

A new technique in double-bundle anterior cruciate ligament reconstruction using implant-free femoral fixation

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Abstract

Purpose The study is a prospective case-series analysis to demonstrate a new double bundle technique for anterior cruciate ligament (ACL) reconstruction with the use of hamstring tendons through a single tibial tunnel, a double femoral socket with implant-free femoral fixation and interference screw for tibial fixation.

Materials and methods Twenty-one patients were treated with the same technique. Hamstring tendons were not removed from the tibial side, and using a single tibial and a double femoral tunnel of 8 and 6 mm, respectively, anatomic ACL reconstruction was performed. Graft passage was performed from the tibial side to the posterolateral femoral tunnel and was looped back to the anteromedial femoral tunnel to be fixed on the tibial tunnel with an interference screw and additional extracortical fixation. Follow-up of the study group was performed for a two-year period, documenting standard clinical and radiographic parameters.

Results Post-operative follow-up (mean 24 months) revealed radiological widening of tibial tunnel (mean 133.6%) in all patients and minor femoral tunnels widening (119.4% and 117.5%). Clinical evaluation showed no signs of instability, and knee evaluation using the IKDC score was performed.

Conclusion The manuscript describes a novel technique in ACL reconstruction, and reports the radiographic results of

tunnel widening and clinical scores. Implant-free femoral fixation led to minor tunnel widening similar to previously published data. Further studies need to be performed to compare the long-term results with different published techniques of cost-effective implant-free ACL reconstruction.

Introduction

Current literature is inundated by reports of new techniques and complications of anterior cruciate ligament (ACL) reconstruction in the adult population. The most popular graft choices among orthopaedic surgeons involve the use of either the central third of the patellar tendon or the use of hamstring tendons, and the most popular fixation options include interference screws, extracortical fixation and button devices [1–5]. Yet, in terms of morbidity and complications, there is still no consensus regarding the ideal graft or the fixation method [5–7].

One of the most concerning mid-term and long-term complications in ACL reconstruction is bone tunnel widening; the aetiology of which remains unclear, but it is known that biological and biomechanical factors are involved [8–10]. The study of bone tunnel widening with double bands is being increasingly discussed, but there are still just a few studies concerning tunnel widening using three tunnels. Furthermore, the imaging technique that best demonstrates the actual widening, the time that tunnel widening starts or the factors predisposing to it, vary in the literature. Fauno et al. [11], Jansson et al. [12] and Buelow et al. [13] measured bone tunnel widening radiographically, and reported no statistically important difference compared to other imaging examinations. In another retrospective review of bone tunnel widening after ACL reconstruction, Kobayashi et al. mentioned the

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direct measurement of bone tunnels in radiographs (with magnification correction) to be an acceptable method of evaluation [14]. Webster et al. confirmed that bone tunnel widening measurement made only manually with radiographs is acceptable [15]. Otsuka et al. suggested one year as the ideal follow-up period to evaluate tunnel widening in ACL reconstruction [16]. Hantes et al. [17], Vadala et al. [18], Yu et al. [19], and Howell et al. [20] commented that differences in the aggressiveness and duration of a rehabilitation program can affect these results. In addition, Gokce et al. [21] and Siebold et al. [22, 23] indicated that bone tunnel widening was also affected by the tunnel perforation method.

The purpose of this study was to present a new technique for ACL reconstruction with the use of hamstring tendons, that involved a double femoral tunnel with implant-free fixation, a single tibial tunnel with implant fixation with an absorbable interference screw as additional extracortical fixation, and to prospectively evaluate the medium-term results in bone tunnel widening. To validate this procedure, the authors evaluated any potential risk of micromotion with secondary risk of osteolysis and the risk of early pathological rupture at the femoral bone bridge.

Materials and methods

This study was approved by the Lyon Ethics Committee, France. All patients gave their informed consent prior to their inclusion in this study. Between October 2004 and February 2005, 21 patients (15 women and six men; mean age 34 years), underwent ACL reconstruction using the same technique by a single surgeon. All patients were recreational athletes and were clinically and radiographically followed-up at 45 days, six and 24 months. Inclusion criteria for the study were, for the above-mentioned period, all patients with knee instability due to ACL rupture that were to be addressed surgically on an elective basis by the chief-in surgeon. Patients that presented with knee effusion and, especially, restricted range of motion were primarily treated with a four-week rehabilitation and physical therapy regime to return to normal range of knee motion before ACL reconstruction. Further inclusion criteria were the absence of previous or concomitant contralateral ACL injury and the absence of concomitant ligamentous injuries. Knee laxity was diagnosed and confirmed clinically at the time of office examination, radiographically pre-operatively (Telos™ stress radiography) and intra-operatively under sedation with positive Lachman and pivot shift tests. Pre-operatively, knee laxity was clinically determined by the Lachman (values 0: negative; 1: 0–5 mm with end point; 2: 5–10 mm without firm end point; and 3: >10 mm), the anterior drawer (values 0: negative; 1: 0–5 mm with end point; 2: 5–10 mm without firm end point; and 3: >10 mm), and the pivot-shift tests

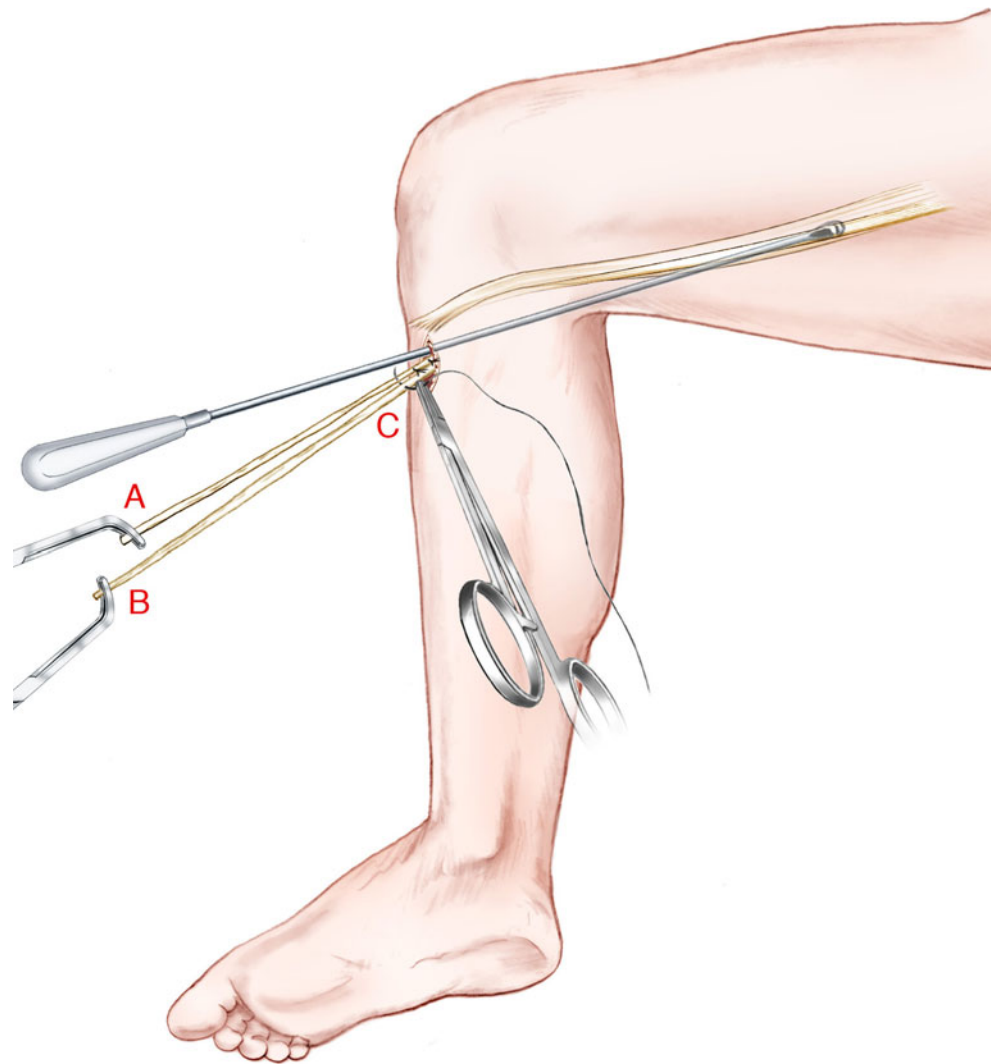
(grades: negative; positive I if only in internal rotation, II if in neutral position and III gross or explosive) and objectively by the Telos™ stress-radiography protocol with the use of 15-kg posterior leg pressure being applied on the affected leg and compared to the contralateral side in 10° of knee flexion and measured in millimeters.

Surgical technique

The technique involved harvesting an average of 25-cm length of hamstring tendons (Fig. 1). After standard muscle remnants cleaning, the tendons were sutured together longitudinally by absorbable sutures, leaving their distal part attached to the tibia. Their proximal end was separately secured with pull-through sutures. Following standard arthroscopical preparation of the femur and tibia, and after addressing concomitant pathology (e.g. meniscal ruptures), tunnel drilling was performed. Double femoral tunnels included drilling with an outside-in technique of one antero-medial (AM) and one posterolateral (PL) tunnel using the anatomical landmarks of the ACL stumps. The two tunnels were 6 mm in diameter, with a divergence of 6 mm being observed via arthroscopy (Fig. 2). A single 8-mm tibial tunnel was then drilled and positioned over the native ACL “footprint”. Lateral femoral condyle notchplasty was systematically performed, to avoid impingement between the graft and the superolateral wall, and to enable a better view of the posterior wall. With the use of a threaded pin, the graft was passed through the tibial tunnel and into the PL tunnel with in an inside-out direction, temporarily secured with a Kocher clamp and cycled ten times. After being pulled out of the skin, the graft was passed subcutaneously as closely as possible to the bone, using curved Kelly or mixer nippers, to exit via the AM tunnel skin incision. With the same threaded pin the graft was then passed through the AM back to the tibia in an outside-in direction. The graft was temporarily secured and the knee was then “cycled” for one minute. While arthroscopically viewing the knee in extension, the tibia was forced posteriorly, and the graft was fastened with traction threads. A bioabsorbable interference screw (Ligafix® 60 SBM 9 mm/25 mm) was screwed up to the subchondral tibial plateau, to limit graft mobility and prevent synovial fluid running into the tunnel. Additional extracortical fixation was performed on the tibial side, either into cortical bone, or on the periosteum, using a strong curved needle. The procedure resulted in the reconstruction of a four-strand graft comprised of two double bundles through three tunnels.

All patients were clinically assessed and radiographically examined post-operatively at 45 days, six and 24 months. Clinical tests for knee laxity included Lachman, anterior drawer and pivot-shift tests. Radiographic analysis included the monopodal anteroposterior view (AP), a monopodal lateral view (L), and Telos™ stress-radiography with a 15-kg

Fig. 1 Semi-tendinosus and gracilis tendons were harvested. The tendon's distal part was left attached at their tibial insertion



posterior weight as previously described. Postoperative patient evaluation included the objective International Knee Documentation Committee (IKDC) score.

Postoperative rehabilitation followed standard protocols and included 0–120° range of motion exercises for the first three weeks, without the use of a brace, walking with the use of crutches for three weeks with partial weight-bearing, quadriceps and hamstring stretching and strengthening and gradual return to running at three months and return to sports after six months postoperatively.

Radiological evaluation

The radiological evaluation included the following measurements: tunnel diameter in both AP and L views (Fig. 3); Telos™ stress-radiography (Fig. 4); tunnel ossification (if cortical bone formation was seen on both sides of the tunnels on both the AP and the L radiographs, the tunnel was considered to be ossified); and screw absorption (Fig. 4). These evaluations took into account the radiograph

magnification, and mean values of tunnel widening were calculated (Figs. 3, 4 and 5).

Results

Twenty-one patients (mean age 34 years; range 21–50 years) were included in the study. Mean follow-up was 24 months (21–27 months). Intra-operatively, all 21 cases had ACL rupture confirmed during arthroscopy, eight underwent partial meniscectomy and four had all-inside meniscal suturing for addressing relevant pathology, but all followed the same rehabilitation protocol. There were no major complications observed in the study population.

Clinical evaluation

Two patients tested positively for both the Lachman (grade 2) and anterior drawer tests (grade 1 and 2, respectively) during final re-evaluation (24 months) but no early graft

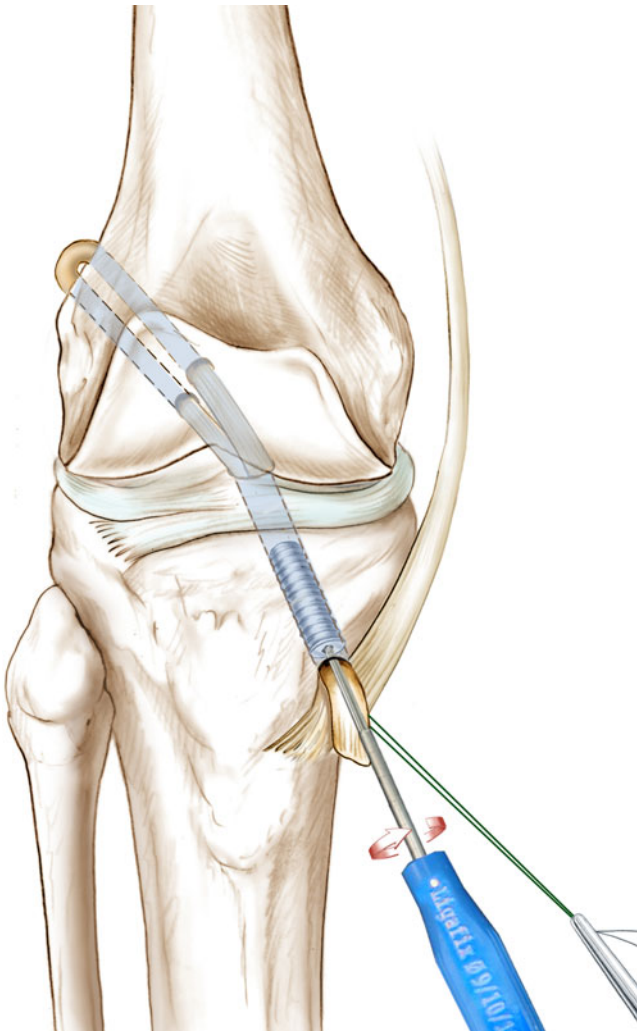


Fig. 2 Tunnel formation. After the tibial tunnel (8-mm diameter) and the two femoral tunnels (6-mm diameter) were drilled, the graft was looped on the femur, and double fixed using an interference screw and extracortical suture on the periosteum

failure occurred and patients reported no symptoms of instability. Nineteen patients had negative clinical examinations (Lachman, pivot-shift and anterior drawer tests) for knee laxity. IKDC score was 85.0 (SD±10.5) for the whole study population.

Radiological results

AM tunnel diameter averaged 7.3 mm (range 6–9 mm) in the immediate postoperative period (45 days); this increased to an average of 8.7 mm (range 7–10 mm) at final evaluation (24 months). PL tunnel widening was from a mean of 7.0 mm (range 6–8.5 mm) in the immediate postoperative period to 8.3 mm (range 7–10 mm) at final evaluation. The tibial tunnel widened from an average of 9.6 mm (range 8–13 mm) in the immediate postoperative period to 12.8 mm (range 10–17 mm) at last follow-up (Table 1). Mean AM

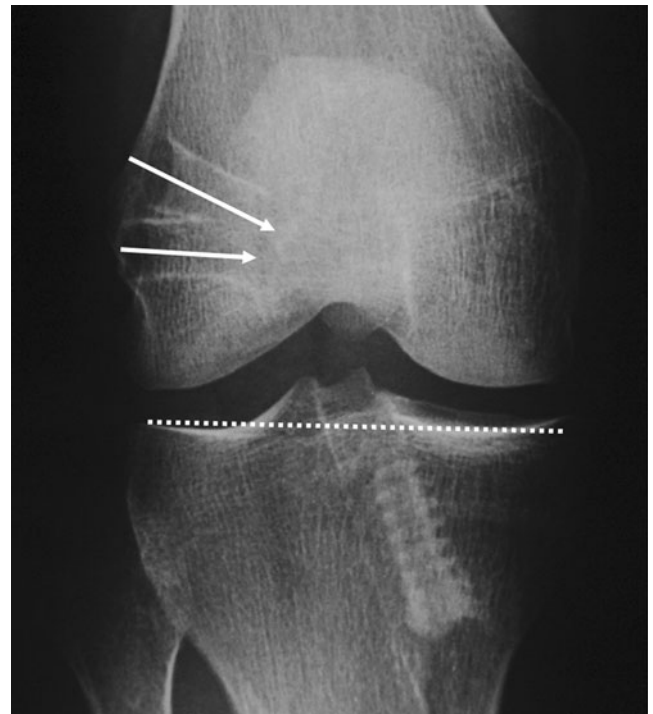


Fig. 3 Measurement of the width of the tibial and femoral tunnels and record of the cortical bone formation in the tunnels as well as the resorption of the interference screw

widening was 119.4%, mean PL widening was 117.5% and mean tibial tunnel widening was 133.6%. The Telos™ value



Fig. 4 Telos™ radiographs were used to measure anteroposterior tibial translation

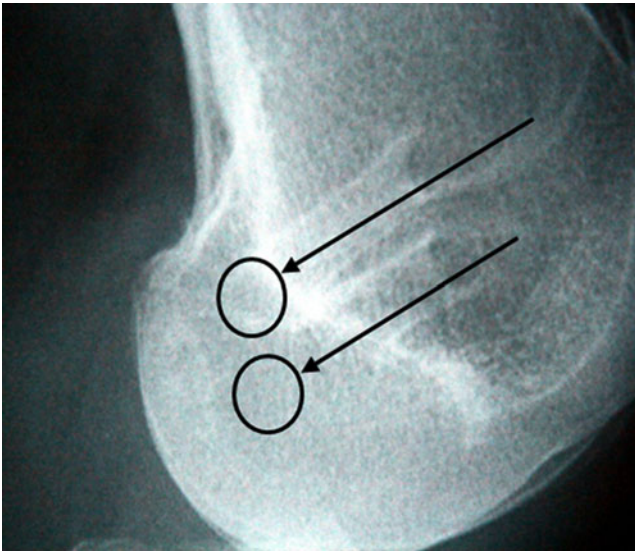


Fig. 5 On lateral radiographs, cortical bone formation was recorded in 80% of the anteromedial (AM) and posterolateral (PL) femoral tunnels

showed a mean of 11.5 mm of anterior tibial translation preoperatively (range 3–20 mm), which decreased to a mean of 7.0 mm (range 0–13 mm) at final follow-up. Although the patient sample was small to exclude safer results, a statistically significant relationship between tunnel diameter and Telos™ anterior tibial translation was not recorded. Cortical bone formation was observed in 80% of tunnels after at least 6 months (81% of tibial tunnels, 85% of AM tunnels, and 72% of PL tunnels). All absorbable screws in the tibial tunnel were still visible on radiographs six months postoperatively, and in 11 cases they were no more visible at 24-month evaluation.

Discussion

Anterior cruciate reconstruction is an emerging field in the literature, especially in terms of anatomically reconstructing the original ACL and reducing the implanted hardware. The

present manuscript intends to describe a new technique and to document standard and common follow-up parameters of clinical laxity, knee instability and tunnel widening for future reference.

Bone tunnel widening is a well-known report following ACL reconstruction and although its etiology is not clear, it has been attributed to both mechanical and biological factors [12, 24]. Although long-term follow-up study results are not yet available, it has been concluded that bone tunnel widening does not correlate with clinical stability [9, 12]. Some authors do not make it clear when the widening process begins, and strong correlating factors between widening and graft choice or fixation methods have not been well-defined [23]. In the present study, the authors observed that in the immediate postoperative period (45 days), tunnel widening had already begun to take place, especially in the tibial side. This finding has also been supported by Kobayashi et al. [14] and Ugutmen et al. [25], who reported a significantly greater tunnel widening in the first six months of follow-up. After this period, a progressive decrease in tunnel widening was noticed. In cases of double bundle ACL reconstruction using more than two tunnels, tunnel widening could be expected to be greater than when reconstruction involves a single band. In addition, breaking of the bone bridge between the tunnels could occur. However, there are insufficient numbers of comparative studies published to enable conclusions to be drawn. Furthermore, it is very difficult to evaluate the widening correlated with anatomic ACL reconstruction and optimal tunnel placement [23]. Additionally, incorrect tunnel placement is a well-established parameter for ACL graft failures [26]. An accepted reason for the occurrence of bone tunnel widening when using hamstring grafts is the point of fixation [23]. This positioning, nearer or more distant to the articulation, allows for a wider or narrower movement inside the tunnel, creating a “windshield wiper” effect [17, 27]. There is much controversy in the literature concerning the correlation between the point of fixation and the tunnel widening. Some authors have recorded that the nearer the fixation to the joint, the narrower is the widening [14, 23, 28]. On the other hand,

Table 1 Radiographic follow-up data (Telos™ stress-radiography and tunnel diameter from X-ray views) for the study population for the whole study period

Parameter	Telos results—anterior tibial translation (mm)	Mean AM tunnel diameter (mm)	Mean PL tunnel diameter (mm)	Mean tibial tunnel diameter (mm)
Preoperatively	11.5 (3.0–20.0)	Not applicable	Not applicable	Not applicable
45 days postoperative	Not performed	7.3 (6.0–9.0)	7.0 (6.0–8.5)	9.6 (8.0–13.0)
6 months postoperatively	6.8 (0–12.0)	8.2 (6.5–9.5)	8.0 (6.4–8.7)	11.9 (9.2–14.5)
24 months postoperatively	7.0 (0–13.0)	8.7 (7.0–10.0)	8.3 (7.0–10.0)	12.8 (10.0–17.0)

AM anteromedial, PL posterolateral

Buelow et al. stated that bone tunnel widening is greater with the use of the interference screw as opposed to extracortical fixation up to three months postoperatively [13], and according to Peyrache et al., widening is irrelevant after this period [24].

In the above-mentioned method the absence of femoral implant-fixation could lead to increased tunnel widening, but the greater tunnel widening was observed in the tibial side, where implant fixation was used *bimodally* and where the pull-out forces were the most important. This demonstrated that in the current technique, the interference screw has to be screwed up to the tibial plateau to prevent any “bungee effect” and further tunnel widening, as well as the addition of extracortical fixation, is advisable. The absence of pathological femoral widening could be explained by the loop formation of the graft with four 90° angles on the femoral side and the tangential pull-out force. This loop did not lead to early rupture at the femoral side and no “killer turn” effect was noticed. Bone tunnel widening will continue to be questioned and studied, since long-term results are not available in the literature and this is further complicated by the implementation of different surgical techniques in ACL reconstruction.

Currently, ACL reconstruction with three or four tunnels is becoming popular among knee surgeons. This double-band technique of ACL reconstruction in the adult knee with the use of three tunnels and a single implant tibial fixation is comparable to the double-band quadriceps tendon grafting technique described by Sonnery-Cottet and Chambat in 2006, which uses a different flexion position for each band in the femur [29]. Weaknesses of the study are the measurement techniques on standard radiographs that can be observer-dependent and a source of error; therefore, a CT scan protocol is now applied by the authors and for future studies such a modality is advised. The small number of the patients treated to exclude safe results and the absence of a control group are further study limitations.

Conclusion

The described technique is a new method of creating a double-bundle anatomic ACL construct through one tibial tunnel and two femoral tunnels, with the use of a single implant fixation on the tibial side. Separate bundle pre-tension and additional tibial extracortical fixation were always performed. Although femoral fixation was without the use of implants, excessive femoral tunnel widening was consistently not observed. Tibial tunnel widening was similar to previously published data and did not seem to affect the clinical results during the follow-up period. Tunnel diameters remained stable after a period of six months to two years, and the lack of implant fixation on the femoral side did not lead to

greater widening. The use of this technique appears both efficient and cost-effective.

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Conflict of interest The senior surgeon (DD) had a conflict of interest with SBM company (royalties), manufacturer of the used bioabsorbable screw. The rest of the authors declare that they have no conflicts of interest.

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