



REVIEW

Arthroscopic single- versus double-bundle posterior cruciate ligament reconstructions using hamstring autograft

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Accepted 21 October 2003

KEYWORDS

Arthroscopic; Posterior cruciate ligament; Reconstructions

Summary This prospective study compared the clinical results of single- and double-bundle posterior cruciate ligament (PCL) reconstruction with a minimum follow-up of 2 years. There were 35 patients including 19 single- and 16 double-bundle posterior cruciate ligament reconstructions using hamstring autograft. The average age was 29.4 ± 13.6 years versus 28.2 ± 10.4 years; and the average follow-up was 41.0 ± 13.1 months versus 28.2 ± 4.2 months for single- and double-bundle reconstruction, respectively. The indication for surgery was functional disability of the knee due to pain and instability as the result of high-energy PCL injury. The evaluation parameters included functional assessment, ligament laxity, functional score and radiographs of the knee. The results showed no significant difference in functional assessment, ligament laxity, functional score and radiographic changes of the knee between the two techniques. The rate of overall satisfaction with the operation was comparable from patient and surgeon perspectives. Contrary to many recent reports, the results of this study showed that single- and double-bundle PCL reconstruction using hamstring autograft produced comparable clinical results in medium-term follow-up. The difference between single- and double-bundle PCL reconstruction, if any, can be concluded only with long-term results and larger number of patients.

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Introduction

Many studies on the clinical result of posterior cruciate ligament (PCL) reconstruction showed good early functional results, but the posterior laxity of the knee was not completely eliminated.^{3,8,16–18,30,31} This was attributed to lack of understanding of functional anatomy and biomechanics of PCL and

the surgical techniques.^{2,4,6,9,11,14,15,18,20–25,28,29} Single-bundle PCL reconstruction theoretically only restores the anterolateral bundle of the PCL fibres, and the two functional components including anterolateral and posteromedial bundles are not properly reconstructed.^{4,6,8,11,12,14,18,20,22,24} Therefore, there is a tendency to recommend double-bundle PCL reconstruction to restore the normal PCL anatomy and improve the surgical result.^{5,7,13,14,19,22,26,31} However, very little information is available comparing the outcomes between single-bundle and double-bundle PCL reconstruction. The purpose of

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this study was to compare the clinical results of single-bundle and double-bundle PCL reconstruction of the knee using hamstring autograft with a minimum follow-up of 2 years.

Patients and methods

This series consisted of 36 patients including 19 single-bundle and 17 double-bundle PCL reconstructions performed at our hospital from 1997 to 2001. The patients were randomly, but not simultaneously selected for single- or double-bundle reconstruction, and this had resulted in a discrepancy in the number of patients and the length of follow-up between the two groups. One patient with a double-bundle reconstruction was excluded because of sepsis of the knee that required graft removal at 23 months from the index surgery. The remaining 35 patients including 19 single- and 16 double-bundle reconstructions were included in this study. The mechanisms of injury were vehicular trauma in 33 (94%) and sports-related injury in 2 (6%). The associated injuries included 2 femur fractures, 1 tibia fracture, 1 chondral injury and 7 meniscal tears. The indication for surgery was functional disability of the knee due to pain and instability as the result of high-energy PCL injury with failure of 3 months of conservative treatment. None of the patients were operated on within one month of injury. The patients with combined ligament injuries and PCL avulsion fracture were not included. The average age was 29.4 ± 13.6 years (range 17–60) versus 28.2 ± 10.4 years (range 16–47); the average time from injury to surgery was 8.5 ± 8.0 months (range 3–24) versus 6.5 ± 5.9 months (range 3–18); and the average length of follow-up was 41.0 ± 13.1 months (range 26–71) versus 28.2 ± 4.2 months (range 24–37) for single-bundle and double-bundle reconstruction respectively. The patient demographics are summarized in Table 1.

Surgical technique

Under either general or spinal anaesthesia, a complete arthroscopic examination of the knee was performed, and the associated injuries including chondral lesion and meniscal tear, if any, were treated first. The concomitant surgery included debridement for a chondral lesion in 1, partial meniscectomy in 5 and meniscus repair in 2. The PCL pathology was carefully examined. Complete disruption of the PCL fibres was noted in 15 knees, and the remaining 20 knees showed lax PCL fibres mixed with fibrous tissues, widening of the posteromedial joint space and pseudo-laxity of the

Table 1 Patient demographics

	Single-bundle	Double-bundle
Number of patients	N = 19	N = 16
Average age (year)	29.4 ± 13.6 (17–60)	28.2 ± 10.4 (16–47)
Male/female	14/5	12/4
Right/left	9/10	10/6
Mechanism of injury		
Trauma	100% (19/19)	87.5% (14/16)
Sports-related	0	12.5% (2/12)
Associated injuries		
Femur fracture	2	0
Tibia fracture	1	0
Chondral fracture	0	1
Meniscus tear	4	3
Duration (month)	8.5 ± 8.0	6.5 ± 5.9
Range	3–24	3–18
Average follow-up time (month)	41 ± 13	28.2 ± 4.2
Range	26–71	24–37

anterior cruciate ligament (ACL) in which the ACL fibres were lax with the knee in a gravity position, and taut when an anterior drawer force was applied to the proximal tibia.

The semitendinosis and gracilis tendons were harvested through an anteromedial incision. For single-bundle repairs, the grafts were doubled or tripled and sutured together at both ends with #2 Ethibond running baseball stitches. For double-bundle repairs, one end of the graft composite was sutured together in a similar fashion, and the other end of the semitendinosis and gracilis tendon was sutured individually (Fig. 1). The graft was pre-tensioned with 15 lb for 15 min in a tension device, and it was sized before use.

Arthroscopic PCL reconstruction was performed using the Acufex PCL guides (Acufex, Andover, MA). For single-bundle reconstruction, the tibia guide pin was placed on the medial aspect of the proximal tibia approximately 4 cm below the medial joint line and 1–2 cm posterior to the anterior tibia surface, and exited posterior at approximately 1.0 cm below the articular surface of the medial tibial plateau slightly lateral to the midline at the PCL insertion site. The tip of the guide pin was carefully protected with a curved curette to prevent injury to the neurovascular structures when it exited posteriorly. The tibial tunnel was then created with a graft-size matched core-reamer. The femoral guide was introduced through the anterolateral portal. The location of the femoral tunnel was 4–5 mm proximal to articular surface and centred between the anterior and posterior articular margins of the

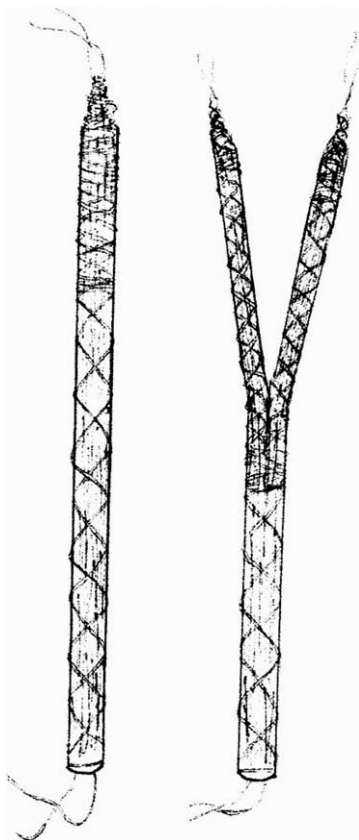


Figure 1 A sketch showing single-bundle graft on the left, and double-bundle graft on the right.

medial femoral condyle. This location was close to the insertion site of the anterolateral bundle of the normal PCL. The guide pin was then driven through the femoral guide and exited on the medial aspect of the knee. A 25–30 mm deep femoral tunnel was created with a graft-size matched reamer. The graft was delivered through the tibial tunnel into the knee joint and the femoral tunnel with #5 Ethibond carrying sutures. The proximal end of the graft was pulled tight inside the femoral tunnel and secured with a 25 mm long bio-absorbable screw of 1 mm smaller in diameter than the tunnel size. In patients with osteoporotic bone, the same tunnel size screw was used instead. With an anterior drawer force of approximately 15 lb applied to the proximal tibia, the distal end of the graft was pulled tight inside the tibial tunnel and transfixed with a 30 mm long bio-absorbable screw of 1 mm smaller diameter or equal size with the knee at 75° of flexion (Fig. 2). The adequate graft fixation was confirmed with direct arthroscopic visualization.

For double-bundle reconstruction, the tibial tunnel was prepared in a similar fashion as the single-bundle technique. The femoral tunnels were located within the PCL footprint on the medial femoral condyle; and were placed 1 cm apart between the

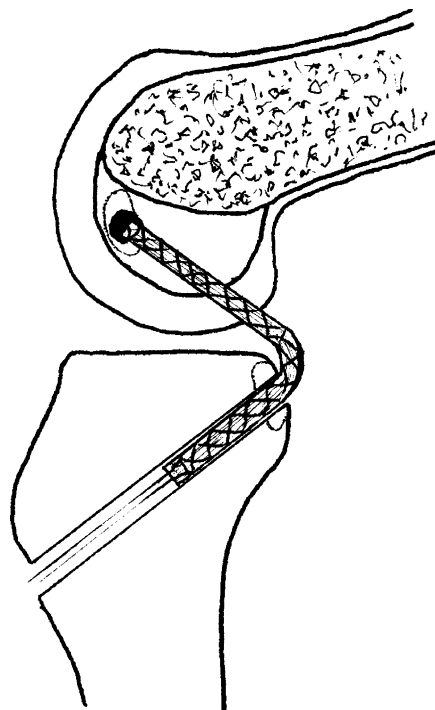


Figure 2 A sketch showing single-bundle PCL reconstruction with hamstring graft.

two tunnels in an anteroposterior fashion. The locations of femoral tunnel so chosen were close to the insertion sites of the anterolateral and posteromedial bundles of the normal PCL respectively. The femoral guides were introduced through the anterolateral portal, and the guide pins were inserted through the guides and exited on the medial aspect of the knee. Femoral tunnels of 25–30 mm deep were created with graft-size matched reamers. The double ends of the graft were delivered through the tibial tunnel into the knee joint and the femoral tunnel with carrying sutures. The distal end of the graft was first secured inside the tibial tunnel at the desirable location with a 30 mm long bio-absorbable screw of 1 mm smaller than the tunnel size. The adequacy of graft fixation was confirmed with direct arthroscopic visualization. With an anterior drawer force of approximately 15 lb applied to the proximal tibia, the larger semitendinosus graft was pulled tight inside the upper tunnel and secured with a bio-absorbable screw of 1 mm undersize or the same size of the tunnel with the knee at 90° of flexion to reconstruct the anterolateral bundle. The smaller gracilis graft was pulled tight inside the lower tunnel and secured with a bio-absorbable screw in similar fashion with the knee at 20° of flexion to reconstruct the posteromedial bundle of the PCL (Fig. 3).

After completion of the PCL reconstruction, the ligament laxity of the posterolateral corner was reassessed. In 30 of 35 knees, mild to moderate

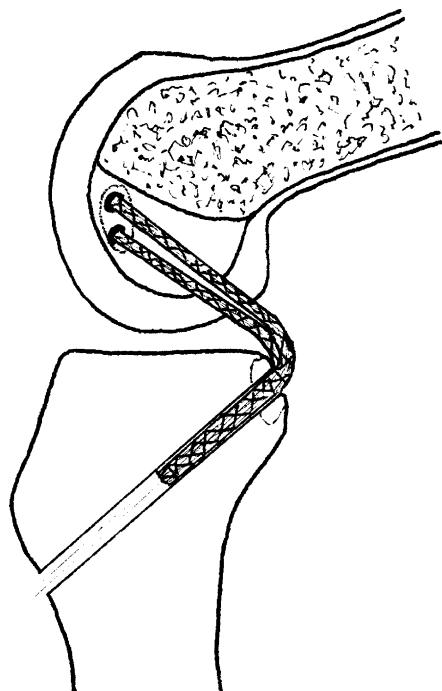


Figure 3 A sketch showing double-bundle PCL reconstruction with hamstring graft.

posterolateral laxity was noted to be clinically evident before surgery, and the laxity was spontaneously corrected after PCL reconstruction with no need for additional reconstruction of the posterolateral corner.

The knee was protected in a functional knee brace postoperatively. The postoperative management included walking with partial weight bearing on the operated leg and physical therapy with partial weight bearing and quadriceps exercises started on the second postoperative day. However, active hamstring exercise was avoided for approximately 6 weeks. Patients were allowed to perform limited range of knee motion out of the knee brace three times during the day. Full weight bearing and full range of motion were allowed after 6 weeks. Patients were prohibited from participation in strenuous activities including contact sports for 6–9 months.

Evaluation parameters

Two junior authors (LHW and CCH) independently performed the evaluations at the latest follow-up examination. The evaluation parameters included functional assessment, ligament laxity, functional knee score, and radiographs of the knee. The functional assessments included pain, giving-way, swelling, locking and squatting pain in the knee. The ligament laxity of the knee was assessed by physical examination and instrumental measurement. Physical examination included posterior sagging sign,

posterior drawer test, reverse Lachman test, varus angulation test and posterolateral drawer test; and the instrumental measurement was performed with the KT-1000 arthrometer (Medmetric Ltd. San Diego, CA). For the purpose of quantifying the ligament laxity, the severity of ligament laxity was graded in millimeters in regard to the amount of tibial displacement on the femur. The functional scores included Lysholm functional score and Tegner activity score,²⁷ IKDC (International Knee Documentation Committee) and single-leg hop test. Radiographs of the knee in standing A-P and lateral, and Merchant's views were examined for the alignment, joint space narrowing and degenerative changes of the knee as well as bone tunnel enlargement. The severity of degenerative changes of the knee was graded according to Ahlback classification.¹ The rate of overall satisfaction with the result of operation was evaluated from patient and surgeon perspectives with scores ranging from 0 to 10 with 0 for unsatisfied and 10 for very satisfied.

The data of single-bundle and double-bundle groups were compared statistically using Mann–Whitney test with statistical significance at $P < 0.05$.

The results

Functional assessments

The results of functional assessment of single- and double-bundle groups are summarized in Table 2. Significant improvements in functional assessment

Table 2 Functional assessments

Operation	Single-bundle (<i>N</i> = 19)	Double-bundle (<i>N</i> = 16)	<i>P</i> -value
Pain (VAS) Range	1.47 ± 1.90 0–5	1.31 ± 1.17 0–3	0.781
Givingway Range	0.89 ± 0.88 0–3	0.56 ± 0.73 0–2	0.243
Swelling Range	0.37 ± 0.68 0–2	0.13 ± 0.34 0–1	0.274
Locking Range	0.37 ± 0.68 0–2	0.19 ± 0.40 0–1	0.361
Squatting pain Range	1.06 ± 0.87 0–3	1.31 ± 1.50 0–4	0.986

Visual analogue scale (VAS) was used to measure the intensity of knee pain ranging from 0 to 10 with 0 for no pain and 10 for severe pain. The severity of symptoms was graded from 0 to 5 with 0 for no symptom and 5 for severe symptom.

Table 3 Functional scores

	Single-bundle (N = 19)	Double-bundle (N = 16)	P-value
Lysholm scores	88 ± 10	89 ± 9	0.529
Range	60–100	71–99	
Tegner scores	4.5 ± 1.7	5.2 ± 1.6	0.237
Range	2–9	3–8	
Single-leg hop test	60 ± 39	72 ± 33	0.605
Range (%)	0–100	10–100	
IKDC			0.288
Normal	4	8	
Nearly normal	7	5	
Abnormal	4	2	
Severe abnormal	4	1	

were noted in both groups postoperatively. Single- and double-bundle PCL reconstructions showed comparable functional results, and no statistically significant difference was noted between the two groups.

Functional scores

The results of functional score including Lysholm score, Tegner score, single-leg hop test and IKDC are summarized in Table 3. Significant improvements in functional scores of the knee were observed in both groups postoperatively, however, no significant difference was noted between the two groups.

Ligament laxity

The results of ligament laxity of single- and double-bundle groups are summarized in Table 4. Significant improvements in ligament laxity were noted postoperatively in both groups, however, no significant

difference in ligament laxity was observed between the two groups. Approximately 25% of the knees in both groups showed mild to moderate posterior ligament laxity (<10 mm).

Radiographic examination

The results of radiographic examination are summarized in Table 5. Single- and double-bundle reconstructions showed comparable results in radiographic examination including the overall alignment, joint space narrowing and degenerative changes of the knee as well as bone tunnel enlargement, and no discernable difference was noted between the two groups. The incidence of degenerative changes of the knee was 32% for single- versus 31% for double-bundle ($P = 0.702$), all cases showed stage I degenerative changes according to Ahlback classification.¹ The average bone tunnel enlargement was 9.5% versus 13.0% for the femoral tunnel ($P = 0.702$), and 14.3% versus 12.8% for the tibia tunnel ($P = 0.903$) for single- and double-bundle, respectively. One case with single-bundle reconstruction showed a 90% tibia tunnel enlargement, however, the ligament laxity was fair and the knee was clinically asymptomatic.

The rate of overall satisfaction with the operation was 7.2 ± 1.6 (range 5–10) for single-bundle versus 8.0 ± 1.2 (range 6–10) for double-bundle from patient's perspective; and 7.9 ± 1.8 (range 3–10) for single-bundle versus 8.1 ± 1.4 (range 5–10) for double-bundle from surgeon's perspective, and the difference was statistically not significant ($P = 0.149, 0.802$).

Complications

The complications included 2 knees with donor site pain and 1 knee with reflex sympathetic dystrophy in the single-bundle group; and 1 acute infection

Table 4 Ligament laxity

	Single-bundle (N = 19)	Double-bundle (N = 16)	P-value
Posterior sagging	0.74 ± 0.73 (0–2)	1.00 ± 0.62 (0–2)	0.237
Posterior drawer test	1.16 ± 0.6 (0–2)	1.13 ± 0.6 (0–2)	0.877
Reverse Lachman test	0.74 ± 0.45 (0–1)	0.82 ± 0.81 (0–2)	0.985
Posterolateral drawer (at 30°)	0.42 ± 0.61 (0–2)	0.60 ± 0.24 (0–1)	0.270
Posterolateral drawer (at 90°)	0.37 ± 0.68 (0–2)	0.12 ± 0.33 (0–1)	0.241
Range of knee motion (°)	126 ± 12 (90–140)	124 ± 14 (80–140)	0.521
KT-1000 arthrometer			
Side to side difference (mm)	2.3 ± 1.4 (1–6)	3.1 ± 3.0 (0–7)	0.681
Maximal displacement (mm)	7.1 ± 3.7 (3–15)	6.7 ± 4.5 (2–16)	0.595

The ligament laxity measured in mm the amount of posterior displacement of the tibia on the femur. The numbers in parenthesis denote the range.

Table 5 Radiographic examination

	Single-bundle	Double-bundle	P-value
Alignment of the knee (°)	3.5 ± 4.0	5.1 ± 2.0	0.521
Range	-3-10	0-8	
Joint space narrowing ^a (%)	0.1 ± 17.8	18.9 ± 14.6	0.098
Range	-25-50	0-40	
Degenerative changes ^b			0.172
Stage 1	6	5	
Stage 2	0	0	
Stage 3	0	0	
Stage 4	0	0	
Bone tunnel enlargement ^c (%)			
Femur tunnel	9.5 ± 15.5	13.2 ± 21.5	0.702
Range	0-55	0-75	
Tibia tunnel	14.3 ± 22	12.8 ± 14.5	0.903
Range	0-90	0-43	

^a Joint space narrowing is shown as the percentage of the value of (medial joint space - lateral joint space)/ the value of the lateral joint space.

^b The degenerative change of the knee is based on Ahlback classification.

^c The bone tunnel enlargement is shown as the percentage of the tunnel width on the postoperative X-rays over that at follow-up.

and 2 knees with donor site pain in the double-bundle group. One knee with acute infection was successfully managed by arthroscopic debridement with retention of the graft and intravenous antibiotic treatment, and the result is good. One knee with reflex sympathetic dystrophy was treated with physical therapy and non-steroidal anti-inflammatory drugs and the result is fair. Four knees with donor site pain were managed successfully with conservative treatments.

Discussion

Unlike the anterior cruciate ligament, surgical reconstruction of the PCL only achieved modest success in the restoration of ligament stability^{3,8,10,16,17,21,26,30,31}. The PCL consists of two functional components, the anterolateral bundle that is taut in flexion, and the posteromedial bundle that is taut in extension. The larger anterolateral bundle has a significantly greater linear stiffness and ultimate load than the posteromedial bundle, and the cross-sectional area increases from tibia to femur.^{14,22-25} In clinical application, the graft is

usually shaped and sized uniformly throughout the entire length. Therefore the tendon graft, regardless of the sources did not reproduce the normal PCL morphology. The impact of mismatched graft morphology, if any, on the outcome of PCL reconstruction is unknown.

Most of the PCL fibres at the attachment site exhibit non-isometric behavior with near isometry demonstrated only by the relatively small posterior fibre attachment site.^{6,9,18} The function of PCL fibres is determined primarily by the femoral attachment,^{6,9,10,14,18} and the femoral attachment site is more sensitive than the tibia attachment site on force displacement.^{2,6,8,9,12,18,20,24} Therefore, in single-bundle PCL reconstruction, the ideal location of the tibial tunnel is within the tibial attachment at the proximal tibia, and that of the femoral tunnel is approximately 4-5 mm distal to the femoral attachment site.^{2,6,9,12,18} Many studies had reported only modest success in the restoration of ligament stability with single-bundle PCL reconstruction.^{3,10,16,30} The results of the current study with the single-bundle technique were comparable with the results of other reported series.

Some authors demonstrated in cadaveric knees that the double-bundle technique is superior to the single-bundle technique in the restoration of PCL stability.¹³ Many studies have reported favourable clinical results of the double-bundle PCL reconstruction using different types of grafts including allograft.^{5,7,19,26} However, recurrent ligament laxity, joint space narrowing and quadriceps atrophy were noted in most cases despite satisfactory functional improvement.³¹ The current study showed comparable results between single- and double-bundle PCL reconstruction, and approximately one quarter of the knees in both groups showed mild to moderate ligament laxity and early degenerative changes.

Thirty of 35 knees showed clinically evident mild to moderate posterolateral laxity prior to PCL reconstruction, and such laxity was spontaneously corrected after single- or double-bundle PCL reconstruction without the need for reconstruction of the posterolateral corner. Other studies reported similar findings.^{19,28} Nyland et al.¹⁹ reported that 18 of 19 patients having posterolateral laxity underwent double-bundle PCL reconstruction without concomitant posterolateral corner reconstruction, and the results were 90% good to excellent. In a cadaveric knee study, section of the PCL was found to produce mild to moderate posterolateral laxity of the knee in addition to the increase in posterior translation of the tibia on the femur.²⁸ In knees with posterolateral corner injury, the magnitude of posterolateral laxity is usually greater, and such laxity

is not corrected by PCL reconstruction alone, and reconstruction of the posterolateral corner is indicated. Therefore, the ligament laxity at the posterolateral corner must be carefully assessed after PCL reconstruction to determine whether posterolateral reconstruction is needed.

Many studies report that PCL injury is associated with an increase in the incidence of degenerative changes of the knee primarily involving the medial, patellofemoral and lateral compartment in that order.^{3,30} The incidence of degenerative changes of the knee in this study was comparable between single- and double-bundle reconstruction.

In conclusion, single-bundle and double-bundle PCL reconstructions showed comparable functional results with high rates of satisfaction with the operation. No significant difference was noted in clinical outcome, ligament laxity and radiographic changes of the knee between the two techniques with medium-term follow-up. The difference between single- and double-bundle PCL reconstruction, if any, can be concluded only with long-term results and a larger patient population.

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