Anatomic double-bundle reconstruction of the anterior cruciate ligament: midterm results

Mohamed Hassan Sobhy[a], Amr A.K.H. Abouelela[b],
Maged M. Samy Abou Elsoud[b]

[a]Department of Orthopedics, Ain-Shams University, [b]Department of Orthopedic Surgery and Traumatology, Ain-Shams University Hospitals, Cairo, Egypt

Correspondence to Mohamed Hassan Sobhy, MD, Department of Orthopedics, Ain-Shams University, 3 Mokhlis El-Alfy St., Nasr City, Cairo, Egypt
Tel: +2 0 100530 0019; fax: +20 24011423;
e-mail: psobsy@gmail.com

Received 5 July 2013
Accepted 25 July 2013

Egyptian Orthopedic Journal 2014, 49:24–28

Purpose

The aim of this study was to investigate the functional outcomes, knee stability, and patient's satisfaction after anatomic double-bundle anterior cruciate ligament (ACL) reconstruction using the three-portal technique.

Patients and methods

A prospective case series study on 48 patients (24 were active athletes) with complete tear of the ACL was conducted. All patients underwent anatomic double-bundle ACL reconstruction. Participants were assessed with history taking, clinical examination, International Knee Documentation Committee (IKDC) score, Lysholm scale, and Tegner scale. All assessments were carried out preoperatively and repeated postoperatively every 6 months until a minimum of 2 years. Data were collected and analyzed to detect significant changes.

Results

Improvement was observed in the mean IKDC score from 68.1 to 93.5, in the Lysholm score from 73.8 to 95.5, and in the Tegner scale from 4 to 9.4. All patients showed negative Lachmann and anterior drawer tests at 24 months follow-up; only two (4.2%) patients showed slight glide (one positive), with overall patient satisfaction of 93.8%.

Conclusion

Anatomic double-bundle ACL reconstruction results in significant improvement in the clinical outcomes and knee stability, with 93.8% satisfaction and return to preinjury level of activity.

Keywords:
double-bundle, anterior cruciate ligament, ACL

Egypt Orthop J 49:24–28

1110-1148

Introduction

Approximately 75 000–100 000 anterior cruciate ligament (ACL) reconstruction surgeries are performed annually in the USA [1]. The majority of the literature on ACL reconstruction has reported 80–90% patient outcome success rates; however, ~10–20% of patients continue to experience persistent knee pain and recurrence of instability [2]. If revision surgery is necessary, the most prevalent cause is faulty surgical technique, particularly improper tibial and femoral bone tunnel placement [3,4].

Although ACL reconstruction techniques encountered a paradigm shift over the last decade, a unified consensus still does not exist for optimal ACL reconstruction. Using cadaveric dissection and radiographic techniques, Colombet *et al.* [5] provided detailed description of the anteromedial (AM) and posterolateral (PL) ACL bundles attachments. Each of the two primary ACL bundles has a unique function; however, the intermediate bundle has a more variable morphology and its functional significance is less well understood [6]. The AM and PL bundles are oriented near parallel with the knee extended, and are twisted around each other as the knee flexes [7].

Recently, the medial portal femoral drilling technique, using the accessory medial portal (AMP), together with better understanding of bone tunnel positioning has allowed for anatomic single-bundle or double-bundle ACL reconstruction. Nevertheless, many authors suggested that the double-bundle ACL reconstruction procedure could enhance healing at the bone–tendon junction by increasing the contact area, and thus the stability of the knee joint could be better controlled by this technique [8,9].

Over the last decade, studies showed that the anatomic ACL reconstruction techniques have better control of the anterior tibial translation with anterior tibial loading in the large magnitude when compared with nonanatomic single-bundle reconstructions. In addition, in response to combined rotatory loads and functional joint activities, the coupled anterior tibial translation of the anatomic ACL reconstruction was significantly less than that of single-bundle reconstruction at 15° of knee flexion [4,10].

The purpose of this study was to investigate the functional outcomes, knee stability, and patient's satisfaction after anatomic double-bundle ACL reconstruction using the three-portal technique. We hypothesized that this technique can lead to satisfactory clinical outcomes, knee stability, and patient's satisfaction.

Patients and methods

This is a prospective case series study on 48 patients with complete tear of the ACL, half (24 patients) of whom were high-level athletes. The study was conducted between 2005 and 2008 in our institution hospitals. We carried out ACL reconstructions using doubled hamstring tendons as graft in 48 patients, only 24 patients were active athletes. The age of the patients ranged from 17 to 33 years. All patients had an isolated ACL injury, with a time interval between injury and surgery ranging from 2 to 28 months (average 10.3 months). Inclusion criteria were complete ACL tear as proved clinically and by MRI in an active patient below 40 years complaining of knee giving way and instability for more than 4 weeks. All patients should regain near full range of knee motion before their surgery. Exclusion criteria included associated ligamentous injuries, chondral lesions, and meniscal tears that required meniscal repair. Preoperative assessment of all patients included:

(1) Manual knee laxity tests:
   (a) Lachmann.
   (b) Anterior drawer.
   (c) Pivot shift.
(2) Rating scales:
   (a) Lysholm score.
   (b) International Knee Documentation Committee (IKDC) 2000 score.
   (c) Tegner score.

These assessments were repeated every 6 months and the final assessment upon which the postoperative results were taken was carried out at the final follow-up at 24 months postoperatively.

All mean scores were compared and analyzed using IBM SPSS statistics software v.19 (IBM Corporation, Somers, New York, USA). Significances were tested using the Wilcoxon signed-rank test for related samples, the Mann–Whitney *U*-test for independent samples, and Pearson's correlation test for bivariate variables. Results were considered significant at 95% confidence interval level for all statistical analyses.

Operative details

The patient was placed in the supine position under general or regional anesthesia, and a knee holder was used. Pneumatic thigh tourniquet was used in all patients. The procedure initiated with examination of the knee under anesthesia. Initial arthroscopic examination was performed to confirm the diagnosis and to manage the associated meniscal injury.

Graft harvest and preparation

A longitudinal AM incision was made over the tibia at the level of the pes anserinus. In thin patients, the hamstring tendons were easily rolled under the skin, helping to decrease the length of the incision to about 2 cm. After identification and release, both semitendinosus (ST) and gracilis (Gr) tendons were stripped using an open-type tendon stripper and removed from their bony attachment at the tibia with as long as possible periosteal sleeve. After clearing the tendons of any muscle fibers, each tendon was sutured as a triplet under equal tension using no. 2 Ethibond nonabsorbable sutures (Ethicon Inc., Somerville, New Jersey, USA).

The diameter × length of the ST graft was usually 7 × 90 mm and of the Gr graft was 6 × 85 mm.

Arthroscopic technique

Working from the standard AM portal, the procedure initiated by removing the remnants of the torn ACL to clearly identify its femoral and tibial footprints using a basket forceps, motorized shaver, and VAPR radiofrequency (DePuy Mitek Inc., Raynham, Massachusetts, USA). While putting the knee in 80–90°, the femoral footprint is located between the lateral intercondylar ridge (resident's ridge) anteriorly and the over-the-top edge posteriorly. The bifurcate ridge separates the AM bundle behind and the PL bundle in front of this ridge (Fig. 1a). On the tibial side, the AM and PL bundles are attached to the AM and PL aspects of the ACL tibial stump, respectively (Fig. 1b).

Femoral tunnels

A tunnel for the AM bundle was drilled first using the endofemoral guide introduced from the AM portal and hanging on the over-the-top bony margin (Fig. 2a). A guide pin with eyelet was introduced with the knee bent to 90°, and then overdrilled with a 7-mm head-only drill bit to a depth of 25 mm (Fig. 2b). An AMP was made 2 cm medial and inferior to the standard AM portal. Using this portal, the PL femoral tunnel was drilled. This was carried out using a 6-mm endofemoral guide hanging on the anterior wall of the AM tunnel (Fig. 2c).

A guide wire is introduced with the knee flexed to 110° (to avoid iatrogenic injury to the peroneal nerve) (Fig. 2d), and overdrilled with a 6-mm head-only drill bit to a depth of 25 mm (Fig. 2e).

We preferred using a 6-mm endofemoral guide for this smaller tunnel to make sure that the bony bridge between the two tunnels would be at least 2–3 mm. Two suture loops were passed into the eyelets of the two guide pins using no. 2 Vicryl suture (Ethicon Inc.). The two guide pins were pulled out from the femoral side, with the loops protruding from each of the portals on one side and the two suture ends coming out from the femoral side for each tunnel.

Tibial tunnels

Both tibial tunnels were drilled through the AM tibial incision. The PL tibial tunnel initiated anterior to the MCL insertion site and terminated at the PL aspect of the tibial footprint. Overdrilling was performed using a 6-mm tibial drill bit. The starting point of the tibial guide for the AM bundle was positioned in a more anterior and central position on the tibia, and the tip was positioned in the AM aspect of the tibial footprint and overdrilled by a 7-mm full-length tibial drill bit (Fig. 2f and g).

Graft passage and fixation

Using an arthroscopic grasper, the Vicryl loop coming out the AM portal is pulled out from the AM tibial tunnel, and the suture loop coming out from the AMP is pulled out from the PL tibial tunnel. The AM bundle is passed first using the Vicryl loop relaying the ST graft,and then fixed to the femur with an 8 × 23-mm bioabsorbable interference screw introduced from the standard AM portal with the knee flexed to 90°.

Then, PL Gr bundle was passed and fixed to the PL femoral tunnel using a 7 × 23-mm bioabsorbable interference screw introduced from the AMP with the knee bent to 110° (Fig. 2h). After cycling the knee for 20 cycles between 0–120° with the grafts under tension, the grafts are fixed to the tibia. The AM bundle was fixed with an 8 × 30-mm bioabsorbable screw under tension with the knee in 60° of flexion, whereas the PL bundle was fixed under tension using an 8 × 23-mm bioabsorbable screw with the knee in 20° of flexion. Using these over-sized screws with this length assures strong fixation with the screws reaching the tibial apertures (aperture fixation). All screws used were PLA absorbable ABSOLUTE (DePuy Mitek Inc.). The incisions were closed, and a no. 12 suction drain was applied for 24 h.

After care

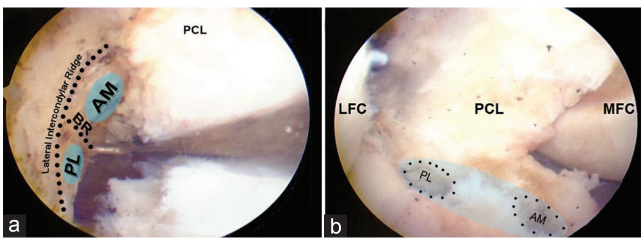
Postoperative immediate weight bearing and full range of motion were allowed as pain tolerated. Crutches were used for 1–2 weeks, and closed kinetic-chain quadriceps exercises were initiated immediately.

Results

Demographics

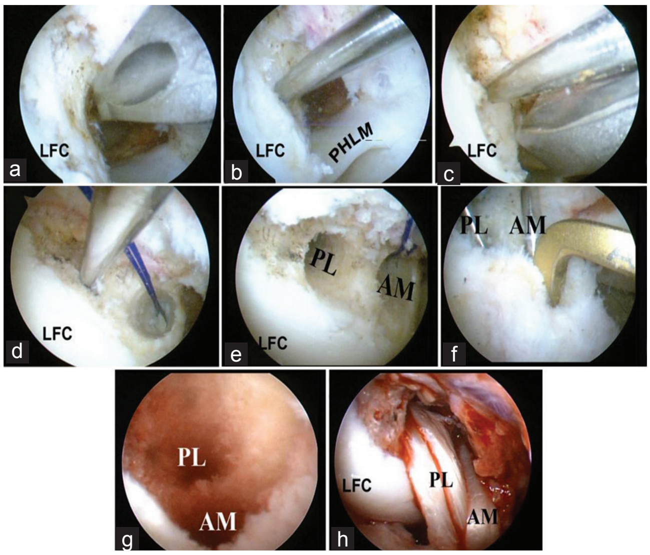
This prospective study included 48 patients: 37 male patients and 11 female patients, with a mean age of 22.7 ± 3.8 years (range 17–33 years). The mean follow-up period was 26.6 ± 2.7 months (range 24–33 months).

Figure 1



Arthroscopic view of the right knee through anterolateral portal with knee bent to 80° showing anterior cruciate ligament footprint. (a) Femoral footprint between the lateral intercondylar ridge and the over-the-top limit [note that the AM bundle is behind the bifurcate (BR) ridge, whereas the PL bundle is anterior] and (b) tibial footprint showing both AM and PL bundles position at the stump. AM, anteromedial; BR, bifurcate ridge; LFC, lateral femoral condyle; MFC, medial femoral condyle; PCL, posterior cruciate ligament; PL, posterolateral.

Figure 2



Right knee viewed through medial portal (standard and accessory). (a) Endofemoral guide hanging on the over-the-top bony margin, (b) a guide pin with eyelet is introduced to the AM bundle footprint, (c) endofemoral guide hanging on the anterior wall of the AM tunnel, (d) through which a guide wire is introduced with the knee flexed to 110° into the PL bundle footprint, (e) to be overdrilled with a 6-mm femoral tunnel reamer, (f) passing two guide pins with eyelet into the AM and PL tibial footprint, (g) to be overdrilled with tibial tunnel reamers, and (h) final view of the double-bundle anterior cruciate ligament after graft passage. AM, anteromedial; PL, posterolateral; LFC, lateral femoral condyle; PHLM, posterior horn of lateral meniscus.

Half of these patients (24 patients) were high-level athletes, and 23 patients had sports-related injuries. Twenty-one patients had small meniscal lesions and all were treated by partial meniscectomy.

Clinical data

Although all patients showed negative Lachmann and anterior drawer tests at 24 months follow-up, only two (4.2%) patients showed (one positive) glide and they did not return to their sports level and reported unsatisfaction (both were professional soccer athletes). Apart from these two patients, 95.8% of the patients returned to the preinjury level of activity. In addition, there was another patient who was unsatisfied because of persistent medial-sided discomfort (which may be explained by MRI grade II meniscal signal). Overall patient satisfaction was 93.8%.

Scores

The mean IKDC score improved from 68.1 to 93.5. The mean Lysholm score improved from 73.8 to 95.5. The mean Tegner scale improved from 4 to 9.4. All these improvements were statistically significant (Table 1).

Although the Tegner score showed statistically significant better values in the athletic group and sports-related injuries, this was not statistically significant with other scores (Table 2). No statistical significance was related to other variables such as age, sex, or mode of injury.

Table 1 Descriptive statistics of the study demographics and preoperative and postoperative rating scales, showing statistically significant improvements in all rating scales postoperatively

	Minimum	Maximum	Mean	SD	*P*-value[a]
Age	17	33	22.69	3.88	
Time	2	28	10.32	7.46	
IKDC					
Pre	58	78	68.12	5.10	<0.05 (0.000000000724)[a]
Post	88	98	93.54	2.78	
Lysholm					
Pre	71	80	73.83	2.73	<0.05 (0.0000000015416)[a]
Post	93	99	95.54	1.8	
Tegner					
Pre	3	6	4.04	0.85	<0.05 (0.0000000012)[a]
Post	7	10	9.42	0.71	

IKDC, International Knee Documentation Committee. [a]Tested with the Wilcoxon signed-rank test.

Table 2 Different correlation significances (*P*-value) between different scores and study variables (age, sex, etiology, being athlete, and time between injury and surgery)

	IKDC post	Lysholm post	Tegner post
Age	0.442	0.471	0.355
Sex	0.218	0.713	0.499
Traumatic	0.443	0.584	0.026*
Athlete	0.096	0.428	0.041*
Time	0.917	0.261	0.164

Note that the Tegner score is the only score to show significance with the traumatic and athletic groups. IKDC, International Knee Documentation Committee. *Correlation is significant at the 0.05 level (two-tailed) (correlations are calculated using Pearson's correlation coefficient).

Discussion

Conventional single-bundle reconstruction techniques often result in nonanatomic tunnel placement, with a tibial PL to a femoral 'high AM' tunnel position. Yasuda *et al.* [4] have demonstrated that nonanatomic single-bundle reconstructions cannot completely restore normal anterior–posterior or rotatory laxity. A cadaveric study by Tsai *et al.* [11] showed that anatomic single-bundle ACL reconstruction had lower rotational knee stability when compared with anatomic double-bundle ACL reconstructions.

Izawa *et al.* [12] in their retrospective controlled study evaluated 48 participants clinically and using the Lysholm and Tegner scores after only 1 year. Although they did not find a statistically significant difference between the single-bundle and double-bundle reconstruction groups with respect to their scores, they found a significantly better rotational stability of the double-bundle reconstruction group using the Slocum's ALRI [12]. Despite the retrospective design of the study, the short-term follow-up, and the limited sample size for a retrospective study, they concluded a better rotational stability of double-bundle reconstruction techniques.

Adachi *et al.* [13] in their prospective randomized study on 108 patients concluded that there is no significant difference between single-bundle and double-bundle ACL reconstruction in terms of stability or proprioception. Although the study was based on an objective arthrometric testing by KT-2000 only, it lacked rotational testing and functional assessment for patients, which are essential to support such a conclusion.

A prospective case series study by Fu *et al.* [14] on 100 patients with anatomic double-bundle reconstruction with an average follow-up of 2.1 years showed 6% grade I (glide) pivot-shift test and a mean side-to-side difference in the KT-2000 arthrometer testing of 1.0 ± 2.3 mm. The mean 2-year IKDC subjective score was 85.0 ± 14.1 [14].

Our prospective study evaluated the midterm results of a case series of 48 consecutive patients with anatomic double-bundle reconstruction using the three-portal technique to provide a proper view of the bony landmarks, facilitating anatomic positioning of the graft. The mean follow-up period was 26.6 months, with a significant improvement in the mean IKDC score, in the Lysholm score, and in the Tegner scale. All patients showed negative Lachmann and anterior drawer tests at 24 months follow-up; only two (4.2%) patients showed grade I (glide), with overall patient satisfaction of 93.8%.

The major limitation of our study is being a case series with no control group with single-bundle reconstruction; a randomized controlled trial is recommended to investigate the difference in the rotational stability between anatomic single-bundle and double-bundle reconstructions. A second limitation is the midterm nature of the follow-up that may need longer period to justify any recommendation for anatomic double-bundle reconstruction. Despite these limitations, our study gave comparable results with previous studies.

Conclusion

Anatomic double-bundle ACL reconstruction results in significant improvement in the clinical outcomes and knee stability, with 93.8% satisfaction and return to preinjury level of activity.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Griffin LY, Agel J, Albohm MJ, Arendt EA, Dick RW, Garrett WE, *et al.* Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. J Am Acad Orthop Surg 2000; 8:141–150.

2 Buoncristiani AM, Tjoumakaris FP, Starman JS, Ferretti M, Fu FH. Anatomic double-bundle anterior cruciate ligament reconstruction. Arthroscopy 2006; 22:1000–1006.

3 Khalfayan EE, Sharkey PF, Alexander AH, Bruckner JD, Bynum EB. The relationship between tunnel placement and clinical results after anterior cruciate ligament reconstruction. Am J Sports Med 1996; 24:335–341.

4 Yasuda K, van Eck CF, Hoshino Y, Fu FH, Tashman S. Anatomic single- and double-bundle anterior cruciate ligament reconstruction, part 1: basic science. Am J Sports Med 2011; 39:1789–1799.

5 Colombet P, Robinson J, Christel P, Franceschi JP, Djian P, Bellier G, Sbihi A. Morphology of anterior cruciate ligament attachments for anatomic reconstruction: a cadaveric dissection and radiographic study. Arthroscopy 2006; 22:984–992.

6 Hole RL, Lintner DM, Kamaric E, Moseley JB. Increased tibial translation after partial sectioning of the anterior cruciate ligament: the posterolateral bundle. Am J Sports Med 1996; 24:556–560.

7 Takahashi M, Doi M, Abe M, Suzuki D, Nagano A. Anatomical study of the femoral and tibial insertions of the anteromedial and posterolateral bundles of human anterior cruciate ligament. Am J Sports Med 2006; 34:787–792.

8 Karlsson J, Irrgang JJ, van Eck CF, Samuelsson K, Mejia HA, Fu FH. Anatomic single- and double-bundle anterior cruciate ligament reconstruction, part 2: clinical application of surgical technique. Am J Sports Med 2011; 39:2016–2026.

9 Muneta T, Sekiya I, Yagishita K, Ogiuchi T, Yamamoto H, Shinomiya K. Two-bundle reconstruction of the anterior cruciate ligament using semitendinosus tendon with endobuttons: operative technique and preliminary results. Arthroscopy 1999; 15:618–624.

10 Yagi M, Wong EK, Kanamori A, Debski RE, Fu FH, Woo SL. Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. Am J Sports Med 2002; 30:660–666.

11 Tsai AG, Wijdicks CA, Walsh MP, Laprade RF. Comparative kinematic evaluation of all-inside single-bundle and double-bundle anterior cruciate ligament reconstruction: a biomechanical study. Am J Sports Med 2010; 38:263–272.

12 Izawa T, Okazaki K, Tashiro Y, Matsubara H, Miura H, Matsuda S, *et al.* Comparison of rotatory stability after anterior cruciate ligament reconstruction between single-bundle and double-bundle techniques. Am J Sports Med 2011; 39:1470–1477.

13 Adachi N, Ochi M, Uchio Y, Iwasa J, Kuriwaka M, Ito Y. Reconstruction of the anterior cruciate ligament: single- versus double-bundle multistranded hamstring tendons. J Bone Joint Surg Br 2004; 86:515–520.

14 Fu FH, Shen W, Starman JS, Okeke N, Irrgang JJ. Primary anatomic double-bundle anterior cruciate ligament reconstruction: a preliminary 2-year prospective study. Am J Sports Med 2008; 36:1263–1274.