is important to clinically assess the common peroneal nerve, vasculature of the limb, and integrity of the ligamentous structures.
- Internal brace ligament augmentation is a concept that can assist ligament repair. It is a bridging concept using braided suture tape and knotless bone anchors to reinforce ligament strength, acting as a secondary stabilizer after repair.
- Early evidence suggests improved clinical outcomes with ligament reconstruction; however, with improved suture material and implants, ligament suture repair can provide equally successful outcomes.
- Anterior cruciate ligament repair has shown some promising early results, especially in the pediatric group, with low rerupture rates, high level of return to preinjury level of activity, and no growth disturbance.
- Techniques of internal bracing, such as primary medial collateral ligament repair, are minimally invasive, preserve native anatomy, are technically straightforward, and allow immediate rehabilitation because the repair is protected by the internal brace.

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DIAGNOSIS

Multiligament knee injuries (MLKIs) can be caused by both high-energy trauma, such as road traffic accidents and falls from height, and low-energy trauma, including sporting activities.[1] The nomenclature needs to be well-defined. Knee dislocations often result in MLKIs but not all MLKIs are dislocations. Patterns of injury are clear from the history; varus and valgus loads with or without contact are a common presenting complaint. Sudden torsion or hyperextension can be part of the injury spectrum. The clinician should have a high level of suspicion for the MLKI based on the mechanism of injury. For high-energy injuries Advanced trauma life support principles apply and are the initial priority. Vigilance is required because MLKIs often lead to a dislocation and this can spontaneously reduce postinjury or on transfer. A thorough clinical neurologic examination should be performed to exclude a common peroneal nerve palsy. Up to one-third of posterolateral corner (PLC) injuries sustain a concomitant common peroneal nerve injury.[2,3] Because more than 70% of PLC injuries occur with associated cruciate ligament injuries, all aspects of the ligamentous, neurologic, and vascular integrity need to be interrogated. Foot pulses and skin color should be monitored and documented. Vascular assessment is critical because the risk of popliteal artery injury can be as high as 44%.[4] Normal and symmetric pulses and capillary refill can provide valuable information. The specificity and sensitivity of ankle-brachial index (ABPI) assessment in MLKI are well documented.[5] The systolic arterial pressure of the injured limb is divided by the systolic arterial pressure of the uninjured limb; ABPI less than 0.9 is indicative of arterial injury.

Further detailed information with MRI should be ascertained. Valuable information can be sourced from stress radiographs. Varus stress radiographs demonstrating greater than 2.7 mm to 4 mm side-to-side difference between the injured and noninjured sides indicate an isolated fibular collateral ligament tear whereas greater than 4 mm indicates a complete PLC injury. Valgus stress radiographs demonstrating a side-to-side difference of 3.2 mm to 9.8 mm demonstrate complete disruption to the superficial medial collateral ligament (sMCL). Greater than 9.8 mm difference demonstrates complete disruption to all the medial structures. Kneeling stress radiographs also can provide useful information about the integrity of the posterior cruciate ligament (PCL). A posterior translational side-to-side difference of up to 6 mm demonstrates a partial injury, whereas an 8 mm to 11 mm difference indicates an isolated complete PCL tear and greater than 12 mm difference implies a PCL rupture as part of an MLKI, such as an associated PLC or posteromedial corner (PMC) injury.[6,7]

CONCEPTS OF INTERNAL BRACE

The concept of internal brace ligament augmentation (IBLA) was popularized by Mackay and colleagues.[8] The concept is based on a ligament repair bridging concept using braided ultra–high-molecular-weight polyethylene/polyester suture tape to allow mobilization during early-phase healing. It is believed to act as a secondary stabilizer and work as a check rein that is only loaded at the end of range.

CLINICAL MANAGEMENT

van Eck and colleagues[9] performed a systematic review of the literature to assess if there is a role for internal bracing and repair of the anterior cruciate ligament (ACL). Clinical studies were reviewed and factors that could influence the outcome, such as tear type and location, fixation technique, and suture material were evaluated. The primary outcomes of interest for the clinical studies were the revision rate, anterior laxity, and pivot shift. Secondary outcome measures included patient-reported outcome measures (PROMs) and patient satisfaction. More recent preclinical studies on ACL repair have shown the strength of the repair improved when nonabsorbable sutures were used. Fisher and colleagues[10] tested the biomechanical properties of internal bracing of the ACL repair in a goat model. Anterior tibial translation was closer to the intact state when internal bracing was added to the ACL repair. Wilson and colleagues,[11] Smith and colleagues,[12] and Eggli and colleagues[13] all published small case series of ACL internal bracing.

Internal bracing is a concept and technique used in ligament repair. Several concepts have evolved, however, from using ultra–high-molecular-weight polyethylene/polyester suture tape within ligament repair and reconstruction. Several surgical techniques[14–17] have been published mainly describing the technique of internal suture augmentation. Graft reinforcement is a novel distinct entity, which the senior author has been using since 2011. It is a concept and technique of using a high-strain suture tape, FiberTape (Arthrex, Naples, Florida), to reinforce ligament reconstructions around the knee. Short-term functional PROMs and results of a series of 282 patients are in the process of publication. Indications for intra-articular reinforcement include the following:

- All PCL reconstructions
- All allografts
- All grafts of less than 8 mm in diameter
- All revisions
- All hypermobile patients
- Use in elite athletes

Extra-articular reconstruction indications include PLC reconstructions and some medial patellofemoral ligament (MPFL) reconstructions.

Anterior Cruciate Ligament Repair and Augmentation

Aboalata and colleagues[16] elegantly present internal suture augmentation to protect the all-inside ACL reconstruction surgical technique.[18,19] The ultra–high-molecular-weight polyethylene/polyester tape is fixed on both the femoral and tibial buttons in an all-inside manner. A backup fixation with a BioKnotless (Arthrex, Naples, Florida) anchor is added distal to the exit of the tibial socket. Two adjustable cortical suspensory devices are used on both the femoral and tibial sides. A single semitendinosus tendon harvest is performed and quadrupled for the preparation of a GraftLink (Arthrex, Naples, Florida) construct. A quadrupled semitendinosus graft rarely yields a graft diameter of less than 8 mm. This single-bundle anatomic ACL reconstruction is performed by using a FlipCutter (Arthrex, Naples, Florida) to create the retrosockets in a retrograde fashion after introduction through an outside-in maneuver. The graft is passed into the femoral socket initially by pulling of the traction sutures, followed by graft advancement and docking by synching down the white sutures (TightRope, Arthrex). The fixation is backed up by passing the internal suture augmentation tape tails (FiberTape) in a bioabsorbable bone anchor (SwiveLock, Arthrex), which is subsequently anchored into the anteromedial tibia distal to the tibial tunnel.

This method of internal brace suture augmentation to protect the ACL reconstruction graft also can be performed using a cortical suspensory button device on the femur and a Bio-Interference (Arthrex, Naples, Florida) screw on the tibial side.[17] The tibial tunnel can be completed and all the sutures, including the internal suture augmentation tails, are tensioned under 80 N of traction with the knee in 30° of flexion, valgus position, and the foot in external rotation. Several options are available for the internal suture augmentation tails, including a bone anchor, cortical button, staple, or 6.5 mm cancellous screw.

MacKay and colleagues[8] reviewed the PROMs and reoperation rates of a technique of ACL repair that combined repair with a synthetic IBLA; 68 of the 82 cohort patients were suitable to undergo a repair with the IBLA; however, only 27 patients had a complete data set of PROMs (1-year follow-up). Surgery was performed within 3 months of the original injury. The ACL remnant was whipstitched using an arthroscopic suture passing instrument. The proximal end of the ACL was then reapproximated against the medial wall of the lateral femoral condyle, in an anatomic midbundle position. Discussion of the position of ideal femoral footprint is outside the scope of this article. The side wall of the condyle is freshened with a microfracture probe. The internal brace is then passed through 3.5 mm tunnels in the femur and tibia. Proximal femoral fixation was secured with a TightRope while distal tibial fixation of the internal brace was carried out with the SwiveLock suture anchor. The cumulative reintervention rate for rerupture was 1.5%. The PROMs, including the Knee Injury and Osteoarthritis Outcome Score and Western Ontario and McMaster Universities Osteoarthritis Index, all had statistical significant improvement after 3 months and continued to be the case 1-year postoperatively.

Smith and colleagues[12] have reported on 3 pediatric ACL direct repairs using the internal brace method. A modification to the surgical technique described by MacKay and colleagues[8] was used for 2 additional cases. An all-epiphyseal technique with 2.4 mm diameter intra-epiphyseal femoral and tibial tunnels was used. A looped shuttling suture was passed into the joint through each tunnel and retrieved through the anteromedial (AM) portal. The loop of the femoral suture was divided resulting in 2 snare sutures: 1 suture was used to deliver the ACL repair sutures back through the femoral tunnel; the other snare was attached to the tibial looped suture, which was introduced through the native ACL and pulled through the tibial tunnel. This shuttling suture was then used to advance the internal brace. Further short-term 2-year PROMs and results of 22 pediatric ACL repairs with a modified surgical technique are in the process of publication.

Medial Collateral Ligament Repair and Augmentation

Medial-sided knee injuries are common; however, a majority of medial-sided knee injuries do not require surgical treatment. Grade III injuries or combined MLKIs may require surgical stabilization. Gilmer and colleagues[20] performed a biomechanical analysis using 27 matched cadaveric knees, 9 pairs per assay. Assay 1 compared anatomic repair with internal bracing with the intact state. Assay 2 compared repair alone with internal bracing, and assay 3 compared anatomic repair with internal bracing with allograft reconstruction. Valgus load was applied and failure was the endpoint. Stiffness and valgus displacement angles were measured.

The medial side of the knee was dissected, and particular care was taken to identify the entire medial collateral ligament (MCL) and posterior oblique ligament (POL), medial epicondyle and adductor tubercle, and tibial insertion of the semimembranosus. Repair was performed using 2 suture anchors loaded with high-strength suture at the anatomic MCL and POL femoral footprints. Internal bracing was performed by loading a high-strength suture tie (FiberTape; Arthrex) into each of the anchors at the femoral MCL and POL footprints. The suture tie from the MCL anchor was secured to the anatomic tibial insertion of the MCL. The suture tie from the POL anchor was secured to the anatomic tibial footprint of the POL. Care was taken not to overconstrain the repair. Reconstruction was performed using 2 bovine tendon allografts, as described by LaPrade.[21] The results demonstrated for assay 1 were as follows: the mean moment for internal bracing was significantly less than the intact state; however, the mean valgus angle at failure was not significantly different than for the intact state. The results demonstrated for assay 2 were as follows: the mean moment for internal bracing was significantly greater than for repair, and the mean valgus angle at failure was significantly greater than for repair. The results demonstrated for assay 3 were as follows: the mean moment for internal bracing was not significantly different than for reconstruction neither was there a difference in the the mean valgus angle at failure; when comparing internal bracing with repair alone, the moment to failure was significantly greater for internal bracing, and valgus angle at failure was significantly less, suggesting the ability of the knee to resist deformity.

Anatomy of the MCL is crucial in reconstruction. The sMCL has 1 femoral and 2 tibial attachments. The femoral attachment of the sMCL is slightly oval in shape and is located in a depression that was an average 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle. As the sMCL courses distally, it has 2 separate tibial attachments. The proximal attachment of the sMCL is primarily to soft tissues rather than directly to bone. The majority of the soft tissue deep to the proximal tibial attachment of the sMCL was the anterior arm of the semimembranosus tendon, which itself is attached to bone. The distal tibial attachment is broad based and is located anterior to the posteromedial crest of the tibia.

The POL consists of 3 fascial attachments that course off the distal aspect of the semimembranosus tendon at the knee: superficial, central, and capsular arms. The POL attaches on average 7.7 mm distal and 6.4 mm posterior to the adductor tubercle and 1.4 mm distal and 2.9 mm anterior to the gastrocnemius tubercle. The central arm is the thickest and largest portion of the POL. It courses from the distal aspect of the semimembranosus tendon and has thick fascial reinforcement of both meniscofemoral and meniscotibial portions of the posteromedial capsule. The distal tibial attachment site of the sMCL is deep within the pes anserine bursa, 6 cm distal to the joint line. The POL tibial site of attachment is to replicate the central arm of the POL and is identified slightly anterior to the direct arm attachment of the semimembranosus tendon.

Lubowitz and colleagues[22] described a MCL and PMC anatomic repair with internal bracing. Deep dissection to identify the anatomic landmarks is critical. If there is any doubt as to the positions of the critical landmarks, an isometry test can be performed. A 1.6 mm guide pin is inserted into the MCL femoral origin proximal and posterior to the medial femoral epicondyle. The tibial guide pin is inserted only after identifying the MCL and POL insertions, and the tibial insertion of the semimembranosus tendon. The exact insertion point should be within the posterior fibers of the tibial sMCL, which is located 6-cm distal to the joint line. To construct the internal brace, a high-strength suture is loaded on the femoral anchor before anchor insertion. After the femoral-sided repair is complete, internal brace augmentation is performed by tensioning the suture tape while inserting the tibial suture anchor at the MCL tibial footprint.

van der List and colleagues[23] described their surgical technique of a minimally invasive MCL internal brace. An MRI is suggested preoperatively to identify which medial structures are ruptured. The first stage is to perform a primary MCL repair. A 4 cm longitudinal incision is made over the medial epicondyle and carried down through layer 1. The most common site of injury is the femoral side. The proximal and retracted avulsed MCL should be identified. An interlocking Bunnell-pattern suturing is performed. The femoral origin of the sMCL is then identified and a bone anchor (4.75 mm vented BioComposite SwiveLock suture anchor [Arthrex]) is inserted proximal and posterior to the medial epicondyle with the repair sutures through the eyelet. The ultra–high-molecular-weight polyethyelene/polyester suture tape (FiberTape) is also inserted through the eyelet before being deployed. The second stage is to complete the internal brace for the sMCL. For this, a second incision over the tibial insertion, which is located 6-cm distal to the joint line, is made. Dissection to identify the distal fibers of the MCL is made. A curved artery clamp to tunneled deep to layer one, creating a subcutaneous tunnel, to exit the proximal wound. The suture tape is then channeled under the skin bridge along the repaired sMCL and should be anchored down at the distal insertion site of the sMCL. The most important factors, at this stage, are the position of the knee at tensioning and to not over-constrain or under-constrain the knee. The suture tape should be tensioned with the knee in 30° of flexion. The bone anchor can be partially deployed and the knee examined for range of movement and valgus instability. Final adjustments then can be made. Neutral rotation of the tibia is ideal. The knee should be kept in varus to prevent gapping of the joint medially. To avoid over-constraint, a small instrument, such as a hemostat, can be placed under the suture tie during anchor implantation.

Kovachevich and colleagues[24] performed a systematic review of the literature for the outcomes of surgical management of the MCL in the setting of an MLKI. After selection of specific inclusion criteria (English, human subjects, and mean follow-up of 24 months), 8 articles were identified that were all level IV evidence. Five articles reported on MCL repair and 3 on MCL reconstruction. There were no articles comparing MCL repair with reconstruction at this time. Of the limited evidence, repair and reconstruction both yield satisfactory results. More recently,[25] a small cohort study presented the medium-term patient reported outcomes after MLKIs comparing MCL repair with reconstruction. Patients undergoing MCL repair generally had higher PROMs than those undergoing reconstructions at a mean 6-year follow-up. The repair technique was performed using anchors and sutures. The PMC and POL were then mobilized and imbricated anteriorly using a pants-over-vest technique. Reconstruction used nonirradiated semitendinosus allografts. They did not compare the use of the internal brace with reconstruction.

Posterior Cruciate Ligament and Posterolateral Corner Repair and Augmentation

PLC injury management has evolved over the past 2 decades. Repair was the gold standard until Stannard and colleagues[26] demonstrated significantly higher failure rates in patients who underwent repair compared with reconstruction. Levy and colleagues[27] validated this, showing similar findings. There has been a recent resurgence of early intervention compared with delayed reconstruction,[28] and this is echoed throughout the literature.[29] Surgical reconstruction is recommended for grade III PLC injuries.[30] In a recent systematic review,[31] several surgical techniques were described, including the anatomic-based PLC reconstruction and the fibular sling technique; however, there are no case series that described an internal brace repair technique. Geeslin and colleagues,[31] in this systematic review, did establish that repair of grade III PLC injuries and staged treatment of combined cruciate injuries were associated with a substantially higher postoperative PLC failure rate.

MacKay and colleagues[8] have presented their experience with PCL and PLC internal brace with no adverse effects. The senior author's surgical preference for PCL reconstruction is a single-bundle reinforced peroneus longus allograft GraftLink PCL reconstruction with back-up fixation on the ultra–high-molecular-weight suture tape. The senior author has published 2 arthroscopic techniques on PCL reconstruction.[32,33]

Trasolini and Rick Hatch[34] described an all-arthroscopic technique for suture augmentation of incomplete PCL injuries that preserve the native anatomy and ligament balance while allowing for accelerated rehabilitation. A 70° arthroscope from the posteromedial portal is used to evaluate the PCL. If incomplete tears were seen, with a significant percentage of fibers intact, internal bracing would be performed. The interval adjacent to the medial femoral condyle in the intercondylar notch is used. The posterior septum is divided and the space posterior to the PCL tibial insertion site is developed. The tibial tunnel is created with the aid of fluoroscopic assistance. The femoral tunnel is created and an anterolateral-bundle position is adopted, which is juxta-articular. The instruments used for the preparation of the suture augmentation device is a combination of the FiberTape and TightRope (Arthrex). The RetroButton (Arthrex, Naples, Florida) is passed through the intact PCL ligament and into the femoral tunnel. The internal brace is then pulled through via a TigerStick (Arthrex, Naples, Florida) and tensioned with a 4.75 mm BioComposite SwiveLock. Tension is maintained in 90° of flexion ensuring over-reduction is not performed.

Frosch and colleagues[35,36] performed a meta-analysis comparing suture repair of the cruciates versus reconstruction in the setting of knee dislocations. The difficulty arises due to the lack of homogeneity in the injury pattern after knee dislocations. Levy and colleagues'[37] systematic review demonstrated decreased stability, reduced range of movement, and a lower return to preinjury activity level in the cruciate repair group compared with the reconstruction group. Autologous tendon reconstruction of the cruciate ligaments yielded superior results compared with those undergoing suture repair. Frosch and colleagues[35] accounted for injury pattern with respect to the Schenck[38] classification and compared the clinical outcome of ACL and PCL suture repair with nonoperative treatment. Suture repair outcomes were significantly better because 70% of the nonoperative patient cohort resulted in moderate or poor outcomes. Likewise, the reconstruction group showed improved outcomes compared with the nonoperative group. No significant difference was found in clinical outcome when comparing the ligament suture and reconstruction groups; 77.5% of patients with Schenck III and IV knee dislocations undergoing suture repair demonstrated good and excellent clinical outcomes.

Internal bracing does not come without risk. Concerns continue about the risk of over-constraint of the knee with internal bracing, which may lead to premature osteoarthritis; hence, care must be taken when tensioning the construct.

SUMMARY

Internal bracing is a technique that all surgeons treating MLKIs should be aware of. It provides a robust stable repair to the knee joint and allows the tissues to bridge while promoting early rehabilitation. This inevitably avoids joint stiffness due to restricted or protected range of joint movement.

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