Arthroscopic biological internal bracing with remnant repair for subacute ACL femoral avulsions

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A B S T R A C T

Arthroscopic anterior cruciate ligament (ACL) reconstruction predictably restores sagittal plane knee stability, however its inability to replicate a complex fan-shaped ligament of multiple fascicles, along with deficient restoration of normal rotational knee kinematics, results in failure to reverse a high risk for premature post-traumatic osteoarthritis. Although arthroscopic repair for acute ACL femoral avulsions is proposed to counter these deficiencies, the risk of early failure following non-healing, along with lack of convincing evidence of efficacy has impeded its universal acceptance. Moreover, since ACL repair needs to be performed in the acute phase following injury, it has an increased risk of developing arthrofibrosis, besides precluding any possibility to achieve natural healing of an ACL avulsion with non-operative treatment. The technique of biological internal bracing with remnant repair incorporates the advantages of both reconstruction and repair, and is indicated for patients with persistent ACL deficiency in the subacute phase (6–12 weeks) following an ACL femoral avulsion. This operation essentially involves two steps. The step of biological internal bracing is similar to a conventional ACL reconstruction using a small diameter hamstring graft that is targeted to the centre of the anteromedial ACL bundle on the femur, whereas the tibial socket is located posteriorly within the ACL tibial footprint so as to preserve the anterior fan-shaped morphology of the ACL tibial insertion. The second step involves repairing the remnant ACL tibial stump using one of three techniques. Although technically more complex than an ACL reconstruction, this novel technique provides native anatomy restoration with potential biomechanical and functional advantages, and should be considered for unhealed subacute ACL avulsion injuries.
Advantages and disadvantages

Advantages

- A ‘time-tested’ ACL reconstruction which predictably restores knee stability is performed, and the risk of failure of ACL repair due to non-healing is avoided.
- This technique restores the complex native ACL anatomy, especially the fan-shaped morphology of the tibial insertion which is impossible to replicate with available reconstruction techniques using cylindrical or flat grafts.
- Potentially restores normal rotational knee kinematics, and in the long-term may avoid the risk of osteoarthritis associated with reconstructed ACLs.
- Preservation of neural receptors within the remnant which possibly ensures early return of proprioception and a more normal feeling of the knee.
- Unlike ACL repair, this procedure is performed in the subacute phase following an ACL tear, and decreases the risk of post-operative arthrofibrosis noted with surgical procedures performed in the acute phase.
- Since narrow sockets of 7.0–8.0 mm are created, revision surgery is expected to be similar to primary reconstruction.

Disadvantages

- As compared to ACL repair, autograft harvest and its associated morbidity are not avoided.
- Biological healing of the remnant ACL native tissue is critical for the potential advantages of anatomical and neuromotor restoration to occur. The healing interfaces include remnant to femoral insertion site, and between autograft and remnant. In the absence of biological healing and incorporation, there is a risk of this technique being equivalent to a narrow graft ACL reconstruction.
- There is a risk of overstuffing the notch and resultant ACL impingement in extension, hence the autograft diameter should not exceed 8.0 mm in an average-sized patient.
- With unstable Sherman Type II avulsions that are sutured to the biological internal brace at the femoral insertion, if healing of remnant to autograft does not occur, there is a risk of cyclops formation and impingement.

Surgical technique

Outline of the clinical problem

Arthroscopic reconstruction is the current surgical gold standard for treating instability following an ACL tear. Although ACL reconstruction predictably restores sagittal plane knee stability, significant problems remain. These include autograft harvest and its associated morbidity, delayed biological incorporation and increased failure rates with allografts, loss of neuromotor function with the removal of native ACL tissue [1], inability to surgically replicate a complex fan-shaped ligament of multiple fascicles with a cylindrical bundle of tendon fibres [1], deficiency in restoration of normal rotational knee kinematics, and failure to reverse a high risk for premature post-traumatic osteoarthritis [2].

In view of these problems, arthroscopic repair is gaining acceptance as an alternative to reconstruction for acute femoral avulsions of the anterior cruciate ligament. The advantage of repair includes preservation of native ACL anatomy along with proprioception which potentially ensures a more normal feeling of the knee as compared to ACL reconstruction [3], and which in the long-term may avoid the risk of osteoarthritis associated with ACL reconstruction. ACL repair is a less invasive surgery with limited intra-osseous drilling, no graft harvest, and faster return of function. Revision surgery following the failure of primary repair is expected to be similar in complexity to a primary ACL reconstruction. However, good quality and long-term evidence supporting the efficacy of modern-day ACL repair is lacking [4], with studies demonstrating variable failure rates [5]. ACL repair also needs to be performed in the acute phase following injury [6], and is not advisable for patients who present beyond 3–6 weeks of injury. This precludes any attempt of non-operative treatment to achieve natural healing of an ACL avulsion. Besides, performing the surgery in the acute phase significantly increases the risk of knee arthrofibrosis.

Surgical indications and contraindications

Biological internal bracing with remnant repair for ACL avulsions incorporates the advantages of both reconstruction and repair. It is indicated for patients who present with either instability or persistent ACL deficiency in the subacute phase (6–12 weeks) following an ACL injury, and who demonstrate an ACL femoral avulsion (Sherman Type I and II [7] on MRI). Intraoperative contraindications include insufficient native ACL tissue length for re-tensioning to femoral insertion, or inadequate tissue quality to hold sutures. Under these circumstances, a conventional ACL reconstruction is performed.

This operation essentially involves two steps: biological internal bracing followed by remnant ACL repair. The first step of biological internal bracing is similar to a conventional hamstring autograft ACL reconstruction with the following differences. The graft diameter should not exceed 8.0 mm, and is typically 7.0 mm in an average-sized patient. This can be adjusted by using a double, triple, or quadruple bundle semitendinosus autograft and is based on the ACL footprint size and characteristics of native ACL remnant. Although the ACL femoral socket is anatomic and targeted to the centre of the anteromedial bundle of the ACL, the tibial tunnel is located posteriorly within the ACL tibial footprint so as to preserve the unique fan-shaped morphology of the anterior aspect of ACL tibial insertion. Utmost care needs to be exercised during socket preparation so as to preserve the ACL remnant which will be subsequently repaired and incorporated into the graft construct.

The second step involves repairing the remnant ACL tibial stump using one of three technique variations depending on the location of avulsion and stability of the remnant stump. Sherman Type I ACL avulsions are true ligament avulsions directly off the bone and demonstrate sufficient native ACL tissue length for re-tensioning directly to the femoral insertion. These are repaired to the femoral attachment using a suture anchor inserted within the femoral ACL footprint adjacent to the femoral socket (region of PL bundle insertion) with a curved delivery guide.

Type II ACL avulsions are through the proximal substance of the ACL with up to 20% of ACL tissue left on the femoral insertion. These stumps cannot be re-tensioned up to the femur and are either adherent to the PCL (stable) or can be flipped anteriorly with probing (unstable). For stable stumps, the internal bracing graft is tunnelled within the stump itself, and no further suturing or femoral fixation of the stump is warranted. Unstable stumps are sutured to the internal brace graft a few millimetres distal to the femoral insertion so that they do not cause subsequent roof/
notch impingement or cyclops formation. It is critical to ensure full knee extension and a lack of ACL construct impingement once the procedure is completed.

Rehabilitation and return to sports following this procedure is similar to an arthroscopic ACL reconstruction and an emphasis is placed on early return of active full knee extension.

Discussion

The novelty of this technique is that it offers the ‘best of both worlds’ by incorporating all the potential advantages of ACL repair with gold-standard ACL reconstruction. The graft for biological internal bracing should be large enough to ‘reconstruct’ the ACL; but not so large that it disrupts the anterior fan-shaped tibial insertion, or occupies the entire femoral footprint in Type I avulsions (where remnant healing to femoral footprint is desired), or causes notch impingement. We have found grafts between 7.0 and 8.0 mm optimum in size, although proportionately bigger grafts are acceptable in larger patients.

Remnant preservation not only improves biological healing of the ACL graft via enhanced cell proliferation, revascularisation, and regeneration of proprioception [8], but also possibly reduces subsequent graft re-ruptures [9]. Since this procedure is performed in the subacute phase following an ACL tear, it decreases the risk of postoperative arthrofibrosis noted with surgical procedures performed in the acute phase, and also allows a trial of non-operative treatment to identify patients who heal naturally and do not warrant surgery. Since there is a time-dependent effect to the value of remnant preservation [10], we recommend performing this procedure within 12 weeks of injury.

Outcomes: Our short-term outcomes with this novel technique have been encouraging. A retrospective review of 60 consecutive cases who underwent this technique was performed. Inclusion criteria were patients over 16 years treated surgically with biological internal bracing with remnant repair for persistent instability or demonstrable clinical laxity 6 weeks following isolated ACL Sherman type I and II tears with a minimum follow-up of 12 months following surgery. Data assessed included demographic (age, sex, sport, mechanism of injury), clinical (grading of Lachman test and pivot shift test, range of motion), patient-reported outcomes (Lysholm, subjective IKDC, Forgotten Joint Score FJS-12 Kneec), and whether or not revision ACL surgery was performed. Postoperative MRI to study ACL construct characteristics was performed in 17 patients. All patients had restoration of knee stability (Lachman grade 0 or 1) and no patient had an ACL re-tear within one year of follow-up. One patient had restricted terminal knee extension, and underwent an arthroscopic cyclops excision 10 months following index surgery. The mean post-operative outcome scores were Lysholm 94.2, subjective IKDC 89.4, and FJS-12 Knee 79.1. Each of the 17 post-operative MRIs revealed healed ACL construct with 16 demonstrating preservation of native tibial ACL anatomy.

Conclusions and future perspective

Although technically more complex than an ACL reconstruction, biological internal bracing with remnant ACL repair provides potential advantages and should be considered for unhealed subacute ACL avulsion injuries. Published surgical outcomes following this technique are awaited and future research is needed to validate whether there is any ‘true’ biomechanical and functional advantage with this native anatomy restoration procedure.

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Appendix A. Supplementary data

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References