The Knee 23 (2016) 1098–1105

Contents lists available at ScienceDirect

The Knee

Clinical and arthrometric outcomes of an anatomic outside-in single-bundle anterior cruciate ligament reconstruction using a retrodrill

David Figueroa *, Rafael Calvo, Francisco Figueroa, Daniel Paccot, Guillermo Izquierdo, Nelson Morales

The Knee Surgery Unit, Orthopaedics and Traumatology Department, Clínica Alemana – Universidad del Desarrollo, Santiago, Chile

ARTICLE INFO

Article history:
Received 1 November 2015
Received in revised form 28 May 2016
Accepted 26 July 2016

Keywords:
ACL
Outside-in
Retroconstruction
Anatomic femoral tunnel

ABSTRACT

Background: The main option to perform an anatomic anterior cruciate ligament (ACL) reconstruction is the anteromedial portal (AMP) technique. It has several reported complications (iatrogenic chondral injury, posterior-wall blowout, short sockets, increased risk of injury to common peroneal nerve). In an attempt to avoid these complications the outside-in (OI) technique was revived with the addition of a retrodrill. The aim of this study is to evaluate the clinical and arthrometric outcomes of a series of anatomical OI single bundle ACL reconstruction using a retrodrill.
Methods: Prospective case series. KT-1000 and Pivot Shift Test were done at 24 months follow-up. International Knee Documentation Committee (IKDC), Lysholm and Tegner activity scores preoperatively and at final follow-up. Complications were reported. Statistical analysis was done with t-test.
Results: 275 knees of 200 (73%) males and 75 (27%) females were enrolled in the study. Mean age 29.1 years (15–54). Mean follow-up 34.5 months (24–49). Mean preoperatively Lysholm Score 62 (25–95) versus 95 (76–100) at final follow-up ($p < 0.001$) Mean preoperatively IKDC score 60 (26.4–90.8) versus 92 (59.8–100) at final follow-up ($p < 0.001$) Mean Tegner activity Score pre injury 5 versus 5 at final follow-up. ($p = 0.59$) Mean KT-1000 side-to-side difference 2 mm (1–6). Pivot Shift test negative in 243 patients (90%); positive in 32 (10%) patients. 13 (5%) ACL re-ruptures. 2 (0.7%) infections. No other complications were reported.
Conclusion: OI single bundle anatomic ACL reconstruction using a retrodrill is a valid and safe option that avoids the complications reported with the AMP technique.

1. Introduction

Better positioning of the tunnels is a strategy for reducing rotational instability and future osteoarthritis (OA) in anterior cruciate ligament (ACL) surgery [1–4]. From this perspective, improvements in the understanding of the anatomy and biomechanics of the knee have resulted in a conceptual shift from femoral tunnels located at the isometric point of the ACL to anatomic points located in the footprint [5].

* Corresponding author at: Chief of Knee Surgery, Clínica Alemana, Vitacura 5951, Santiago, Chile.
E-mail address: franciscofigueroab@gmail.com (D. Figueroa).

http://dx.doi.org/10.1016/j.knee.2016.07.007
0968-0160/

The transtibial drilling technique has been the standard surgical method for femoral tunnel placement in ACL reconstruction over the past 20 years [6,7]. However, current interest in the anatomic ACL technique has led to a reconsideration of the proper femoral tunnel positioning, and to an understanding that independent drilling of the tibial and femoral tunnels in ACL reconstruction might be more anatomic than the transtibial technique for femoral ACL tunnel creation because the transtibial technique is associated with a risk of a compromised tunnel position due to the transtibial constraint [8,9].

In attempts to provide more anatomical femoral tunnels, other techniques have been developed, including the anteromedial portal (AMP) technique. This technique can produce more anatomical positioning of the femoral tunnel, but it is associated with several risks including: difficulty visualizing in hyperflexion, possibly leading to iatrogenic chondral injury to the medial femoral condyle; posterior-wall blowout; short or bicortical sockets, which may limit fixation options; and increased risk of injury to the common peroneal nerve [8,10,11]. The shorter tunneling is of special relevance because short tunnels can result in reduced tendon graft lengths within the femoral bone tunnel, and may be more prone to mechanical failure [12,13].

In an effort to provide an anatomical femoral tunnel without the complications attributed to the AMP technique, the outside-in (OI) technique was revived with the addition of a retrodrill to simplify the procedure and to be able to create a femoral socket that can improve the available femoral fixation options (contrary to a complete femoral tunnel). The OI technique provides consistent femoral tunnel placement, no posterior wall blowout, a clear visual field, no screw divergence, easy revision of ACL reconstruction, and longer tunnel lengths. However, this technique has disadvantages that include lateral femoral dissection from an additional incision, and inconsistent femoral reaming due to variability in the starting position [14]. However, because this technique uses retractable retrograde cutting bits, it requires only a portal-sized stab wound rather than a lateral incision and dissection [14]. There are few reports of this technique in the literature, and most of these reports are related to anatomical parameters rather than clinical results.

The aim of this study was to evaluate the clinical and arthrometric results of a clinical series of patients with acute ACL ruptures who were treated with the single-bundle anatomical OI technique for femoral tunneling using a retrodrill. It was hypothesized that using the OI technique for femoral tunneling would have comparable outcomes to those reported for the other techniques, with the advantage of avoiding the complications attributed to the AMP technique.

2. Methods

This study was a prospective, consecutive case series of patients who underwent anatomic ACL single-bundle OI reconstruction using the Flipcutter system (Arthrex, Naples, FL) with autologous hamstring grafts between January 2012 and May 2014. Two experienced knee surgeons (28-year experience each) performed the surgeries and started using this technique in September 2011; they had experience with more than 50 patients each before starting this study.

The institutional ethics committee approved the study, and all patients provided written, informed consent to participate in this study.

2.1. Surgical technique

The patient is positioned in the supine position on an orthopedic table with lateral knee support. An ischemia tourniquet is inflated. The knee is positioned in 90° of flexion. The procedure begins by harvesting the hamstring (semitendinosus and gracilis) grafts with an anteromedial approach five centimeter distal to the joint line. The graft is prepared with high-strength sutures to obtain a quadruple graft. Following the findings of Magnussen et al. [15], it is preferable to use a minimum diameter of eight millimeters. In cases in which the graft is smaller, a triple graft is prepared or the diameter is increased using an allograft (hybrid technique).

The classic anterolateral and anteromedial portals are used. Diagnostic arthroscopy is performed, and the associated injuries (meniscal or chondral lesions) are addressed. The anatomical footprint of the ACL is located in the femur, based on the description of Piefer et al. [16] (43% of the proximal-distal distance of the lateral wall of the intercondylar notch and the radius of the tunnel +2.5 mm anterior to the posterior articular margin), and in the tibia, based on the description of Bhatia et al. [17] (2 ± 0.49 mm anterior to the posterior border of the anterior horn of the lateral meniscus). The injured ACL is debrided, while all attempts are made to preserve all remaining functional bundles. To finish the first step, both of the footprints are marked as described above.

2.2. Femoral tunnel

To place the femoral tunnel, the demarcation of the footprint is guided with the AR-1510H grip (Arthrex Inc., Naples, FL) fixed at 100° (70 to 110°) through the anterolateral portal (Figure 1). The guide is located with arthroscopic viewing in the previously mentioned femoral footprint. A lateral incision approximately the size of an arthroscopic portal is made at the distal femur, where a sleeve is placed. Through the sleeve, an anterograde perforation is made from outside to inside in the direction of the femoral footprint using the Flipcutter™ (Arthrex, Naples, FL) drill (Figure 2). The tip of the Flipcutter is then flipped into a horizontal reamer. Using this reamer, retrograde drilling (Figure 3) is performed with a diameter equal to that of the graft and a previously defined length (tunnels between 30 and 35 mm are preferred). Finally, when the tunnel has been made, the Flipcutter drill is flipped again into the initial longitudinal position and retired. A Fiberstick™ (Arthrex Inc., Naples, FL) is introduced through the tunnel into the joint and is used to pull the graft later on (Figure 4).

Figure 1. Demarcation of the femoral footprint is guided with the AR-1510H grip (Arthrex Inc, Naples, FL) through the anterolateral portal.

2.3. Tibial tunnel

A tibial guide that is fixed between 55° and 60° is used through the medial portal to locate the tibial footprint of the ACL. A sleeve is placed in the anteromedial tibia using the incision that was previously used to harvest the hamstring graft. Next, a standard wire is passed through the sleeve in the direction of the tibial footprint. The tibial tunnel is then made with a cannulated drill with a diameter that is 1 mm less than that of the graft. The tunnel is then expanded with a dilator, and the distal portion of the tunnel is treated with a Quad Notcher™ (Arthrex Inc., Naples, FL) to obtain easy access to the interference screw that will be used for the tibial fixation of the graft. Finally, the Fiberstick that was previously introduced into the joint is pulled out through the tibial tunnel to pull the graft.

2.4. Graft fixation

The present institution uses a Tight Rope™ (Arthrex, Naples, FL) system for femoral fixation. This step can be performed using the arthroscopic view to directly check the passage of the button in the femoral tunnel (Figure 5). Tibial fixation is performed with a Biocomposite Interference Screw™ (Arthrex, Naples, FL) under continuous traction of the graft, with the knee at 20° of flexion and tibial external rotation. Next, the arthroscopic view is used to observe the position and tension of the graft (Figure 6).

Finally, careful hemostasis is performed, and two drains are installed: one is intra-articular and the other is placed in the graft incision. These drains are removed 24 h after surgery. A Robert Jones dressing is applied, and the ischemia is stopped.

The inclusion criteria for this study were: patients with clinical and MRI diagnosis of ACL rupture, and ACL ruptures of <3 month duration. The exclusion criteria were: multi-ligament knee injuries, ACL re-ruptures, inflammatory joint diseases, limb malalignment, and radiographic changes indicating Ahlbäck type II to V knee osteoarthritis [18].

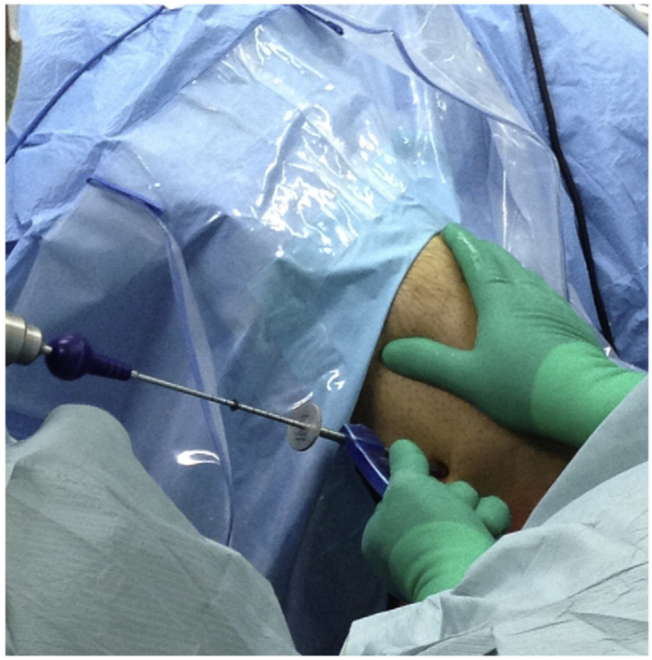

Figure 2. Anterograde perforation from outside to inside in the direction of the femoral footprint using the Flipcutter drill (Arthrex Inc, Naples, FL).

The patients were discharged from the hospital two days after surgery and were followed in the outpatient clinic weekly until one month, monthly until six months, and yearly thereafter. The initial rehabilitation protocol consisted of immediate post-operative rest and continuous passive mobilization twice daily from the first postoperative day, in addition to ambulation with two crutches, isometric quadriceps exercises, and manual patellar mobilization. After that, patients went through an accelerated rehabilitation protocol to return them to full sports activities at six months.

The associated lesions and procedures were reported. Anteroposterior stability was assessed objectively at 24-month follow-up using the maximal manual test with the KT-1000 arthrometer. Rotational stability was assessed using the Pivot Shift Test at the same time [19]. The clinical results were assessed preoperatively and at the final follow-up using the International Knee Documentation Committee (IKDC) [20], Lysholm [21], and Tegner [22] activity scores. Complications and reoperations were recorded, with special emphasis on addressing the complications related to the AMP technique (iatrogenic medial femoral condyle chondral injury, posterior-wall blowout, short or bicortical sockets, and injury to the common peroneal nerve). The femoral tunnels lengths were measured during surgery and the values were recorded.

The statistical analyses were performed with Student's *t*-tests for independent samples.

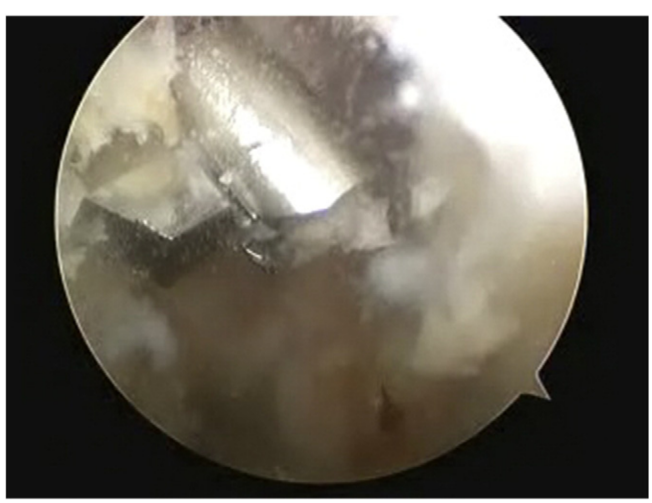

Figure 3. Arthroscopic view of the tip of the Flipcutter (Arthrex Inc, Naples, FL) flipped into a horizontal reamer.

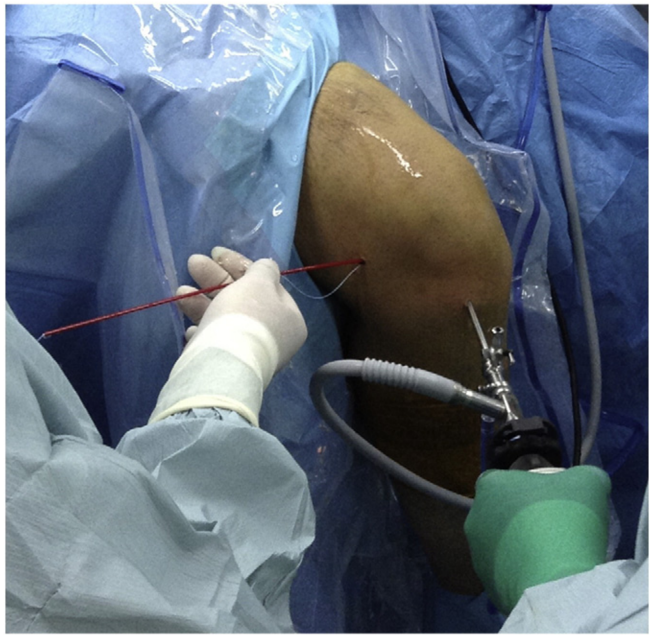

Figure 4. Fiberstick (Arthrex Inc, Naples, FL) introduced through the tunnel into the joint.

3. Results

A total of 275 knees of 200 (73%) males and 75 (27%) females met the inclusion criteria and were enrolled in the study. The mean age was 29.1 years (15 to 54 years). The mean follow-up period was 34.5 months (24 to 49 months). All patients received hamstring autografts. The surgeries were performed at a mean time of 4.1 weeks (one to 12 weeks) after the injuries.

There were 189 patients (70%) with associated injuries (Table 1). Meniscal lesions were the most common and were present in 175 patients (65%). Isolated lateral meniscal tears were present in 102 patients (38%), isolated medial meniscal tears were present in 40 patients (15%), and combined meniscal tears were present in 33 patients (12%). Partial meniscectomy was the most common procedure among these patients (120 patients, 44%) followed by meniscal suture in 50 patients (19%) and subtotal meniscectomy (>70% of the meniscus) in five patients (two percent).

Full-thickness osteochondral defects were present in 25 patients (nine percent). The most common of these defects were isolated lateral femoral condyle lesions in 15 patients (six percent), and less common were medial femoral condyle lesions in eight patients (three percent), patellar lesions in one patient (0.4%) and multi-compartment lesions in one patient (0.4%). Twenty

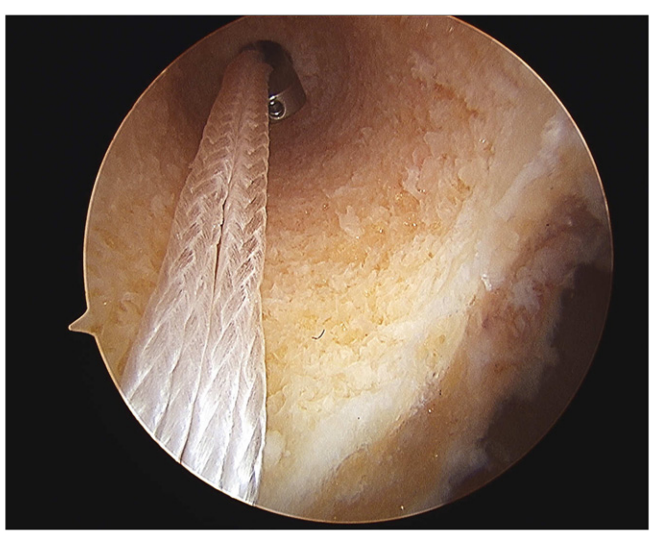

Figure 5. Arthroscopic view checking the passage of the Tight Rope button (Arthrex, Naples, FL) in the femoral tunnel.

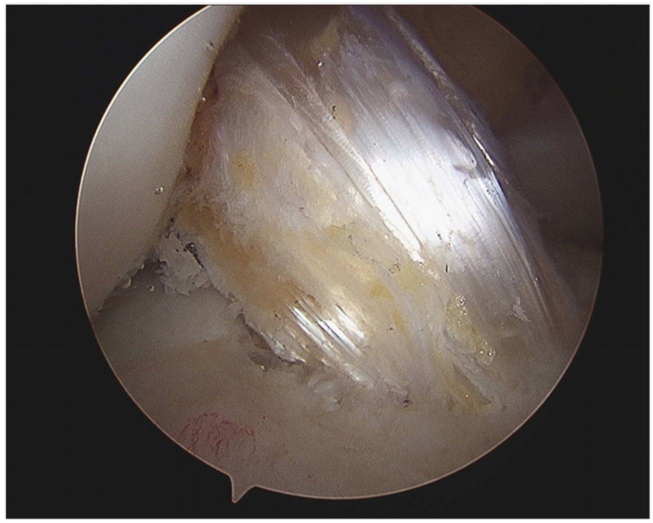

Figure 6. Arthroscopic view observing the position and tension of the graft.

patients (seven percent) underwent osteochondral autologous transfers, four patients (one percent) underwent microfracture, and one patient (0.4%) underwent debridement of the chondral lesion. All additional procedures are detailed in Table 2.

There were 35 complications (13%), each occurred in a different patient. Ten (four percent) patients with meniscal sutures presented with meniscal re-rupture; they were treated with partial meniscectomy. Ten (four percent) patients presented with symptomatic chondral lesions that required a re-intervention. Thirteen (five percent) patients experienced ACL re-rupture at a mean time of 17 months (4–35 months) postoperatively. All of these complications were treated with revision ACL reconstruction. Two (0.7%) patients were treated for postoperative infection. No patients had arthrofibrosis or deep-vein thrombosis.

Table 1
Associated injuries.

Lesion	N (%)
Meniscal injuries	175 (65%)
Medial	40 (15%)
Lateral	102 (38%)
Both	33 (12%)
Full-thickness osteochondral lesions	25 (9%)
MFC	8 (3%)
LFC	15 (6%)
Patellar	1 (0.4%)
Multicompartimental	1 (0.4%)

LFC, lateral femoral condyle; MFC, medial femoral condyle.

Table 2
Associated procedures.

Procedure	N (%)
Partial menisectomy	120 (44%)
Subtotal menisectomy	5 (2%)
Meniscal suture	50 (19%)
Chondral lesion debridement	1 (0.4%)
OATS	20 (7%)
Microfracture	4 (1%)

OATS, osteochondral autologous transfer system.

Table 3
Lysholm, IKDC and Tegner scores.

	Preoperative	Postoperative	P
Lysholm score	62	95	$P < 0.001$
IKDC score	60	92	$P < 0.001$
Tegner score	5	5	$P = 0.59$

IKDC, International Knee Documenting Committee.

There were no iatrogenic medial femoral condyle chondral injuries, posterior-wall blowouts or injuries to the common peroneal nerve. The mean length of the femoral tunnels was 33 mm (30 to 35 mm) with no tunnels shorter than 30 mm. All the tunnels were femoral sockets; there were no lateral cortex blowouts.

Table 3 presents the clinical scores of the patients in the present series. The mean preoperative Lysholm score was 62 points (25 to 95 points). The mean preoperative IKDC score was 60 (26.4–90.8). The mean preoperative Tegner score was five points (two to eight points).

The mean postoperative Lysholm score was 95 points (76 to 100 points). The mean IKDC score was 92 (59.8 to 100). Both of these postoperative scores were significantly better than the corresponding preoperative scores ($P < 0.001$). The mean postoperative Tegner score was five points (one to eight points). There were no significant differences between the preoperative and postoperative activity statuses ($P = 0.59$).

The mean KT-1000 arthrometer side-to-side difference was two millimeters (one to six millimeters). The Pivot Shift test was negative in 243 patients (90%); this test was positive in 32 (10%) patients and graded as grade I (mild sensation of tibial reduction with no audible click) in all of these cases. There was no statistical correlation between the presence of a positive pivot shift and worst clinical results.

4. Discussion

The present study revealed that single-bundle OI ACL reconstruction using a retrodrill produced good and excellent results based on clinical and arthrometric parameters at a minimum 2-year follow-up. There are few reports in the literature that have addressed the clinical results of this technique using a retrodrill [23], as most studies are related to anatomic or imaging findings [14,24–29].

In one of the few studies to date reporting clinical outcomes of the OI technique plus a retrodrill, Seo et al. [23] compared single-bundle ACL reconstructions using the conventional transtibial technique in 41 patients, and the OI technique with a retrodrill in 48 patients. At a mean follow-up of 30 months, the clinical results were excellent in both groups (the mean Lysholm scores were 91.4 in the transtibial group and 93.2 in the OI group), but a statistically significant difference in the pivot shift test favored the OI technique. In the present study regarding rotational stability, there was a 10% rate of positive grade I pivot shift test but with no correlation with worst clinical outcomes. These outcomes are comparable to AMP technique studies with rates of positive pivot shift of 10–30% after ACL reconstruction [30,31].

In a study comparing 10 patients using the OI plus retrodrill technique versus 10 patients using the AMP technique, Lansdown et al. [32] showed that the OI technique resulted in altered knee kinematics compared with the contralateral healthy knee, which is not a problem when using the AMP technique. The clinical implications of these findings were not studied.

Regarding complications found in the present study, 0.7% had infections, a value that is comparable with the literature (0.1 to 1.7%) [33–35]. None of the complications attributed to the AMP technique were seen (iatrogenic medial femoral condyle chondral injury, posterior-wall blowout, short or bicortical sockets and injury to the common peroneal nerve). The rate of these complications when using the AMP technique was very low. There was a possibility that the study was unpowered to show them, but it is believed that nearly 300 cases with no complications of that kind are a meaningful number to say that the technique is safe.

In the present series, a five percent re-rupture rate was observed, which is comparable to the published values that range from 0.7 to 10% [29,36].

A limitation of this study was the relatively short follow-up. It is already known that OI reconstruction produces clinical results that are similar to those of other techniques at short-term and middle-term follow-ups. The longer-term benefits of reconstructing with a more anatomical ACL (with AMP or OI techniques) are not yet clear, particularly in terms of the development of osteoarthritis; therefore, longer studies are needed to address if any benefit exists.

It is believed that the benefit of using an OI technique using a retrodrill in ACL reconstruction is that it has all the advantages of the classic two-incision anterograde OI technique, but with the addition of a smaller lateral incision, the ability to create femoral sockets (with more fixation options) and no risk of causing intra-articular damage with the drill. The authors prefer it to the AMP technique to perform an anatomic ACL reconstruction because of the theoretical complications (medial femoral condyle chondral injury, posterior-wall blowout, short sockets, injury to the common peroneal nerve) and the difficulties in the surgical technique (knee hyperflexion needed, less visualization) associated with it.

5. Conclusion

The present study revealed that single-bundle OI ACL reconstruction using a retrodrill produces excellent results at a minimum of two year follow-up. This is based on clinical and arthrometric parameters that are comparable to other techniques, and the technique avoids the theoretical complications attributed to the AMP technique.

Conflict of interest

None.

References

[1] Loh JC, Fukuda Y, Tsuda E, Steadman RJ, Fu FH, Woo SL. Knee stability and graft function following anterior cruciate ligament reconstruction: comparison between 11 o'clock and 10 o'clock femoral tunnel placement. Arthroscopy 2003;19:297–304.
[2] Markolf KL, Hame S, Hunter DM, Oakes DA, Zoric B, Gause P, et al. Effects of femoral tunnel placement on knee laxity and forces in an anterior cruciate ligament graft. J Orthop Res 2002;20:1016–24.
[3] Ristanis S, Stergiou N, Siarava E, Ntoulia A, Mitsionis G, Georgoulis AD. Effect of femoral tunnel placement for reconstruction of the anterior cruciate ligament on tibial rotation. J Bone Joint Surg Am 2009;91:2151–8.
[4] Scopp JM, Jasper LE, Belkoff SM, Moorman III CT. The effect of oblique femoral tunnel placement on rotational constraint of the knee reconstructed using patellar tendon autografts. Arthroscopy 2004;20:294–9.
[5] Snyder GM, Johnson DL. Anatomic graft placement in ACL surgery: plain radiographs are all we need. Orthopedics 2011;34:116–8.
[6] Bach Jr BR, Tradonsky S, Bojchuk J, Levy ME, Bush-Joseph CA, Khan NH. Arthroscopically assisted anterior cruciate ligament reconstruction using patellar tendon autograft: five to nine-year follow-up evaluation. Am J Sports Med 1998;26(1):20–9.
[7] Kocher MS, Steadman JR, Briggs K, Zurakowski D, Sterett WI, Hawkins RJ. Determinants of patient satisfaction with outcome after anterior cruciate ligament reconstruction. J Bone Joint Surg Am 2002;84(9):1560–72.
[8] Golish S, Baumfeld J, Schoderbek R, Miller M. The effect of femoral tunnel starting position on tunnel length in anterior cruciate ligament reconstruction: a cadaveric study. Arthroscopy 2007;23:1187–92.
[9] Steiner M. Independent drilling of tibial and femoral tunnels in anterior cruciate ligament reconstruction. J Knee Surg 2009;22:171–6.
[10] Neven E, D'Hooghe P, Bellemans J. Double-bundle anterior cruciate ligament reconstruction: a cadaveric study on the posterolateral tunnel position and safety of the lateral structures. Arthroscopy 2008;24:436–40.
[11] Robin BN, Jani SS, Marvil SC, Reid JB, Schillhammer CK, Lubowitz JH. Advantages and Disadvantages of Transtibial, Anteromedial Portal, and Outside-In Femoral Tunnel Drilling in Single-Bundle Anterior Cruciate Ligament Reconstruction: A Systematic Review. Arthroscopy 2015;31(7):1412–7.
[12] Panni AS, Milano G, Tartarone M, Demontis A, Fabbriciani C. Clinical and radiographic results of ACL reconstruction: a 5- to 7-year follow-up study of outside-in versus inside-out reconstruction techniques. Knee Surg Sports Traumatol Arthrosc 2001;9:77–85.
[13] Zantop T, Ferretti M, Bell K, Brucker P, Gilbertson L, Fu F. Effect of tunnel-graft length on the biomechanics of anterior cruciate ligament-reconstructed knees intra-articular study in a goat model. Am J Sports Med 2008;36:2158–66.
[14] Lubowitz JH, Konicek J. Anterior cruciate ligament femoral tunnel length: cadaveric analysis comparing anteromedial portal versus outside-in technique. Arthroscopy 2010;26:1357–62.
[15] Magnussen RA, Lawrence JT, West RL, Toth AP, Taylor DC, Garrett WE. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. Arthroscopy 2012;28(4):526–31.
[16] Piefer JW, Pflugner TR, Hwang MD, Lubowitz JH. Anterior cruciate ligament femoral footprint anatomy: systematic review of the 21st century literature. Arthroscopy 2012;28(6):872–81.
[17] Bhatia S, Korth K, Van Thiel GS, Gupta D, Cole BJ, Bach Jr BR, et al. Effect of reamer design on posteriorization of the tibial tunnel during endoscopic transtibial anterior cruciate ligament reconstruction. Am J Sports Med 2013;41(6):1282–9.
[18] Ahlbäck S. Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol Diagn (Stockh) 1968(Suppl. 277):7–72.
[19] Galway HR, MacIntosh DL. The lateral pivot shift: a symptom and sign of anterior cruciate ligament insufficiency. Clin Orthop 1980;147:45–50.
[20] Hefti F, Müller W, Jakob RP, Stäubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1993;1(3–4):226–34.
[21] Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 1982;10:150–4.
[22] Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 1985;198:43–9.
[23] Seo SS, Kim CW, Kim JG, Jin SY. Clinical results comparing transtibial technique and outside in technique in single bundle anterior cruciate ligament reconstruction. Knee Surg Relat Res 2013;25(3):133–40.
[24] Kim JG, Chang MH, Lim HC, Bae JH, Ahn JH, Wang JH. Computed tomography analysis of the femoral tunnel position and aperture shape of transportal and outside-in ACL reconstruction: do different anatomic reconstruction techniques create similar femoral tunnels? Am J Sports Med 2013;41(11):2512–20.
[25] Kim JG, Wang JH, Ahn JH, Kim HJ, Lim HC. Comparison of femoral tunnel length between transportal and retrograde reaming outside-in techniques in anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2013;21(4):830–8.
[26] Kim JG, Wang JH, Lim HC, Ahn JH. Femoral graft bending angle and femoral tunnel geometry of transportal and outside-in techniques in anterior cruciate ligament reconstruction: an in vivo 3-dimensional computed tomography analysis. Arthroscopy 2012;28(11):1682–94.
[27] Shin YS, Ro KH, Jeon JH, Lee DH. Graft-bending angle and femoral tunnel length after single-bundle anterior cruciate ligament reconstruction: comparison of the transtibial, anteromedial portal and outside-in techniques. Bone Joint J 2014;96-B(6):743–51.
[28] Shin YS, Ro KH, Lee JH, Lee DH. Location of the femoral tunnel aperture in single-bundle anterior cruciate ligament reconstruction: comparison of the transtibial, anteromedial portal, and outside-in techniques. Am J Sports Med 2013;41(11):2533–9.
[29] Getelman MH, Friedman MJ. Revision anterior cruciate ligament reconstruction surgery. J Am Acad Orthop Surg 1999;7:189–98.
[30] Hussein M, van Eck CF, Cretnik A, Dinevski D, Fu FH. Prospective randomized clinical evaluation of conventional single-bundle, anatomic single-bundle, and anatomic double-bundle anterior cruciate ligament reconstruction: 281 cases with 3- to 5-year follow-up. Am J Sports Med 2012;40(3):512–20.
[31] Alentorn-Geli E, Samitier G, Alvarez P, Steinbacher G, Cugat R. Anteromedial portal versus transtibial drilling techniques in ACL reconstruction: a blinded cross-sectional study at two- to five-year follow-up. Int Orthop 2010;34(5):747–54.
[32] Lansdown DA, Allen C, Zaid M, Wu S, Subburaj K, Souza R, et al. A comprehensive in vivo kinematic, quantitative MRI and functional evaluation following ACL reconstruction—a comparison between mini-two incision and anteromedial portal femoral tunnel drilling. Knee 2015;22(6):547–53.
[33] Makhni EC, Steinhaus ME, Mehran N, Schulz BS, Ahmad CS. Functional outcome and graft retention in patients with septic arthritis after anterior cruciate ligament reconstruction: a systematic review. Arthroscopy 2015;31(7):1392–401.
[34] Cadet ER, Makhni EC, Mehran N, Schulz BM. Management of septic arthritis following anterior cruciate ligament reconstruction: a review of current practices and recommendations. J Am Acad Orthop Surg 2013;21(11):647–56.
[35] Calvo R, Figueroa D, Anastasiadis Z, Vaisman A, Olid A, Gili F, et al. Septic arthritis in ACL reconstruction surgery with hamstring autografts. Eleven years of experience. Knee 2014;21(3):717–20.
[36] Greis PE, Johnson DL, Fu FH. Revision anterior cruciate ligament surgery: causes of graft failure and technical considerations of revision surgery. Clin Sports Med 1993;12:839–52.