

All-Inside Anterior Cruciate Ligament Reconstruction With Augmentation Using the Native Anterior Cruciate Ligament Remnant by Suture Approximation



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Abstract: Anterior cruciate ligament (ACL) rupture remains a debilitating orthopaedic pathology with a substantial economic and psychological burden on patients, especially athletes. The purpose of ACL reconstruction is to attain maximum joint stability and functionality, allowing patients to resume their previous level of activity. Several graft options and techniques are available for ACL reconstruction. The all-inside remnant-preservation technique is a minimally invasive approach aiming for improved proprioception, better graft integration, and increased graft strength via ACL augmentation by suture approximation with an optimal anatomic reconstruction. ACL augmentation is associated with a decreased risk of rerupture. Moreover, enhancement of knee proprioception via the presented technique allows an early return to activity by patients because weight bearing (with a brace) can be initiated as early as day 1 postoperatively. Patients can resume running activities by 2 months postoperatively and return to pivot sports by 3 months postoperatively. Despite this surgical procedure being technically demanding, it is associated with improved clinical outcomes and functional capacities. Patients are also found to better tolerate the postoperative rehabilitation protocol.

Rupture of the anterior cruciate ligament (ACL) represents an overwhelming insult sustained by the knee via contact and/or noncontact mechanisms, with a high incidence seen in contact sports, especially when patients partake in high-impact landing and twisting athletic events.¹⁻³ ACL injuries impact patients financially in terms of the cost of operative management and postoperative rehabilitation. Additionally, ACL injuries constitute a personal and psychological burden for professional athletes because of the inability to participate in sports.^{3,4}

ACL reconstruction is advised in patients aiming to return to sports.⁵ It aims for maximum joint stability and increased functional capacity, allowing patients to resume their previous level of activity while reducing the risk of development of osteoarthritic changes to the knee.⁶ Several surgical techniques and graft types exist in practice for ACL reconstruction and knee stability restoration.⁷ Bone—patellar tendon—bone graft is still considered by some orthopaedic surgeons to be the standard for ACL reconstruction.⁸ Although it was first introduced in 1979 and 1984,⁹ quadriceps tendon graft for ACL reconstruction has recently been introduced as a suitable alternative in ACL reconstruction,^{7,10-12} accounting for 11% of all grafts used for ACL reconstruction.¹³ The purpose of this study is to describe a technique of all-inside ACL reconstruction with augmentation using the native ACL remnant by suture approximation.

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Surgical Technique

Under spinal anesthesia, the patient undergoes scrubbing and draping of the knee, with inflation of a tourniquet over the thigh. By use of a 2-portal technique, with standard central medial and anterolateral portals, the ACL remnant is observed (Fig 1). Examination of the

knee joint is performed with the patient under anesthesia.

The anterolateral portal is located above the joint line, next to the lateral border of the patellar tendon. It is used as a viewing portal during tibial insertion drilling, if needed, and as a working portal throughout the surgical procedure. The central medial portal is situated marginally above the joint line, above the meniscus, next to the edge of the inferomedial part of the patellar tendon. It can be used as a viewing or working portal. After both portals are established, the pattern of the ACL tear, as well as the bony landmarks of the ACL insertion, is identified. Subsequently, a small incision around 2 cm in size is made over the medial aspect of the knee for harvesting of the semitendinosus tendon using a tendon stripper proximally; the tendon is then traced to its insertion and released with a knife to gain as much length as possible. It is prepared as a quadrupled graft around 6.5 cm on a graft preparation station (Arthrex) depending on the anatomic size of the native ACL. The tunnel size is chosen according to the graft size. To minimize devascularization, no shaver or controlled ablation is used during this process to resect the bursa and fat pad.

The anatomic starting location for the femoral guide including the drill pin for an ACL TightRope device (Arthrex) is found with the knee flexed to 90°. In this position, the guide pin is aimed so that it passes through the ridge between the footprints of the anteromedial bundle and posterolateral bundle of the ACL in the case of partial ACL rupture (Fig 2). In case of total ACL rupture, the guide pin should be inserted directly into the

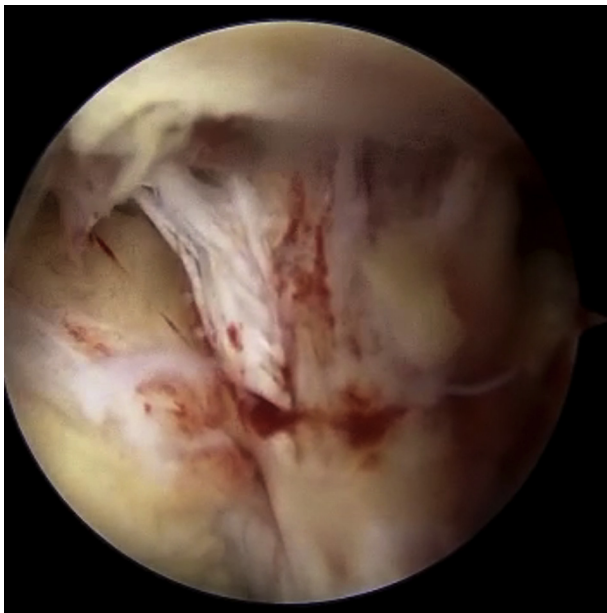


Fig 1. Arthroscopic evaluation showing rupture of the anterior cruciate ligament viewing from anteromedial portal, left side of the patient.

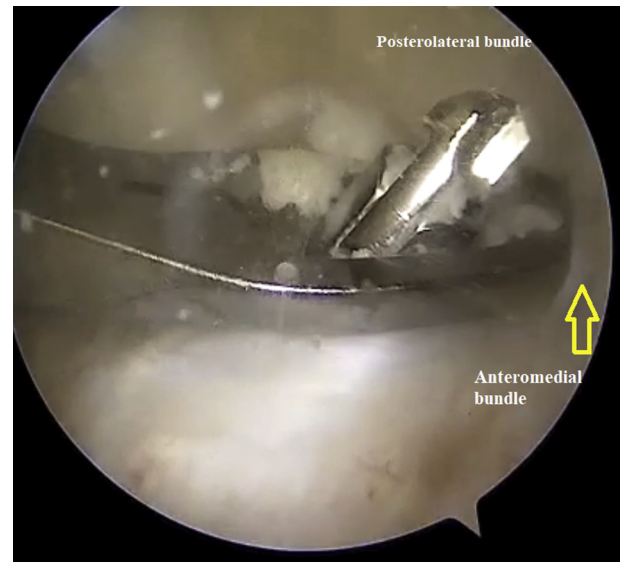


Fig 2. Guide pin aiming through the ridge between the footprints of the anteromedial bundle and posterolateral bundle of the anterior cruciate ligament viewing from anteromedial portal, left side of the patient. Yellow arrow represents anteromedial bundle of ACL.

middle of the footprint. While the guide is kept in this position, the knee is flexed to 120°; then, the guide pin is drilled through the femoral condyle until it comes out through the skin anterolaterally. A femoral low-profile reamer can now be passed into the joint over this flexible drill pin without damaging the medial femoral condyle by bending the drill pin away from the condyle as the cannulated drill is introduced through the portal.

With the knee remaining flexed to 120°, the socket is established by drilling to a depth of 27 to 30 mm. A FiberWire (Arthrex) is passed through the femoral tunnel after the reamer and drill pin are removed. The knee is flexed to 90°, and a FlipCutter (Arthrex) is then used to apply retro-drilling of the tibial tunnel according to the size of the graft while the ACL fibers on the tibia are preserved as much as possible. The surgeon should aim for an entry site of the guide pin into the joint that is in the middle of the ACL footprint. After retrograde drilling of the tibial tunnel with the FlipCutter, the debris is removed by a shaver and irrigation and a FiberStick (Arthrex) is inserted into the tibial tunnel. The femoral and tibial FiberWires are retrieved together from the anteromedial portal using a FiberWire retriever to avoid any soft-tissue interposition. By use of a No. 11 blade, the ACL remnant fibers on the tibial and femoral sides are cut in the direction of the fibers (Fig 3). Using a Knee Scorpion (Arthrex) loaded with No. 2-0 FiberWire, we separate the 2 ends of the ACL to prevent any remnants from going into the tibial socket while entering the graft. The wires of the TightRope are loaded in the loop of the femoral FiberWire and retrieved into the femoral socket; then, by use

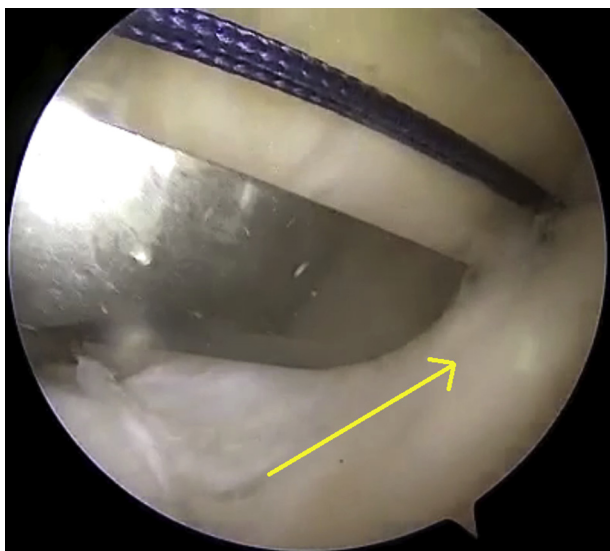


Fig 3. A No. 11 blade cutting the remnant anterior cruciate ligament fibers on the tibial and femoral sides in the direction of the fibers to preserve the biomechanical function and orientation of the remnant anterior cruciate ligament bundles viewing from anteromedial portal, left side of the patient. Yellow arrow represents ACL remnant.

of the blue FiberWire of the TightRope, the button to flip is retrieved on the anterolateral cortex of the femur, after which the graft is retrieved into the femoral socket using the white fiber of the TightRope (Fig 4). The TightRope wires are loaded in the loop on the tibial side and retrieved into the tibial socket; then, by use of the blue FiberWire of the TightRope, the button to flip is retrieved on the tibial cortex. With the use of a knife and a small periosteal elevator, all the tissue under the tibial TightRope is retrieved in a fashion in which the entire circumference is applied on the tibial cortex. Afterward, the graft is retrieved into the tibial socket using the white FiberWire of the TightRope.

After cycling 20 times, the graft is again checked for adequacy under arthroscopy. Then, the ACL remnant on the tibia is approximated over the new graft using a Scorpion needle (Arthrex) around the remnant for suture passing that better envelops the new ACL (Video 1, Fig 5). This is believed to reinforce anatomic stability while optimizing postoperative proprioception for earlier mobilization and return to sports.¹⁴

Rehabilitation

Regarding postoperative rehabilitation, the described technique allows full weight bearing and full range of motion immediately postoperatively owing to the high degree of stability, as tolerated by the patient and musculature. A return to full and active competitive sports is allowed postoperatively after 6 to 9 months. Use of an extension knee brace is advised at a minimum of 4 weeks after surgery on ambulation.

Discussion

In the aforementioned technique, augmentation with suture approximation is believed to increase proprioception, graft integration, and graft strength. By using a minimally invasive technique for graft harvesting and an all-inside technique for ACL reconstruction, soft-tissue damage is minimized and, subsequently, recovery is fast.

The 4 fundamental principles of anatomic reconstruction of the ACL include appreciation of the native anatomy of the ACL, tailoring the surgical procedure to satisfy the patient's anatomy or needs, with native anatomy restoration by placing the graft at the center of the footprint. Furthermore, the native function must be replicated as closely as possible by adequate tensioning.¹⁵ A meta-analysis by Meredick et al.¹⁶ showed no advantage of double-bundle techniques over the anatomic single-bundle procedure. Moreover, encouraging results of ACL augmentation performed arthroscopically are constantly being published in the literature, with most showing improved clinical and functional outcomes with a decreased risk of rerupture.¹⁷ Multiple choices of graft are available; however, the literature shows that bone–patellar tendon–bone graft for ACL reconstruction is associated with morbidities such as anterior knee pain during the postoperative course,⁹ as well as an increased risk of patellar tendon rupture and fracture of the patella.⁸ On the other hand, the use of hamstring tendon autograft for ACL reconstruction is associated with fewer morbidities when compared with bone–patellar tendon–bone graft in terms of knee pain and the development of osteoarthritis.⁷ However, hamstring autograft for ACL reconstruction is associated with a higher infection



Fig 4. Retrieval of the graft into the femoral socket using the white fiber of the TightRope viewing from anterolateral portal, left side of the patient. Yellow arrow represents femoral socket.

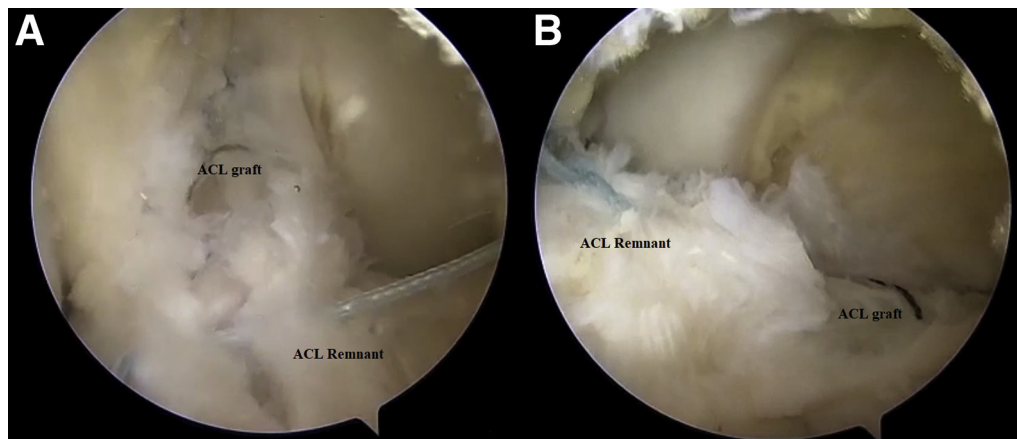


Fig 5. (A) Insertion of the suture of the remnant anterior cruciate ligament (ACL) over the inserted graft for more stability and preservation of the native anatomy. (B) Suturing of the ACL remnant over the inserted graft in an anatomic configuration to preserve proprioception for early mobilization and a better functional recovery viewing from anteromedial portal, left side of the patient.

rate,¹⁰ as well as weakness in hip extension and terminal knee flexion.¹¹ Despite the tremendous advances in surgical procedures for ACL reconstruction, graft failure still occurs at a rate of 2% in the 2 years after surgery,¹⁸ and this rate increases to 11.9% at 10 years after surgery.¹⁹ As such, several factors are responsible for reinjuries, such as a patient's young age and high level of athletic activity. Moreover, reinjuries may be due to previous meniscectomy or even surgical technique errors related to graft handling, such as placing, tensioning, and/or fixing the harvested graft.^{20,21}

The rate of ACL reconstruction revision surgery has increased over the past several years, and it is projected to further increase in the future, especially with the social and cultural emphasis on sports participation and physical activity.^{21,22} Despite the literature being sparse, study results have shown the superiority of primary ACL reconstruction over revision ACL reconstruction with better patient-reported outcome scores.^{22,23} However, these reported scores and stability evaluations may not reflect the clinical benefit of revision ACL reconstruction experienced by the patient.²⁴ In their meta-analysis, Andriolo et al.²¹ (2015) reported that of the 75% of patients who returned to sports, only around 43% were able to return to the same level of

activity.²² Furthermore, it is estimated that a third of patients will have another ACL tear within a few years after the primary ACL reconstruction.²⁵ Patients with a ruptured ACL are at a significantly increased risk of osteoarthritis development, especially those with a concomitant meniscal injury.²⁶ Around half of ACL-injured patients will require surgical intervention for meniscal injury within the first 5 years post-operatively, which increases the prognosis of osteoarthritis from a rate of 0% to 13% to a rate of 21% to 48%.²⁷ Hence, preventing a secondary meniscal injury serves as a major element in reducing the rate of osteoarthritis development.²⁵ Grindem et al.²⁵ (2016) reported a 4 times greater rate of reinjury in patients who participate in level I sports (e.g. jumping and pivoting) after ACL reconstruction. Moreover, a 9-month delay before returning to sports, along with symmetrical strengthening of the quadriceps muscles, was associated with an 84% decreased risk of reinjury after ACL reconstruction. Additionally, reinjuries were seen among 38.2% of patients who did meet the return-to-sport criteria versus 5.6% of patients who met these criteria.²⁵ On the other hand, a study conducted by Corradini et al.²⁸ (2010) showed significant improvement among patients who underwent

Table 1. Risks and Limitations of Technique

Risks
Tendency to insert graft in anterior fashion, leading to extension limitation
Risk of cyclops lesion owing to remnant preservation
Overconstraint of joint
Tendency to have increased overall thickness owing to combined size of remnant and graft, leading to PCL impingement
Limitations
Lack of long-term outcome data
Strict patient compliance required for rehabilitation

PCL, posterior cruciate ligament.

Table 2. Advantages and Disadvantages of Technique

Advantages
Invasion of 1 cortex, leading to less morbidity and pain, yielding early return to activities
Anatomic reconstruction with ACL remnant preservation
Preservation of proprioception with early mobilization and return to sports
Rigid fixation
Disadvantages
Technically demanding anterior tibial tunnel and anterior femoral tunnel
Requirement for incision of remnants in direction of fibers

ACL, anterior cruciate ligament.

accelerated rehabilitation of proprioception after ACL reconstruction via perturbation-based exercises. This enhancement in knee proprioception might allow an early return to athletic activities by patients.²⁸

The sites of intra-articular graft remodeling and intra-tunnel graft incorporation are 2 different sites where graft healing occurs during the postoperative course.²⁹ After ACL reconstruction, graft healing occurs in 3 stages. The early stage is characterized by hypocellularity and limited necrosis of the graft that shows no detectable revascularization. This is followed by a stage of intense graft remodeling and revascularization associated with cellular proliferation. The last stage is the intra-articular remodeling of the graft (ligamentization) during which the graft is restructured toward the characteristic properties of an intact ACL.²⁹ In their study, Howell et al.³⁰ reported no detectable revascularization of the graft during the first 2 postoperative years. The un-impinged hamstring graft retained the same hypovascular profile as the native posterior cruciate ligament. However, magnetic resonance imaging scans showed rich vascularization of the soft tissue surrounding the graft, which led the authors to postulate that the graft viability after ACL reconstruction is more dependent on synovial diffusion than on revascularization.³⁰ Additionally, graft biopsy specimens showed limited neovascularization that was below the threshold that could be seen on magnetic resonance imaging.³¹ Janssen et al.³² reported that the completion of the stages of hamstring remodeling can take up to 2 years after ACL reconstruction.

Our technique is an all-inside technique with remnant preservation, whereby drilling of the tunnel is performed through the soft tissue after proper identification. To prevent joint pain and stiffness, it is important not to over-tighten the graft. Moreover, immediate weight bearing with a brace is allowed on day 1 postoperatively, in addition to physiotherapy for strengthening, proprioception, and range of motion. Typically, running is achieved by 2 months postoperatively, and pivoting sports are allowed by 3 months postoperatively. When this technically demanding surgical procedure is performed while taking into account its risks and limitations (Table 1), the clinical and functional outcomes of patients are very promising, with an earlier return to sports activity and better tolerance of the rehabilitation protocol (Table 2).

The described technique for ACL reconstruction merges ACL augmentation and all-inside techniques, with an emphasis on proprioception preservation and increased anatomic construct stability. The aim of this technique is early mobilization and an early return to activity, with decreased postoperative pain, along with improved postoperative patient-reported clinical and functional scores.

References

- Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *J Athl Train* 2007;42:311-319.
- Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med* 1995;23:694-701.
- Webster KE, Hewett TE. Meta-analysis of meta-analyses of anterior cruciate ligament injury reduction training programs. *J Orthop Res* 2018;36:2696-2708.
- Filbay SR, Ackerman IN, Russell TG, Crossley KM. Return to sport matters—Longer-term quality of life after ACL reconstruction in people with knee difficulties. *Scand J Med Sci Sports* 2017;27:514-524.
- Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. *Br J Sports Med* 2011;45:596-606.
- Heijink A, Gomoll AH, Madry H, et al. Biomechanical considerations in the pathogenesis of osteoarthritis of the knee. *Knee Surg Sports Traumatol Arthrosc* 2012;20:423-435.
- Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: A systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone-patellar tendon-bone and hamstring-tendon autografts. *Am J Sports Med* 2019;47:3531-3540.
- Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: A comprehensive review of current literature and systematic review of clinical results. *Arthroscopy* 2015;31:541-554.
- Blauth W. A new drill template for the operative treatment of injuries of the anterior cruciate ligament. *Unfallheilkunde* 1984;87:463-466 [in German].
- Geib TM, Shelton WR, Phelps RA, Clark L. Anterior cruciate ligament reconstruction using quadriceps tendon autograft: Intermediate-term outcome. *Arthroscopy* 2009;25:1408-1414.
- DeAngelis JP, Cote M, Fulkerson JP, Caminiti S. Central quadriceps tendon for anterior cruciate ligament reconstruction: Long-term results (SS-33). *Arthroscopy* 2008;24:e18 (suppl, abstr).
- Marshall JL, Warren RF, Wickiewicz TL, Reider B. The anterior cruciate ligament: A technique of repair and reconstruction. *Clin Orthop Relat Res* 1979;143:97-106.
- Middleton KK, Hamilton T, Irrgang JJ, Karlsson J, Harner CD, Fu FH. Anatomic anterior cruciate ligament (ACL) reconstruction: A global perspective. Part 1. *Knee Surg Sports Traumatol Arthrosc* 2014;22:1467-1482.
- Lee B-I, Kwon S-W, Kim J-B, Choi H-S, Min K-D. Comparison of clinical results according to amount of preserved remnant in arthroscopic anterior cruciate ligament reconstruction using quadrupled hamstring graft. *Arthroscopy* 2008;24:560-568.
- van Eck CF, Schreiber VM, Liu TT, Fu FH. The anatomic approach to primary, revision and augmentation anterior

- cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1154-1163.
16. Meredith RB, Vance KJ, Appleby D, Lubowitz JH. Outcome of single-bundle versus double-bundle reconstruction of the anterior cruciate ligament: A meta-analysis. *Am J Sports Med* 2008;36:1414-1421.
 17. Ouanezar H, Blakeney WG, Fernandes LR, et al. Clinical outcomes of single anteromedial bundle biologic augmentation technique for anterior cruciate ligament reconstruction with consideration of tibial remnant size. *Arthroscopy* 2018;34:714-722.
 18. Andernord D, Desai N, Björnsson H, Ylander M, Karlsson J, Samuelsson K. Patient predictors of early revision surgery after anterior cruciate ligament reconstruction: A cohort study of 16,930 patients with 2-year follow-up. *Am J Sports Med* 2015;43:121-127.
 19. Crawford SN, Waterman BR, Lubowitz JH. Long-term failure of anterior cruciate ligament reconstruction. *Arthroscopy* 2013;29:1566-1571.
 20. Barber-Westin SD, Noyes FR. Factors used to determine return to unrestricted sports activities after anterior cruciate ligament reconstruction. *Arthroscopy* 2011;27:1697-1705.
 21. Andriolo L, Filardo G, Kon E, et al. Revision anterior cruciate ligament reconstruction: Clinical outcome and evidence for return to sport. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2825-2845.
 22. Warme BA, Warren RF. Outcomes of revision ACL. In: Marx RG, ed. *Revision ACL reconstruction*. New York: Springer, 2014;255-263.
 23. Wright RW, Gill CS, Chen L, et al. Outcome of revision anterior cruciate ligament reconstruction: A systematic review. *J Bone Joint Surg Am* 2012;94:531-536.
 24. Ross MD, Irrgang JJ, Denegar CR, McCloy CM, Unangst ET. The relationship between participation restrictions and selected clinical measures following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2002;10:10-19.
 25. Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L, Risberg MA. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: The Delaware-Oslo ACL cohort study. *Br J Sports Med* 2016;50:804-808.
 26. Frobell RB, Roos HP, Roos EM, Roemer FW, Ranstam J, Lohmander LS. Treatment for acute anterior cruciate ligament tear: Five year outcome of randomised trial. *BMJ* 2013;346:f232.
 27. Øiestad BE, Engebretsen L, Storheim K, Risberg MA. Winner of the 2008 systematic review competition: Knee osteoarthritis after anterior cruciate ligament injury. *Am J Sports Med* 2009;37:1434-1443.
 28. Corradini C, Albonico S, Lucchesi G, Colantuono V, Verdoia C. Accelerated rehabilitation of proprioception after ACL reconstruction may enhance knee proprioception and help the early return to sports activities. *Orthop Proc* 2010;92-B:347 (suppl II, abstr).
 29. Janssen RPA, Scheffler SU. Intra-articular remodelling of hamstring tendon grafts after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2014;22:2102-2108.
 30. Howell SM, Knox KE, Farley TE, Taylor MA. Revascularization of a human anterior cruciate ligament graft during the first two years of implantation. *Am J Sports Med* 1995;23:42-49.
 31. Scheffler SU, Unterhauser FN, Weiler A. Graft remodeling and ligamentization after cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2008;16:834-842.
 32. Janssen RPA, van der Wijk J, Fiedler A, Schmidt T, Sala HA, Scheffler SU. Remodelling of human hamstring autografts after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2011;19:1299-1306.