Arthroscopic anterior cruciate ligament repair with and without suture augmentation: technical note

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ABSTRACT

Anterior cruciate ligament (ACL) tears are routinely treated with an ACL reconstruction. This is based on historical literature reporting high failure rates after ACL repairs in addition to the limited healing potential of the ACL. Recently, improved understanding of pathophysiology of ligamentous healing has led to increasing interest in treating proximal avulsions with excellent tissue quality in the acute setting, as this technique allows for ACL healing. Potential advantages of ACL repair include preservation of native proprioceptio and kinematics of the knee, avoidance of graft harvesting morbidity and the possibility to perform a primary ACL reconstruction in case of failure. As a consequence, several techniques for ACL repair have been proposed that can be performed in isolation or with suture augmentation. The primary aim of this technical note is to describe step-by-step the ACL repair technique with and without suture augmentation. The secondary aim of the current study is to review the indications, patient selection and advantages of the technique.

INTRODUCTION

Anterior cruciate ligament (ACL) tears are one of the most common injuries observed in orthopaedic clinics and are usually treated with an ACL reconstruction.1 Recently, increasing interest has been observed in attempting arthroscopic ACL repair as a potential option for patients with proximal, acute tears.2 3 This technique was routinely performed by arthroscopy; and (4) takes advantage of the ACL repair technique with and without suture augmentation. The secondary aim of the current study is to review the indications, patient selection and advantages of the technique.

As a consequence of renewed interest in the application of ACL repair in the setting of an acute ACL rupture, several new techniques for ACL repair have been proposed. The benefits of primary ACL repair include potential maintenance of cellular density, knee proprioception and kinematics, lower donor morbidity in avoiding graft harvest and the potential to convert to an ACL reconstruction in cases of failure. Though previous literature has presented ACL repair techniques, the current method is novel in that it is: (1) amenable to treatment of patients of all ages and activity levels; (2) takes advantage of repairing both the anteromedial (AM) and posterolateral (PL) bundles with the same suture if preferred; (3) allows for an anatomic repair by arthroscopy; and (4) takes advantage of using small bone tunnels that in case of failure allow for primary reconstruction. The primary aim of this technical note is to describe step-by-step the ACL repair technique and without suture augmentation. The secondary aim of the current study is to review the indications, patient selection and advantages of the technique.

SURGICAL TECHNIQUE

Indications and patient selection

ACL repairs are best indicated for patients with an acute, proximal ACL injury with good quality ligament remnants. Patient selection is critical and the key for the success of the technique.9

Current techniques

► Anterior cruciate ligament (ACL) reconstructions are considered the gold standard treatment for ACL injuries.
► Non-anatomic and more anatomic reconstruction techniques have been described with excellent clinical results.
► Both non-anatomic and anatomic reconstruction alter knee proprioception and kinematics and do not prevent the development of osteoarthritis at long-term follow-up.
► Open ACL repair with donor site morbidity is possible.2 5
► Potential for difficult revision in case of failure.

New technique

► Open ACL repair was commonly performed in 1970s and 1980s and then abandoned for high failure rates. Modern advancements in arthroscopic surgery combined with new understanding of pathophysiology of ligamentous healing had led to the development of new minimally invasive arthroscopic ACL repair techniques.
► Preserves native ACL with knee proprioceptive and kinematics potential advantages.
► No need of graft harvesting avoiding donor site morbidity.
► Faster healing.
► Lack of high level of evidence and long-term follow-up in literature.
Due to a denser vascularity and healing potential, primary ACL repairs should only be performed in proximal ACL tears.\textsuperscript{8,9} The Sherman classification describes ACL tear location and is described as the following: type I (ACL avulsion injury from the top of the femoral notch); type II (tear through the substance of the upper one-third of the ACL); type III (midsubstance tear); type IV (distal tear) and type V (distal tibial bone avulsion tear).\textsuperscript{4,10} According to Sherman’s classification, only type I or eventually type II tears should be repaired.\textsuperscript{4,10}

The quality of the ACL remnant is critical to perform an effective reattachment of the remaining ligament to the femoral wall. To ensure a remnant of a good quality, the ACL repair should be performed in the acute or subacute phase, between 1 week and 3 months after the injury has occurred.\textsuperscript{11–13} Good quality is defined as a consistent ACL amenable to being grasped and reducible (can reach the footprint). On the contrary, poor quality ACL tissue is defined as when the ligament is hypoplastic with poorly defined margins and friability that makes it difficult to grasp. The location of the tear may be evaluated preoperatively by MRI. MRI assessment of the ACL stump has been reported to be reliable in determining tear location in acute ACL injuries.\textsuperscript{14} However, a final determination of the location of the tear and the quality of the remnant should be confirmed during the arthroscopy.

When the ACL injury is suitable for the repair, surgeons can decide to associate a non-biological augmentation to the repair with the use of a suture. The authors’ decision to augment or not the repair depends on injury type and the ability to reduce the remnant anatomically. The authors prefer isolated ACL repair when one or both bundles of ACL present a Sherman type I injury. When during the arthroscopy a Sherman type II injury of at least one of the ACL bundles is observed, an ACL repair with suture augmentation is preferred. Therefore, repair augmentation in our practice is performed only in cases of type II tears, whereas age and activity level do not play a role in surgical decision making. Our main indications for suture augmentation include higher risk patients (adolescents, those with generalised laxity and those who engage in high contact sports) or the presence of a Sherman type II injury with reducible remnant of at least one of the ACL bundles.

**General and patient preparation**

Prophylactic antibiotics are administered and spinal anaesthesia or an adductor canal block is commonly used for anaesthesia. With the patient under anaesthesia, a complete physical exam should be performed by evaluating the ACL with a Lachman manoeuvre, anterior drawer and pivot shift test. The patient is placed in the supine position with all appropriate prominences adequately padded. At the operative side, the foot of the bed is maximally flexed, and the leg is secured in a leg holder. A tight tourniquet is applied and inflated. The arthroscopic pump can be used at the surgeon’s discretion, though the authors prefer to not use a pump system. The lower extremity is prepared with an antiseptic solution (chlorhexidine and isopropyl alcohol) and subsequently draped in the standard sterile fashion.

**Arthroscopic approach to the knee and ligament tear**

Standard anterolateral (AL) and AM portals are created. The anatomical landmarks can be marked at the surgeon’s discretion. A limited fat pad debridement is performed to enhance visualisation. After debridement of the fat pad, a diagnostic arthroscopy is performed, including evaluation of the patellofemoral, medial and lateral compartments. If any intra-articular pathology is noted, such as meniscal or cartilage injury, this is addressed before the ligament repair is performed.

The arthroscopic evaluation of the ACL injury is crucial in the decision-making process. By direct visualisation and probing, the location of the tear and the quality of the ACL remnant is confirmed. The reducibility of the remnant is assessed with the use of a grasper (figure 1) in order to check if the remnant is able to reach the femoral footprint. At this point, if arthroscopic visualisation reveals a more distal ACL injury (type III) or a remnant of insufficient quality, the surgeon should be prepared to convert to an ACL reconstruction.

**ACL repair**

Once the ligament is deemed suitable for repair, the femoral footprint is debrided with a shaver, and microfractures are performed to provide bleeding of the notch wall and to encourage healing (figure 2). A minimal lateral condyle notch-plasty can be performed with a burr to provide better visualisation of the femoral footprint.

Next, the ACL remnant is sutured using an interlocking Bunnel-type suture. A self-retrieving suture passer (First Pass, Smith & Nephew, Tennessee, USA) is introduced through the AM portal. Suturing of the ACL remnant is performed starting from the intact tibial end to the most proximal aspect of the stump using a N.0 high-resistance suture (Ultrabraid, Smith & Nephew). Generally, three stitches are placed using the same limb of the suture, while the other limb is kept under tension by the assistant (figure 3). If resistance is experienced, the suture passer should be repositioned.
At this point, the portals are switched, and the arthroscope is introduced through the AM portal. The free limb of the suture is passed through the AL portal with the help of a grasper and loaded into the suture passer. With the suture passer introduced through the AL portal, stitches are thrown in the same way as the first limb. Generally, three passes with each limb are made before reaching the proximal avulsed end of the ligament (figure 4). The authors’ preference when performing an ACL repair is to suture both ACL bundles with the same suture. If the surgeon prefers to suture both bundles independently, the same process may be repeated twice for each bundle.

With the knee flexed to 90°, a 3.2 mm drill is introduced through the AM portal to aid in the anchor placement. The target should be located at the native footprint of the AM bundle. With the current technique, location of the tunnel is more important than degree of knee flexion, as the tunnel is drilled the anchor. It is important to drill the tunnel in the footprint of the ACL, which is usually done in 90° of flexion, as this allows adequate space for the drill to be positioned at the footprint. The sutures are passed through a 4.5 mm knotless anchor (FOOTPRINT Ultra) and introduced into the joint through the AM portal. Sutures are then tightened, and the anchor is introduced into the tunnel (figure 5). Of note, the tension of the suture cannot be further modified after the anchor is deployed. If the surgeon has opted for suturing both bundles independently, a second anchor loaded with the sutures from the posterolateral bundle is positioned in the footprint of the posterolateral bundle with the knee in hyperflexion.

Finally, the remnants of the sutures are cut flush, and the tension of the ACL is checked with a probe (figure 6). An intraoperative Lachman test is performed to check the minimal degree of anteroposterior translation with a firm endpoint.

**ACL repair with suture augmentation**

If suture augmentation is desired once the repair is completed, another 4.5 mm anchor preloaded with a doubled Ultratape suture (Smith & Nephew) is obtained. With the knee hyperflexed, the tunnel for the anchor is drilled into the posterolateral bundle footprint, after which the anchor preloaded with the doubled Ultratape suture is deployed into the femur (figure 7). The augmentation suture tape is introduced into the anchor repairing the AM bundle.

In order to provide an anatomical augmentation, the tibial tunnel must be located into the anterior half of the ACL tibial insertion. As a reference, the limit between AM and the posterolateral bundle may be used. To create the tibial tunnel, an ACL aiming guide is used for pin insertion. Once the pin is inserted in a satisfactory position, a 4.5 mm tunnel is drilled while being cautious of the ACL tibial remnant. This tunnel is created with a 4.5 mm endobutton reamer and fixed with a 7 mm interferential screw. Since this screw is conical, it can be easily introduced into a tunnel that is smaller than the actual screw. An arthroscopic suture retriever is introduced into the joint through the tibial tunnel to pass the double Ultratape into the tunnel (figure 8).
With the knee in 20° of flexion, sutures are tightened, and tibial fixation is performed with a 7×25 mm interference screw (Biocomposite, Smith & Nephew) (figure 9). The remnants of the suture are cut flush with the tibial cortex. The degree of ACL remnant tension is tested with a probe, while range of motion (ROM) and absence of impingement are also checked. The intraoperative Lachman test is performed and should reveal anteroposterior stability with clear endpoint.

Postoperative management
Postoperative management is similar in cases of both isolated ACL repair and ACL repair with suture augmentation. A knee brace locked in extension is used for the first 2 weeks in order to protect the repair. Immediate full weight bearing is encouraged with the aid of crutches at the patient’s discretion. Once the knee brace is discontinued, physical therapy is initiated with the same protocol used as an ACL reconstruction. Progressive ROM exercises, patella mobilisation and isometric quadriceps contraction are stimulated with the expectation of normal walking, full extension and 110° of flexion at 1 month after surgery. Non-contact sport (swimming or cycling) is allowed 2 months postoperatively, while running is permitted at 4 months. If strength and physical function tests compared with contralateral limb are restored, a return to pivoting sports is allowed at 7–8 months postoperatively.

CLINICAL RESULTS
Between April 2019 and January 2020, a total of 54 patients underwent primary arthroscopic ACL repair. Inclusion criteria consisted of all patients with primary ACL tears that occurred proximally and were classified as type I or type II. Exclusion criteria consisted of revision ACL repair, >type II tears and distal ACL tears.

A total of 13 patients had type I tears treated with an isolated ACL repair, while the remaining 41 cases had type II tears treated with repair and suture augmentation. The mean age of all patients was 28.6 years (range: 16–50). A total of 40 (74.1%) patients were males. Injury to the ACL occurred in the right knee in 29 patients and the left knee in 25 patients. The mean time from injury to surgery was 8.1 weeks (range: 3–48).

Patients routinely filled out the Tegner and visual analogue scale (VAS) for pain scores preoperatively. Prior to ACL repair, the mean Tegner and VAS pain scores were 69.2 (range: 42–89) and 3.6 (range: 2–8). At a minimum of 1 year follow-up, a total of four patients were lost to follow-up. The mean Tegner score postoperatively was 94.4 (range: 80–100), while the mean VAS pain score was 0.9 (range: 0–2). There were a total of three failures that necessitated revision surgery.

DISCUSSION
The most important factor for a successful ACL repair is patient selection. The ACL is an intra-articular, extrasynovial ligament. Blood supply to the ACL is provided due to the fact that it is covered almost entirely by synovial tissue, which is rich in blood vessels. These vessels from the synovial sheath penetrate the ligament in a horizontal direction, while intraligamentous vessels are oriented longitudinally. It is well established that the vascularisation of the ACL is provided by the middle geniculate artery, an anterior branch of the popliteal artery piercing the oblique popliteal ligament. In addition, secondary blood supply to its distal aspect is provided by the inferomedial and AL genicular arteries through the anterior fat pad. The proximal part of the ACL is better vascularised than the rest of the ligament, thereby making its blood supply more important. Based on these anatomical features, current literature supports that only acute, proximal ACL injuries with a good quality remnant are suitable for a repair as these have a greater cellular density and potential to heal.

Although advances in diagnostic imaging techniques allow the recognition of the different types of ACL tears, this must be confirmed intraoperatively by direct visualisation. In cases of a distal injury or a remnant of poor quality, the surgeon must be prepared to convert to an ACL reconstruction. Likewise, the...
presence of a midsubstance tear should be a contraindication to primary repair as it may have a higher propensity for failure. The presence of a good quality remnant is a crucial aspect of a successful ACL repair. To ensure a good quality remnant, the technique is recommended to be performed in the acute or subacute phase, which means that it should be performed within 3 months of injury. Our recommendations are in accordance with previous literature, which has suggested that there is a significantly higher likelihood of encountering a repairable remnant when surgery is performed within the first months of injury. A long delay between injury and surgery may cause retraction and reabsorption of the ligament, which can lead to a poor remnant ligament quality that is not amenable to repair. However, in our experience, we have still observed good outcomes when repaired after 3 months in patients that have presented with type I or II tears of good quality. Regardless, preoperative assessment and intraoperative confirmation of good ACL remnant quality is essential, both to predispose the patient to a good outcome and avoid unexpected need for reconstruction.

The addition of suture augmentation to the ACL repair provides support to the ligament and prevents excessive stretching during the healing process. Though we choose to only augment ACL repair in cases of type II tears, some authors routinely perform suture augmentation in all primary ACL repair as it has been proposed that augmentation protects the ligament during early rehabilitation. In addition, some in vitro studies have demonstrated faster healing with augmented repair compared with non-augmented repairs. However, in our experience using the proposed technique, we have observed good clinical and functional outcomes based on this decision making at 1 year postoperatively as described above. Indeed, our preference is to add suture augmentation only in selected cases to protect the repaired ligament, especially during early range of motion, and in higher risk patients (eg, adolescents, generalised laxity and high contact sports) or the presence of a Sherman type II injury with reducible remnant of at least one of the ACL bundles. Future studies are warranted to further investigate the necessity and utility of augmentation in primary ACL repair.

ACL repairs have several potential advantages and disadvantages compared with ACL reconstruction that are summarised in Box 1. Advantages include a less invasive surgery with absence of graft harvesting and preservation of the native ACL. These preserve proprioceptive function and original kinematics of the knee. Moreover, an ACL repair does not ‘burn any bridges’ for the future, and patients with failed repair can undergo standard primary ACL reconstruction. The main disadvantages of the technique include the requirement for careful selection of patients, as previous literature has demonstrated that failure rates are generally more favourable when performing ACL reconstruction in comparison with ACL repair. For this reason, the surgeon should be ready to switch to an ACL reconstruction if needed and the patient informed with an appropriated consent.

The major difference between the indications for reconstruction versus repair of the ACL is the location and degree of ACL injury. Additionally, recent evidence has suggested that select patients who undergo ACL reconstruction may benefit from concomitant stabilisation in the form of lateral extra-articular tenodesis or AL ligament reconstruction, which is a topic that has not been well explored in the ACL repair literature. Despite these differences, many indications between the procedures remain similar, such as patient selection as it pertains to the procedures being efficacious in a wide variety of age ranges and for patients of various activity levels.

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**Figure 7** To perform an augmentation, a tunnel for an anchor is drilled into the PL bundle footprint with the knee hyperflexed. A knotless anchor preloaded with a doubled tape suture is introduced into the hole by impaction. PL, posterolateral.

**Figure 8** The tibial tunnel for the augmentation is located into the anterior half of the ACL tibial insertion with the help of an aimer. An arthroscopic suture retriever is introduced into the joint through the tibial tunnel to pass the double tape into the tunnel.

**Figure 9** Final view of the repaired anterior cruciate ligament with suture augmentation.
CONCLUSION

Arthroscopic ACL repair is a potential option for patients with proximal ACL tears and good quality of the ACL remnant. However, patient selection is critical to ensure a successful outcome with a low failure rate. Suture augmentation can be used for protection of the repaired ligament during early rehabilitation or in high-risk patients. Further studies are warranted to determine ACL repair long-term outcomes, indications and failure rates.

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