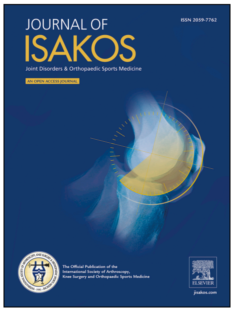
Journal Pre-proof



Biological Internal Bracing With Remnant Repair for Subacute ACL Femoral Avulsions

Dinshaw N. Pardiwala, Dave Lee

PII: S2059-7754(22)00100-6

DOI: https://doi.org/10.1016/j.jisako.2022.10.007

Reference: JISAKO 65

To appear in: *Journal of ISAKOS*

Received Date: 4 June 2022

Revised Date: 19 October 2022

Accepted Date: 26 October 2022

Biological Internal Bracing With Remnant Repair for Subacute ACL Femoral Avulsions

ABSTRACT

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 center 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.

NOVELTY

- Allows the "best of both worlds" by incorporating all the potential advantages of ACL repair with gold-standard ACL reconstruction, whilst avoiding most problems of either approach.
- This procedure can be performed in the subacute phase, and hence allows a trial of non-operative treatment to identify patients who do not warrant surgery : either those that heal naturally, or those capable of "coping" with ACL deficiency.

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 ensure 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 postoperative 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 is 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 8.00 mm.
- 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.

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 removal of native ACL tissue[1], inability to surgically replicate a complex fan-shaped ligament of multiple fascicles with a cylindrical bundle of tendon fibers[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 construction. ACL repair is a less invasive surgery with limited intra-osseous drilling, no graft harvest, and faster return of function. Revision surgery following 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 retensioning to femoral insertion, or inadequate tissue quality to hold sutures. Under these circumstances, a conventional ACL reconstruction is performed.

Surgical technique

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. 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 center 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 bone and demonstrate sufficient native ACL tissue length for retensioning directly to the femoral insertion. These are repaired to the femoral attachment using a suture anchor inserted within the femoral ACL footprint anterior 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 upto 20% of ACL tissue left on the femoral insertion. These stumps cannot be retensioned upto 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 tunneled 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 millimeters 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.

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. 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 do not warrant surgery : either those that heal naturally, or those capable of “coping” with ACL deficiency. 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

A retrospective review of 60 consecutive cases who underwent this novel technique at a single institution 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. All patients had excellent postoperative knee stability (Lachman grade 0 or 1) and no patient had an ACL retear within one year of follow-up. 1 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 Forgotten Joint Score FJS-12 Knee 79.1. Of 17 post-operative MRIs performed, all 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. Future studies including outcomes research is needed to validate whether there is any "true" biomechanical and functional advantage with this native anatomy restoration technique.

REFERENCES

1. Murray MM. Current status and potential for primary ACL repair. *Clin Sports Med.* 2009;28(1):51-61.
2. von Porat A, Roos EM, Roos H. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. *Ann Rheum Dis*. 2004;63:269-273.
3. Vermeijden HD, van der List JP, O'Brien R, DiFelice GS. Patients forget about their operated knee more following arthroscopic primary repair of the anterior cruciate ligament than following reconstruction. *Arthroscopy*. 2020;36(3):797–804. 10.1016/j.arthro.2019.09.041
4. Heusdens CHW. ACL repair: a game changer or will history repeat itself? A critical appraisal. *J Clin Med*. 2021;10(5):912. 10.3390/jcm10050912
5. Hoogeslag RAG, Brouwer RW, de Vries AJ, Boer BC, Huis In't Veld R. Efficacy of nonaugmented, static augmented, and dynamic augmented suture repair of the ruptured anterior cruciate ligament: a systematic review of the literature. *Am J Sports Med*. 2020;48(14):3626–37. 10.1177/0363546520904690
6. Magarian EM, Fleming BC, Harrison SL, Mastrangelo AN, Badger GJ, Murray MM. Delay of 2 or 6 weeks adversely affects the functional outcome of augmented primary repair of the porcine anterior cruciate ligament. *Am J Sports Med.* 2010;38(12):2528-2534. DOI: 10.1177/0363546510377416
7. Sherman MF, Lieber L, Bonamo JR, Podesta L, Reiter I. The long-term followup of primary anterior cruciate ligament repair. Defining a rationale for augmentation. *Am J Sports Med.* (1991) 19(3):243–55. 10.1177/036354659101900307
8. Takahashi Y, Kondo E, Yasuda K, Miyatake S, Kawaguchi Y, Ondera J, Kitamura N. Effect of remnant tissue preservation on tendon graft in anterior cruciate ligament

reconstruction: A biomechanical and histological study. *Am J Sports Med* 2016; 44: 1708-16.

9. Takazawa Y, Ikeda H, Kawasaki T, Ishijima M, Kobuta M, Saita Y, Kaneko H, Kim SG, Kurosawa K, Kaneko K. ACL reconstruction preserving the ACL remnant achieves good clinical outcomes and can reduce subsequent graft re-ruptures. *Orthop J Sports Med* 2013;1(4):2325967113505076.
10. Zhang S, Matsumoto T, Uefuji A, Matsushita T, Takayama K, Araki D, Nakano N, Nagai K, Matsuzaki T, Kuroda R, Kurosaka M. Anterior cruciate ligament remnant tissue harvested within 3 months after injury predicts higher healing potential. *BMC Musculoskeletal Disorders* 2015;16:390 https://doi.org/10.1186/s12891-015-0855-0

Biological Internal Bracing With Remnant Repair for Subacute ACL Femoral Avulsions

Dinshaw N. Pardiwala, MS(Orth), DNB(Orth), FCPS
Head – Centre for Sports Medicine
Director – Arthroscopy & Knee Preservation Service
Kokilaben Dhirubhai Ambani Hospital, Mumbai, India.

Dave Lee, MBBS, FRCS(Ortho), Mmed(Ortho),
Head - Sports Shoulder and Elbow Surgery
National University Hospital, Singapore.

Financial grants received for this study : None

Financial renumeration / biases for any author : None

Declaration of interests : The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.