Original Article

Anterior Cruciate Ligament Repair with Suture Augmentation for Proximal Avulsion Injuries

Wiemi A. Douoguih, M.D., Ralph T. Zade, M.D., Blake M. Bodendorfer, M.D., Yalda Siddiqui, B.S., and Andrew E. Lincoln, D.P.H.

Purpose: To assess failure rate, outcomes, and patient satisfaction in patients who underwent anterior cruciate ligament (ACL) repair with suture augmentation for clinical instability and proximal avulsion of the ACL. **Methods:** We retrospectively reviewed consecutive suture-augmented ACL repairs performed by a single surgeon between January 2014 and June 2016 for proximal ACL avulsion. Patients were included if they were at least 24 months postoperative from repair surgery. Patients were excluded from the study if they underwent primary ACL reconstruction instead of repair or if they had a concomitant multiligamentous knee injury. Knee Injury and Osteoarthritis Outcome Score (KOOS), visual analog scale (VAS), Veterans RAND-12 (VR-12), Marx Activity, and Single Assessment Numeric Evaluation data were collected. **Results:** Of 172 patients who underwent ACL surgery between January 2014 and June 2016, 28 (16%) with Sherman type I or II ACL tears or high-grade partial avulsion with clinical instability underwent ACL repair with suture augmentation. One patient was not available for follow-up. The 27 patients were age 27.4 ± 8.6 years, 18 males (66.7%), and 2.8 ± 0.7 years follow-up (range, 2.0-3.8 years). Of these 27 patients, 4 recurrent ACL injuries (14.8%) required revision to reconstruction. The remaining 23 patients had successful ACL repair with no clinical instability and no subjective complaints at final follow-up. Final scores were KOOS 83.7 ± 12.8, Marx 8.6 ± 4.0, VAS 1.1 ± 1.8, physical VR-12 53.6 ± 5.2, mental VR-12 53.1 ± 8.1, and Single Assessment Numeric Evaluation 83.0 ± 12.9. In the 11 patients with baseline data, significant improvements were observed in composite KOOS (50.4 ± 11.5 to 85.7 ± 8.4; $P < .001$; VAS: 3.9 ± 2.6 to 0.8 ± 0.8; $P = .002$; and physical VR-12: 39.9 ± 6.5 to 55.5 ± 3.3; $P < .001$). All 11 patients (100%) met or exceeded the KOOS composite minimum clinically important difference (mean 34.0 increase). **Conclusions:** In patients with proximal ACL avulsion, arthroscopic primary ACL repair with suture augmentation demonstrated high functional outcome and improved patient-reported outcomes at 2-year follow-up. The rate of graft failure was 15%. **Level of Evidence:** Level IV, therapeutic case series.

Anterior cruciate ligament (ACL) reconstruction has improved the treatment of ACL injury, with numerous reports showing excellent subjective and objective postoperative outcomes across all patient populations and irrespective of graft type.[1-4] Large studies with long-term follow-up have found that rates of osteoarthritis and recurrent injury may be higher than previously reported.[5-9] ACL reconstruction is also associated with the potential for reinjury and revision, particularly in young cutting and pivoting athletes.[5,6,9] Recent reports of return to play rates[5-7] and time to return to previous performance levels suggest that there is room for improvement in the science of ACL surgery.

ACL repair may be a possible alternative to ACL reconstruction in some patients. Early surgical treatment of ACL rupture was typically performed with an open repair of the native ligament. However, primary ACL repair fell out of favor after unacceptable mid-term

From the Department of Orthopaedic Surgery, MedStar Washington Hospital Center, Washington, DC (W.A.D., Y.S.); MedStar Union Memorial Hospital, Baltimore, MD (R.T.Z.); MedStar Georgetown University Hospital, Washington, DC (B.M.B.); and MedStar Sports Medicine Research Center, Baltimore, MD (A.E.L.).

The authors report the following potential conflicts of interest or sources of funding: W.D. is a paid consultant for Arthrex and has a 1.5% ownership stake in Ultimaxx Health. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Presented at AANA19 meeting of the Arthroscopy Association of North America, Orlando, FL, May 2-4, 2019.

Received September 12, 2019; accepted May 10, 2020.

Address correspondence to Wiemi A. Douoguih, M.D., c/o Lyn Camire, Editor, Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, 3333 North Calvert Street, Suite 400, Baltimore, MD 21218. E-mail: lyn.camire@medstar.net

2666-061X/191116

https://doi.org/10.1016/j.asmr.2020.05.003

outcomes were reported.[10-13] Early results in 1 study were promising, but patient outcomes declined at 5 years with only 5 of 64 patients reporting resolution of symptoms.[10] Instability was reported in 91% of these patients, and 15 required reoperation.[10] Other groups produced results that corroborated these outcomes.[14-18] ACL reconstruction emerged as an effective alternative and eventually replaced ACL repair as the standard treatment. However, improvement in surgical material technology, rehabilitation principles, and minimally invasive surgical techniques have led to renewed interest in primary ACL repair.[6,19-23]

The purpose of this study was to assess failure rate, outcomes, and patient satisfaction in patients who underwent ACL repair with suture augmentation for clinical instability and proximal avulsion of the ACL. We hypothesized that we would find significantly improved functional outcome and a high percentage of patients who exceeded the minimum clinically important difference (MCID) and patient acceptable symptom state (PASS) threshold for ACL surgery.

Methods

After institutional review board approval (MedStar Health Research Institute institutional review board protocol no. 2018-070) and patient consent was obtained, the operative reports of all patients who underwent surgical treatment for an ACL injury between January 2014 and June 2016 by the senior author (W.A.D.) were reviewed. All patients who underwent primary ACL repair with suture augmentation for proximal ACL avulsion (Internal Brace; Arthrex, Inc., Naples, FL) were identified. To be included in the study, patients had to be at least 24 months postoperative from their repair surgery. Patients were excluded from the study if they underwent primary ACL reconstruction instead of repair or if they had a concomitant multiligamentous knee injury.

Indications for arthroscopic primary ACL repair included clinical instability of the anterior cruciate ligament (confirmed by patient history and examination under anesthesia), preoperative magnetic resonance imaging confirming a torn ACL, preoperative consent for the possibility of arthroscopic primary ACL repair, intraoperative assessment confirming a proximal avulsion of the ACL from the lateral femoral condyle (Sherman type I or II or high-grade partial tear with clinical instability), and satisfactory tissue quality to support primary repair (Fig 1).

All patients were followed in the office until they were released to return to unrestricted activity. All included patients were contacted by phone using an institutional review board-approved phone script. Recurrent clinical instability, number of reoperations, reason for reoperation, and return to sport or previous activity level data were collected for all patients. Functional and clinical outcomes scores, including the visual analog score (VAS) for pain, the Veterans RAND-12 Survey (VR-12), the Marx activity scale, the Knee injury and Osteoarthritis Outcome Score (KOOS), and the Single Assessment Numerical Evaluation (SANE) knee scores (postoperative only), were collected for each patient using an automated database (Surgical Outcomes System, SOS, Arthrex, Inc.). All included patients who underwent knee surgery in 2015 or later enrolled in the database preoperatively. All patients who underwent surgery before 2015 and were not enrolled preoperatively in the SOS database were contacted and asked to complete 2-year outcomes surveys.

Surgical Technique

All patients were consented for both primary ACL repair with suture augmentation and primary ACL reconstruction. The choice of treatment was determined intraoperatively by the senior investigator, a fellowship-trained orthopaedic sports surgeon (W.A.D.). Standard knee arthroscopy was performed and the ACL was examined. If the tear configuration and tissue quality were appropriate, the patient was selected for primary repair with suture augmentation and suture button fixation as described previously.[20,21] A suture passer was used to pass a single #2 nonabsorbable suture (FiberLink, Arthrex, Inc) with multiple whip stitches through the ACL remnant in a locking fashion from the distal (attached) end to the proximal end. The free suture end was then retrieved through a cannula in the anteromedial portal. The femoral ACL footprint was identified, and the center of the footprint was marked with a 5-mm round burr. The remaining ACL tissue was then removed from the lateral aspect of the femoral wall with an arthroscopic shaver. A microfracture device (PowerPick, Arthrex, Inc) was used to create a bleeding insertion site for healing response by penetrating the tidemark with multiple small holes. Next, an accessory anteromedial portal was created and a spade tip guide wire 3.5 mm in diameter was used to create a small tunnel through the center of the ACL remnant on the lateral femoral condyle with the knee in hyperflexion. A passing suture was left emanating from the femoral drill hole.

An all-in-one guide pin and reamer (FlipCutter, Arthrex, Inc) was then centered in the tibial ACL footprint and a small incision was made over the anteromedial tibia for passage of a drill sheath. The all-in-one guide pin and reamer was drilled into the center of the tibial ACL footprint without deploying the blade, and a FiberStick (Arthrex) was passed through the drill sheath. The passing suture was then retrieved through the anteromedial portal. On the back table, a suture augmentation and suture button construct was created by passing a high-tensile strength braided suture (FiberTape, Arthrex, Inc.) through the loop of a reverse

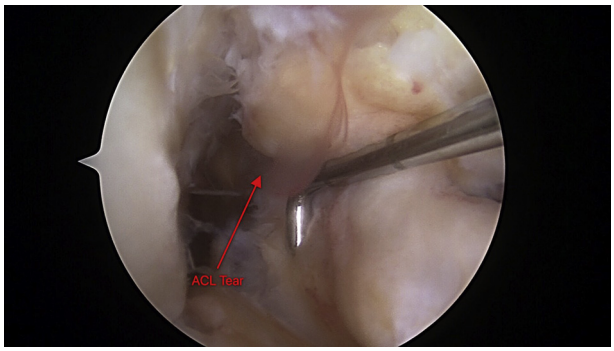

Fig 1. Sherman type 1 ACL tear (right knee, anterolateral viewing portal).

tensioning cortical ACL button (TightRope RT, Arthrex, Inc.). The 2 tails of the suture augmentation and suture button construct (Internal Brace) were passed distally out through the tibial tunnel. The suture button was then passed out through the lateral femur along with the free end of the ACL repair suture, using the passing suture from the femoral tunnel. Once the button was secured against the lateral femoral cortex, a 4.75-mm knotless interference screw (SwiveLock, Arthrex, Inc.) was used to secure the distal limbs of the suture augmentation and suture button construct to the tibial cortex just distal to the tibial tunnel. This step was performed with manual tensioning on the ACL repair suture to avoid overtensioning the suture augmentation and suture button construct. Care was also taken to tension the construct in full extension to avoid overconstraining the knee. Finally, the ACL repair suture was tied to a #2 nonabsorbable suture (FiberWire, Arthrex, Inc.) embedded in the lateral cortical button (Fig 2).

After surgery, patients were immediately weightbearing in a brace. They discontinued use of the brace and began functional strength training after they developed protective quadriceps function. When they had adequate muscle tone and normalization of gait, they began reduced weight running and progressed to full body weight jogging by 4 months. Patients were cleared for return to unrestricted activity 6 months after surgery if they successfully performed a battery of functional tests designed to simulate the return to prior activity level.

Statistical Analysis

KOOS data were reported as mean ± standard deviation. The data were tested for normal distribution, and paired *t*-tests were used to compare preoperative and postoperative clinical scores in applicable patients with significance level set at $P < .05$.

In the 11 patients with baseline data, we interpreted KOOS score differences between baseline and final follow-up score in relation to the MCID for that instrument. For the KOOS instrument, MCID has been established as 8.[24,25] The PASS for KOOS components in patients who underwent ACL reconstruction has been reported as pain, 88.9; symptoms, 57.1; activities of daily living (ADL), 100.0; sport/recreation, 75.0; and quality of life (QoL), 62.5.[26]

Results

Of 172 patients who underwent ACL surgery between January 2014 and June 2016, 28 (16%) with Sherman type I or II ACL tears or high-grade partial avulsion with clinical instability underwent ACL repair with suture augmentation. One patient was unavailable for follow-up. Twenty-seven patients (96.4%) (mean age 27.4 ± 8.6 years, 18 males (66.7%), and follow-up 2.8 ± 0.7 years [range, 2.0-3.8]) were included in the study. Of these patients, 17 were diagnosed with Sherman type I tear and 10 were diagnosed with Sherman type II tear. All 27 patients available for follow-up had postoperative scores, and 14 patients had preoperative scores.

Of these 27 patients, 4 recurrent ACL injuries (14.8%) required revision to reconstruction. The remaining 23 patients had successful ACL repair with no clinical instability and no subjective complaints at final follow-up. Final scores were KOOS 83.7 ± 12.8, Marx 8.6 ± 4.0, VAS 1.1 ± 1.8, physical VR-12 53.6 ± 5.2, mental VR-12 53.1 ± 8.1, and SANE 83.0 ± 12.9. In the 11 patients with baseline data, significant improvements were observed in composite KOOS (50.4 ± 11.5 to 85.7 ± 8.4; $P < .001$), VAS (3.9 ± 2.6 to 0.8 ± 0.8; $P = .002$), and physical VR-12 (39.9 ± 6.5 to 55.5 ± 3.3; $P < .001$). All 11 patients (100%) met or exceeded the KOOS composite MCID (mean, 34.0 increase). At baseline, few patients met KOOS PASS thresholds: pain (0%), symptoms (36%), ADL (0%), sport and recreation (27%), and quality of life (0%). At final follow-up, substantial improvement was observed in the percentage of patients who met KOOS PASS thresholds: pain (73%), symptoms (100%), ADL (64%), sport and recreation (80%), and quality of life (45%).

Discussion

These data indicate that at minimum 2-year follow-up, primary ACL repair with suture augmentation for

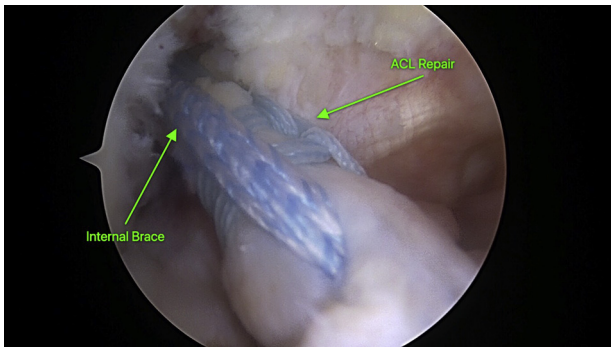

Fig 2. Final ACL repair construct of a Sherman type 1 ACL tear (right knee, anterolateral viewing portal).

proximal ACL avulsion resulted in a low reoperation rate with a high level of patient satisfaction. Patients with both preoperative and postoperative data showed significant improvement in functional outcomes based on validated outcome measures. This procedure shows promise for treating patients with clinical instability from proximal ACL avulsion (Sherman grade I and II and high-grade ACL tears) using a lateral femoral cortical button repair with suture augmentation.

Our findings are consistent with recent reports on ACL repair.[19,22,23,27] A recent study reported on 56 consecutive patients who underwent primary ACL repair using a suture anchor technique.[19] The latter 27 patients (48.2% [27/56]) received additional internal bracing with ACL repair. Mean age at surgery was 33.5 ± 11.3 years (59% male) and mean follow-up 3.2 ± 1.7 years. Good objective and subjective outcomes were observed. Six repairs (10.7%) failed and 4 additional patients underwent reoperation (7.1%), 2 for meniscus tears and 2 for suture anchor irritation. Objective International Knee Documentation Committee (IKDC) scores were A in 38 (73%), B in 8 (15%), and C/D in 6 (12%) patients. Mean Lysholm score was 94 ± 7.6, modified Cincinnati 94 ± 8.9, SANE 90 ± 12.5, preinjury Tegner 6.7 ± 1.5, current Tegner 6.2 ± 1.5, and subjective IKDC 90 ± 10.9. Failures rates were 13.8% without and 7.4% with internal bracing ($P = .672$). In a study comparing 20 patients who underwent primary ACL repair with 20 patients who underwent primary hamstring autograft ACL reconstruction with anchor fixation using a single knotless suture anchor and microfracture for Sherman type I ACL tears, 3 patients in the repair group were revised because of instability (15%) compared with none in the ACL reconstruction group.[27] Among 27 patients who underwent ACL repair with suture augmentation and platelet-rich plasma augmentation, 24 of 27 (89%) had returned to sport at their preinjury level and 3 patients had failed at 3-year follow-up. All r-injuries occurred during cutting-and-pivoting sports. No patient sustained a contralateral knee injury.[28]

Early ACL repair studies showed conflicting results with some studies showing good stability and return to play,[29-31] whereas others showed high failure rates and high instability rates.[10,15-18] Several factors could have contributed to poorer historical ACL repair outcomes. ACL repair procedures in early studies were performed using open techniques, which might have been associated with high surgical morbidity and could have increased the risk of postoperative stiffness and pain. Further, all types of ACL tears were repaired without regard for the location of the tear or the quality of the tissue.[8,16,17] Some studies have suggested that proximal tears may have a better healing potential than midsubstance tears.[30,32] It is possible that ACL repair would have demonstrated better outcomes if studies focused on proximal avulsion. Early studies employed highly restricted rehabilitation protocols in which patients were routinely immobilized in a cast for 6 weeks postoperatively. We focused on proximal avulsions, and our rehabilitation protocol included immediate weightbearing with functional strength training after discontinuation of the brace, in line with previous studies demonstrating the benefit of early weightbearing and range of motion after ACL surgery.[33-36]

A recent meta-analysis showed a 15% failure rate after ACL reconstruction, with ipsilateral reinjury rate of 7% and contralateral new injury of 8%. The secondary injury rate for patients younger than 25 years was 21%, secondary reinjury rate with return to sport was 20%, and combined secondary injury rate in patients who were younger than age 25 and returned to sport was 23%.[37] In the current study, 3 of the 4 patients who required reoperation and revision were under the age of 22. This finding is in line with a recent study that reported a 50% failure rate after ACL repair in adolescent athletes with proximal tears.[9] These findings are concerning and warrant further study. However, they are not specific to ACL repair in that high rates of failure and new ACL injury have also been reported in young patients who undergo ACL reconstruction.[5,37]

In our study, we used a suture button technique with multiple whipstitches placed in the torn ACL with suture augmentation. Outcomes of the current study are consistent with previous reports. Both suture button and anchor fixation techniques have been described clinically.[20,21,38] Excellent results have been reported with a healing response technique using an arthroscopic awl without suture fixation in both young high-level athletes and older active patients with proximal ACL tears.[39,40] Their results indicated a 70% survivorship at 5 years in the young population of high-level athletes and a 91% survivorship at an average of 7.6 years in athletes >40 years of age. Another study demonstrated 64% survivorship at an average of 4.3 years postoperatively using a healing response technique.[41]

Limitations

This study has several limitations. It is retrospective. It has a relatively small sample size and the potential for selection bias cannot be excluded. Preoperative and final follow-up data could be compared for only 11 of 23 patients with successful outcome. Finally, our data do not include clinical stability testing with a KT-1000 examination and imaging assessment with magnetic resonance imaging, but all patients had postoperative physical examinations.

Conclusions

In patients with proximal ACL avulsion, arthroscopic primary ACL repair with suture augmentation demonstrated high functional outcome and improved

patient-reported outcomes at 2-year follow-up. The rate of graft failure was 15%.

Acknowledgment

We thank Lyn Camire, MA, ELS, of the Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, for editorial assistance.

References

1. Leys T, Salmon L, Waller A, Linklater J, Pinczewski L. Clinical results and risk factors for reinjury 15 years after anterior cruciate ligament reconstruction: A prospective study of hamstring and patellar tendon grafts. *Am J Sports Med* 2012;40:595-605.
2. Spindler KP, Kuhn JE, Freedman KB, Matthews CE, Dittus RS, Harrell FE Jr. Anterior cruciate ligament reconstruction autograft choice: Bone-tendon-bone versus hamstring: Does it really matter? A systematic review. *Am J Sports Med* 2004;32:1986-1995.
3. Bach BR Jr. ACL reconstruction: Revisited, revised, reviewed. *J Knee Surg* 2004;17:125-126.
4. Wright R, Spindler K, Huston L, et al. Revision ACL reconstruction outcomes: MOON cohort. *J Knee Surg* 2011;24:289-294.
5. Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of second ACL injuries 2 years after primary ACL reconstruction and return to sport. *Am J Sports Med* 2014;42:1567-1573.
6. Brophy RH, Schmitz L, Wright RW, et al. Return to play and future ACL injury risk after ACL reconstruction in soccer athletes from the Multicenter Orthopaedic Outcomes Network (MOON) group. *Am J Sports Med* 2012;40:2517-2522.
7. Read CR, Aune KT, Cain EL Jr, Fleisig GS. Return to play and decreased performance after anterior cruciate ligament reconstruction in National Football League defensive players. *Am J Sports Med* 2017;45:1815-1821.
8. Feagin JA Jr, Blake WP. Postoperative evaluation and result recording in the anterior cruciate ligament reconstructed knee. *Clin Orthop* 1983;172:143-147.
9. Gagliardi AG, Carry PM, Parikh HB, Traver JL, Howell DR, Albright JC. ACL repair with suture ligament augmentation is associated with a high failure rate among adolescent patients. *Am J Sports Med* 2019;47:560-566.
10. Feagin JA Jr, Curl WW. Isolated tear of the anterior cruciate ligament: 5-year follow-up study. *Am J Sports Med* 1976;4:95-100.
11. Cabaud HE, Feagin JA, Rodkey WG. Acute anterior cruciate ligament injury and repair reinforced with a biodegradable intraarticular ligament. *Experimental studies.* Am J Sports Med 1982;10:259-265.
12. Cabaud HE, Rodkey WG, Feagin JA. Experimental studies of acute anterior cruciate ligament injury and repair. *Am J Sports Med* 1979;7:18-22.
13. Spencer EE, Chissell HR, Spang JT, Feagin JA Jr, Manoff EM, Rohatgi SD. Behavior of sutures used in anterior cruciate ligament reconstructive surgery. *Knee Surg Sports Traumatol Arthrosc* 1996;4:84-88.
14. Warren RF. Primary repair of the anterior cruciate ligament. *Clin Orthop Relat Res* 1983;172:65-70.
15. Lysholm J, Gillquist J, Liljedahl SO. Long-term results after early treatment of knee injuries. *Acta Orthop Scand* 1982;53:109-118.
16. Engebretsen L, Benum P, Sundalsvoll S. Primary suture of the anterior cruciate ligament. A 6-year follow-up of 74 cases. *Acta Orthop Scand* 1989;60:561-564.
17. Odensten M, Lysholm J, Gillquist J. Suture of fresh ruptures of the anterior cruciate ligament. A 5-year follow-up. *Acta Orthop Scand* 1984;55:270-272.
18. Kaplan N, Wickiewicz TL, Warren RF. Primary surgical treatment of anterior cruciate ligament ruptures. A long-term follow-up study. *Am J Sports Med* 1990;18:354-358.
19. Jonkergouw A, van der List JP, DiFelice GS. Arthroscopic primary repair of proximal anterior cruciate ligament tears: Outcomes of the first 56 consecutive patients and the role of additional internal bracing. *Knee Surg Sports Traumatol Arthrosc* 2019;27:21-28.
20. Wilson WT, Hopper GP, Byrne PA, MacKay GM. Anterior cruciate ligament repair with internal brace ligament augmentation. *Surg Technol Int* 2016;29:273-278.
21. Heusdens CHW, Hopper GP, Dossche L, Mackay GM. Anterior cruciate ligament repair using independent suture tape reinforcement. *Arthrosc Tech* 2018;7:e747-e753.
22. Difelice GS, Villegas C, Taylor S. Anterior cruciate ligament preservation: Early results of a novel arthroscopic technique for suture anchor primary anterior cruciate ligament repair. *Arthroscopy* 2015;31:2162-2171.
23. DiFelice GS, van der List JP. Clinical outcomes of arthroscopic primary repair of proximal anterior cruciate ligament tears are maintained at mid-term follow-up. *Arthroscopy* 2018;34:1085-1093.
24. Spindler KP, Huston LJ, Wright RW, et al. The prognosis and predictors of sports function and activity at minimum 6 years after anterior cruciate ligament reconstruction: A population cohort study. *Am J Sports Med* 2011;39:348-359.
25. Irrgang JJ, Anderson AF. Development and validation of health-related quality of life measures for the knee. *Clin Orthop Relat Res* 2002;402:95-109.
26. Muller B, Yabroudi MA, Lynch A, et al. Defining thresholds for the patient acceptable symptom state for the IKDC subjective knee form and KOOS for Patients Who Underwent ACL Reconstruction. *Am J Sports Med* 2016;44:2820-2826.
27. Achtnich A, Herbst E, Forkel P, et al. Acute proximal anterior cruciate ligament tears: Outcomes after arthroscopic suture anchor repair versus anatomic single-bundle reconstruction. *Arthroscopy* 2016;32:2562-2569.
28. Nyland J, Caborn D, Wheeldon B, Kalloub A. ACL femoral avulsion reapproximation with internal bracing and PRP augmentation: Excellent return to sports outcomes and low re-injury rates at 3-year follow-up. Presented at the 18th ESSKA Congress, Glasgow, UK. May 9-12, 2018. 2018. Available at, https://academy.esska.org/esska/2018/glasgow/209475/john.nyland.acl.femoral.avulsion.reapproximation.with.internal.bracing.and.prp.html?f=media=1. Accessed May 7, 2020.
29. Hughston JC, Bowden JA, Andrews JR, Norwood LA. Acute tears of the posterior cruciate ligament. Results of

operative treatment. *J Bone Joint Surg Am* 1980;62:438-450.
30. 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;19:243-255.
31. Marshall JL, Warren RF, Wickiewicz TL. Primary surgical treatment of anterior cruciate ligament lesions. *Am J Sports Med* 1982;10:103-107.
32. Nguyen DT, Ramwadhdoebe TH, van der Hart CP, Blankevoort L, Tak PP, van Dijk CN. Intrinsic healing response of the human anterior cruciate ligament: An histological study of reattached ACL remnants. *J Orthop Res* 2014;32:296-301.
33. Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am J Sports Med* 1990;18:292-299.
34. Shelbourne KD, Wilckens JH, Mollabashy A, DeCarlo M. Arthrofibrosis in acute anterior cruciate ligament reconstruction. The effect of timing of reconstruction and rehabilitation. *Am J Sports Med* 1991;19:332-336.
35. Millett PJ, Wickiewicz TL, Warren RF. Motion loss after ligament injuries to the knee. Part II: Prevention and treatment. *Am J Sports Med* 2001;29:822-828.
36. Tyler TF, McHugh MP, Gleim GW, Nicholas SJ. The effect of immediate weightbearing after anterior cruciate ligament reconstruction. *Clin Orthop Relat Res* 1998:141-148.
37. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of secondary injury in younger athletes after anterior cruciate ligament reconstruction: A systematic review and meta-analysis. *Am J Sports Med* 2016;44:1861-1876.
38. DiFelice GS, van der List JP. Arthroscopic primary repair of proximal anterior cruciate ligament tears. *Arthrosc Tech* 2016;5:e1057-e1061.
39. Steadman JR, Cameron-Donaldson ML, Briggs KK, Rodkey WG. A minimally invasive technique ("healing response") to treat proximal ACL injuries in skeletally immature athletes. *J Knee Surg* 2006;19:8-13.
40. Steadman JR, Matheny LM, Briggs KK, Rodkey WG, Carreira DS. Outcomes following healing response in older, active patients: A primary anterior cruciate ligament repair technique. *J Knee Surg* 2012;25:255-260.
41. Wasmaier J, Kubik-Huch R, Pfirrmann C, Grehn H, Bieg C, Eid K. Proximal anterior cruciate ligament tears: The healing response technique versus conservative treatment. *J Knee Surg* 2013;26:263-271.