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A new technique in double-bundle anterior cruciate ligament reconstruction with implant-free tibial fixation

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Abstract

Purpose This case-series outcome study presents a surgical technique for anatomic double-bundle anterior cruciate ligament (ACL) reconstruction with 4-tunnel using two interference screws. There was a 2-year minimum follow-up.
Methods From January to December 2009, an ACL 4-tunnel, anatomic, double-bundle reconstruction was performed on 27 patients. Double-strand hamstring tendon grafts were used in each femoral tunnel as well as two interference screws. Tibial fixation was insured through manual tension, by tying non-absorbable sutures on the bone bridge between the two tunnels at 20° of knee flexion. Clinical assessments included the International Knee Documentation Committee (IKDC) and Lysholm knee scores, range of motion (ROM), pivot-shift test, single-leg hop, and quadriceps-hamstrings strength tests using a hand-held dynamometer. Anterior knee laxity was also assessed using a rolimeter. A single examiner performed all testing preoperatively at 6 months and during the 2-year follow-up.
Results All patients were assessed during the 2-year follow-up. At that time, 92 % of the patients presented normal anterior laxity (average, 1.3 ± 0.5 mm) and rotational knee stability. No statistical side-to-side difference was found for ROM, muscle strength, single-leg hop, and function (n.s.). All patients presented a normal knee function according to the IKDC and the Lysholm score. In addition, no infection, graft failure, or pain were observed at the harvesting site.
Conclusion The study shows that satisfactory results in relation to knee laxity, function, and strength can be achieved with the implant-free tibial fixation in the ACL double-bundle reconstruction with two interference screws.
Level of evidence Therapeutic case series, Level IV.

Keywords Knee · ACL · Reconstruction · Rehabilitation

Introduction

Due to the growing interest in sports participation during adulthood, the reconstruction of the anterior cruciate ligament (ACL) became a commonly performed procedure. Furthermore, good-to-excellent reconstruction results have been reported [7]. However, a critical review of the literature revealed that the success rate varies between 69 and 95 %. Conventional reconstruction techniques are more successful in limiting anterior tibial translation, but they may be insufficient in controlling combined rotatory movements of the knee [22]. Thus, ACL reconstruction with an anatomic double-bundle technique has become popular in recent years. However, the double-bundle reconstruction with four tunnels and with four implants for grafts fixation increases the cost of the surgery when compared to single-bundle reconstruction.

Several biomechanical [28–30] and clinical studies [11, 13, 19] have investigated the relevance of additional

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posterolateral (PL) bundle on knee transversal plane stability. Recent systematic review reported superior clinical results in relation to the anterior and rotational stability in patients who received an anatomic double-bundle technique when compared to a single-bundle technique [27]. Although there is a trend to reconstruct the ACL with the double-bundle technique, some surgeons still prefer using the single-bundle technique due to its low cost and convenience [7].

However, if the anatomic, double-bundle reconstruction is performed using the same material as the single-bundle reconstruction, patients could benefit from greater rotational stability and better function, without increasing the cost of the surgical procedure. Therefore, the purpose of this study is to present a new surgical technique and prospectively report the clinical outcomes of anatomic double-bundle ACL reconstruction with two interference screws with an evaluation at 6 months and at 2-year follow-up. The authors of the present study hypothesized that no significant side-to-side difference would be found in relation to knee stability, muscle strength, range of motion (ROM), and function.

Materials and methods

From January to December 2009, ACL reconstruction with an anatomic double-bundle using hamstring tendon grafts was performed on 27 males. All patients were evaluated pre-operatively, at 6 months and at 2 years post-operatively. Patient data are presented in Table 1. The indication for surgery was a diagnosis of ACL rupture based on clinical evaluation and magnetic resonance imaging (MRI) in a patient with marked instability who wished to regain his pre-injury level of activity. The exclusion criteria included combined collateral ligament injury, posterior cruciate ligament or PL corner injury, previous knee surgery, and grade II or III osteoarthritis. All patients had to have at least two positive tests for instability (Lachman test, anterior drawer test, or pivot-shift test).

Surgical technique

Initially, a full arthroscopic assessment was performed on each patient to confirm the ACL tear and other injuries to the meniscus and cartilage. The harvesting step for hamstring tendons was similar to the technique utilized in the single-bundle hamstring graft. The diameter of the semitendinosus and gracilis was tripled, usually 8 and 7 mm, respectively. The semitendinosus graft was used for the anteromedial (AM) bundle reconstruction, whereas the gracilis was utilized for the PL bundle. Grafts were prepared individually using No. 1-0 Vicryl suture (*Ethicon, SP, BR*) on both ends. At the end of the tibial grafts, three non-absorbable Ethibond wires No. 5 were sutured with a 1-cm space between each one.

Table 1 Clinical data and arthroscopic findings

No. of patients	27
Male/female	27/0 (100 %)
Age at operation (range) (years)	28 (18–45)
Injury mechanism	
Sports injury	26 (96 %)
Traffic injury	1 (4 %)
Time between injury and surgery (month)	8 ± 1.6
Arthroscopic findings	
Medial meniscal tear	12 (44 %)
Lateral meniscal tear	7 (26 %)
Cartilage damage	
Medial compartment	2 (8 %)
Lateral compartment and PFJ	2 (8 %)
Follow-up (range) (month)	25 (22–29)

PFJ patellofemoral joint

The AM femoral tunnel was created through the transportal technique on a conventional surgical table. The position of the AM tunnel was posterior to the femoral condyle wall, approximately at 11 o'clock in the right knee and 1 o'clock in the left knee. The guidewire was then drilled into the lateral femoral condyle. The AM tunnel was placed as posterior as possible without breaking the posterior wall of the femoral condyle. It was placed at the posterior part of the intercondylar notch at 120° of knee flexion. The tunnel was drilled with a cannulated drill (diameter of 4 mm) over the guidewire. The final drilling of the tunnel was made according to the diameter of the grafts obtained intra-operatively. The diameter of the AM tunnel was typically 7 mm, and the depth of the tunnel was 30 mm. Furthermore, the surgeon drilled the PL tunnel at the same position. This tunnel was performed at 130° of knee flexion at approximately 9:30 o'clock position for the right knee and 2:30 o'clock position for the left knee. The angle between the AM and PL femoral tunnels was kept at approximately 25°–30° between the AM and PL femoral tunnels. The wall between both tunnels was at least 2 mm with a tunnel depth of 30 mm. Conventional metal screws provided fixation of the grafts for both femoral tunnels.

The tibial tunnels were performed with a tibial guide, starting with the PL tunnel. This tunnel was performed with the guidewire positioned on the PL aspect of the tibial insertion of ACL. The position of the AM tibial tunnel was based on the footprint of the remaining ACL fibres. A bone bridge of approximately 1–2 mm was maintained between both tibial tunnels. The AM and PL tunnels were typically 8 and 7 mm, respectively. The grafts were passed retrograde, i.e. from the tibial tunnel to the femoral tunnel. A guidewire was used, followed by a fixation with titanium interference screws (inside out). The PL bundle was first fixed in the PL tunnel, and then, the AM bundle was fixed in the AM femoral tunnel. Afterwards, a cycling of 40 repetitions was performed.

The fixation of the tibial graft was made by lashing a non-absorbable No. 5 Ethibond suture, i.e. without using screws. In the present technique, both bundles were fixed at 20° of knee flexion. While the surgeon performed the fixation in the first pair of wires, the surgical assistant maintained a moderate traction on the other two pairs of wires. Thus, the surgeon gave the node in the second pair of wires (pair identified with two nodes), while the assistant maintaining a moderate traction on the third pair (pair identified with three nodes). Finally, the last pair of wires was fixed. Six usual nodes were made in each pair of wires, being supported and blocked with a tweezers, on the edge of the orifice of the AM bundle tibial tunnel. After the graft fixation in the tibial tunnels, the surpluses of nodes were removed with a short Kelly into the hole on the AM tibial tunnel. There was a concern to avoid friction of the subcutaneous tissue and, consequently, difficulties in subcutaneous tissue healing.

Postoperative rehabilitation

The patients were encouraged to recover ROM and to tolerate full weight bearing on the first day after surgery. Crutches were used during for 2–3 weeks. No orthotic brace was prescribed. A rehabilitation programme was prescribed that included quadriceps-strengthening exercises and ROM activities emphasizing full extension. Cycling was allowed when patient showed 100° of knee flexion. Closed kinetic chain exercises were immediately suggested. However, the open kinetic chain exercises in a full ROM (90°–0° of knee flexion) were allowed only after 9 weeks. Running was allowed at 3 months, and pivoting exercises at 6 months post-operatively [9, 20]. A therapist provided all treatment until a return to sports was possible.

Follow-up evaluation

Clinical evaluation of knee function and stability was performed pre-operatively, at 6 months and at 2 years after reconstruction during regular follow-up. All patients were evaluated regarding activity level with the International Knee Documentation Committee (IKDC), the Lysholm subjective knee evaluation forms [19, 28, 29], ROM with a goniometer [20], and the pivot-shift test [19, 28, 29].

Quadriceps and hamstring muscle strength was evaluated by measuring the maximum isometric voluntary contraction (MIVC), using a hand-held dynamometer (*Lafayette Instrument Co, IL, USA*) [26]. In order to measure the quadriceps, the subject was asked to sit on a table, with his arms held against his body, and his hips and knees positioned at 90° and 60° of flexion, respectively. The dynamometer was positioned 2 in. proximal to the lateral malleolus on the anterior aspect of the tibia. To measure the hamstrings, the subject was positioned in a prone position on the table, with the knee flexed at 30°. The dynamometer was placed two inches proximal to the lateral malleolus on the posterior aspect of the leg. The leg was stabilized by an inelastic band. Previous studies indicated good-to-excellent reliability and intra-class correlation coefficients (ICCs) of 0.89 and 0.92, respectively [6, 17, 23]. The single-leg hop test was also used to measure knee function. When performing the hop test, the patient was instructed to jump forward as far as possible [5].

Anterior knee laxity was analysed by an arthrometer (*Rolimeter TM, Aircast®, FR*). The subject was positioned in a supine position on the table, with a cushion under the knee to stabilize the joint at 25° of flexion. A Lachman test was then performed to quantify the anterior tibial translation [18]. The examiner applied the maximum manual force until the anterior endpoint was reached. The side-to-side difference below 3 mm was considered normal, between 3 and 5 mm "nearly normal", between 6 and 10 mm "abnormal", and above 10 mm "severely abnormal". These factors were all rated according to the IKDC guidelines. All surgical procedures were performed by a senior orthopaedic surgeon with more than 17 years of knee surgery experience. All pre- and post-operative assessments were made by an independent examiner, not involved in the treatment.

This work received approval from The Institutional Review Board of Bandeirantes Hospital (CAAE—12233113.3.0000.5485), and all participants gave informed, written consent prior to participation.

Statistical analysis

The sample size estimation calculated was justified based on the change of anterior laxity between the injured limb and the contralateral limb. A 2.0-mm difference between limbs and the corresponding standard deviation of 2.0 mm was considered to be clinically relevant. It was determined that a sample size of 25 patients would be necessary to detect the 2.0 mm difference with 80 % power when alpha was set equal to 0.05 [12]. Data were analysed with SPSS Version 13.0 (*SPSS Inc, Chicago, IL, USA*). Descriptive statistics for demographic data and all outcome measures were expressed as averages and standard deviations. Chi-square test was performed to compare data from the subjective IKDC assessment, the Lysholm scale, ROM, pivot-shift test, anterior knee laxity, muscle strength, and the single-leg hop test. These analyses were categorized in accordance with the IKDC form.

Results

In the present study, no graft failure, no pain complaints, nor infection were found near the graft incision. The surgical time was on average 89.0 ± 4.0 min. Concomitant injuries such as posterior cruciate ligament, collateral ligaments, PL complex, or moderate-to-severe osteoarthritis were excluded (Table 1).

IKDC and Lysholm scores

According to the IKDC and the Lysholm final score, all patients presented a significant knee function improvement at follow-ups when compared to pre-operatively (n.s.) (Tables 2, 3).

ROM, strength, and single-hop test

Pre-operatively, a significant side-to-side deficit in ROM was found for knee extension (3.9 ± 1.2, $P < 0.03$) and flexion (11.0 ± 3.1, $P < 0.01$). However, no side-to-side difference was found at 6 months (extension, 0.8 ± 0.4; flexion, 1.0 ± 0.6; n.s.) and the 2-year follow-up (extension, 0.6 ± 0.3; flexion, 0.5 ± 0.6; n.s.). All patients showed “normal” ROM post-operatively. On average, the patients presented side-to-side quadriceps strength deficits of 9 % at the 6-month follow-up and 6 % at the 2-year follow-up. For the hamstrings strength, the deficit was 10 % at 6 months and 8 % at the 2-year follow-up. However, this side-to-side strength deficit for both muscle groups was not statistically significant (n.s.). Therefore, all patients presented “normal” or “nearly normal” strength scores at follow-up. Finally, no significant difference was found for the single-leg hop test at 6 months and at the 2-year follow-up when the injured and non-injured limbs (n.s.) were compared. No patient showed an “abnormal” or “severely abnormal” score for ROM, strength, and the hop test post-operatively (Table 4).

Table 2 Evaluation of the knee by the IKDC final score pre-operatively and 2-year follow-up

IKDC final score		P value
Pre-operatively	($N = 27$)	
Normal	0	
Nearly normal	0	
Abnormal	4	
Severely abnormal	23	
At 2-year follow-up[a]	($N = 27$)	0.001
Normal	27	
Nearly normal	0	
Abnormal	0	
Severely abnormal	0	

IKDC International Knee Documentation Committee

[a] Comparison between 2-year follow-up and pre-operative data

Table 3 Lysholm score (0–100) pre-operatively and at 2-year follow-up

Lysholm score	Mean ± SD	P value
Preoperatively	($N = 27$) 67 ± 13	
At 2-year follow-up[a]	($N = 27$) 97 ± 2	0.0001

[a] Comparison between 2-year follow-up and pre-operative data

Anterior knee laxity and pivot-shift tests

There was a significant lower anterior displacement at the post-operative evaluation when compared to pre-operative ($P < 0.05$) (Table 5). A significant rotational instability was found in the injured knee pre-operatively ($P < 0.001$). However, there was no side-to-side difference at 6 months and at the 2-year evaluation (n.s.) (Table 6).

Discussion

The most important findings of the present study were the satisfactory clinical outcomes of double-bundle ACL reconstruction technique using two interference screws during the 2-year follow-up. Patients presented normal side-to-side rotational and anterior knee laxity, ROM, as well as satisfactory and excellent results in function, muscle strength, and subjective assessments.

Despite the fact that the double-bundle ACL reconstruction has become popular in recent years, the cost of the procedure can increase the cost of surgery more than ten times due to the material and surgical time required when compared to the single-bundle technique [7]. However, this study presents a technique using two metallic interference screws, which costs less than conventional double-bundle technique with four bioabsorbable screws, or four metallic interference screws, or endobutton, or even two bioabsorbable interference screws [8, 15]. These findings imply additional direct costs to the health system of emerging countries. As aforementioned, the patients in the present study were submitted to femoral fixation with metallic screws, despite the fact that some biomechanical studies have shown that bioabsorbable screws are stronger than metallic screws in the single-cycle load-to-failure test [3, 16, 21]. The initial doubt was in relation to loss of graft fixation due to using a tibial fixation by tying. However, it is important to highlight that no patient experienced any “giving way” episodes during the rehabilitation protocol or even during the 2-year follow-up.

Table 4 Comparison between injured and uninjured knee for the ROM, strength, and single-leg hop test according to IKDC form

	Preoperatively ($N = 27$)	At 2-year ($N = 27$)
ROM extension[a]		
Normal	5	27
Nearly normal	16	0
Abnormal	5	0
Severely abnormal	1	0
ROM flexion[a]		
Normal	8	27
Nearly normal	14	0
Abnormal	4	0
Severely abnormal	1	0
Strength (MVIC)		
Quadriceps[b]		
Normal	NA	27
Nearly normal		0
Abnormal		0
Severely abnormal		0
Hamstrings[b]		
Normal	NA	26
Nearly normal		1
Abnormal		0
Severely abnormal		0
Single-leg hop test[b]		
Normal	NA	27
Nearly normal		0
Abnormal		0
Severely abnormal		0

IKDC International Knee Documentation Committee, *MVIC* maximum voluntary isomeric contraction, *ROM* range of motion, *NA* not assessed

[a] Significant side-to-side difference was observed pre-operatively ($P < 0.05$), but no difference was observed at 2-year follow-up (n.s.)

[b] No side-to-side difference was observed at 2-year follow-up (n.s.)

Table 5 Anterior knee laxity measured with rolimeter[a] and according to IKDC form

Mean rolimeter difference, mm (±SD)	IKDC form
Pre-operatively[b]	
($N = 27$)	($N = 27$)
4.9 (±1.3)	Normal (0)
	Nearly normal (4)
	Abnormal (11)
	Severely abnormal (12)
At 2-year follow-up[c]	
($N = 27$)	($N = 27$)
1.3 (±0.5)	Normal (25)
	Nearly normal (2)
	Abnormal (0)
	Severely abnormal (0)

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[a] Difference between the injured and uninjured knee

[b] Significant side-to-side difference was observed pre-operatively ($P < 0.05$)

[c] No side-to-side difference was observed at 2-year follow-up (n.s.)

Table 6 Pivot-shift test of the injured knee according to IKDC form[a]

	IKDC form	P value
Pre-operatively	($N = 27$)	
Normal	0	0.001
Nearly normal	4	
Abnormal	11	
Severely abnormal	12	
At 2-year follow-up	($N = 27$)	
Normal	25	n.s.
Nearly normal	2	
Abnormal	0	
Severely abnormal	0	

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[a] Difference between the injured and uninjured knee

Many researchers have focused on replicating anatomic ACL reconstruction studies in order to reproduce similar kinematics of the injured knee when compared to the healthy knee [1, 2, 4, 8, 10, 14, 24, 25]. The patients in the present study showed no side-to-side difference for the anterior and rotational clinical knee stability. In addition, no patients presented “abnormal” or “severely abnormal” knee laxity or graft failures at the 2-year follow-up. These data corroborate previous studies that showed low graft failure incidence in patients submitted to double-bundle reconstruction [13, 25]. Moreover, the present outcomes referring to normal function, satisfactory stability, and an absence of post-operative complications allow the authors of this study to affirm that double-bundle reconstruction without tibial implants is a safe technique and provides similar outcomes than other technique with four implants.

The limitations of this case-series study include a small number of patients, no comparison group treated with the single-bundle reconstruction, or other double-bundle reconstruction. However, when considering the comparison with the healthy knee, the results were satisfactory in all clinical measurements. There was also a lack of comparison between “aggressive” and “nonaggressive” rehabilitation protocols for evaluation of the effect of implant-free tibial fixation. Another possible bias was the fact that both bundles were fixed simultaneously at 20 degrees of knee flexion. While some studies have suggested a fixation at approximately 45°–60° of knee flexion [2, 28], the authors of the present study believe that both bundles fixed at 20° of knee flexion can restore relatively normal tension curves in each bundle, thus avoiding excessive stress in the graft. Another limitation of this fixation is the fact that it was not possible to apply quantitative force to the grafts. The clinical relevance of this study is the determination that satisfactory results can be achieved with double-bundle, ACL reconstruction while using the same surgical material as is utilized in single-bundle reconstruction. Biomechanical studies are also needed to evaluate the dynamic rotational stability of the knee between the tibial implant-free double-bundle and conventional double-bundle, as well as the tibiofemoral and patellofemoral stress.

Conclusion

The study demonstrated satisfactory results in relation to knee stability, function, and strength. This was achieved with an implant-free tibial fixation of a double-bundle ACL reconstruction with two interference screws.

Conflict of interest None.

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