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Arthroscopic intra- and extra-articular anterior cruciate ligament reconstruction with gracilis and semitendinosus tendons

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Abstract Numerous surgical procedures have been developed and used for anterior cruciate ligament (ACL) reconstruction. Patellar tendon is probably the most common graft used, but gracilis and semitendinous tendons present some interesting advantages: small incision, large graft when doubled, characteristics close to ACL, rapid harvest. We describe a combined intra- and extra-articular arthroscopic ACL reconstruction using hamstring tendons which includes some original steps. The tendons are harvested, leaving the distal insertion intact, and sutured together. After drilling of the tibial tunnel, an over-the-top arrangement is formed, creating a groove in the posterolateral aspect of the femur. The tendons are then fixed with double staples in the groove, and their remaining part is fixed distally to Gerdy's tubercle passing under the fascia, but over the lateral collateral ligament (LCL). This technique ensures sufficient strength in the graft and permits correction of any associated instability, because of the presence of the extra-articular portion of the tendons. Furthermore, the over-the-top arrangement reduces trauma and possible pitfalls related to tunnel construction and permits isometry of the extra-articular portion to be established. Forty patients involved in sports activity were prospectively selected and evaluated at a minimum 2 years' follow-up. IKDC score and Lysholm score were used for clinical evaluation, and the KT-2000 was used for instrumental laxity measurements. Resumption of sport and time to that point were recorded as well as Tegner activity score. We had 92.5% normal and fairly normal knees according to IKDC score and only 7.5% abnormal knees. Mean Lysholm score was 95. Mean Tegner score was 7.2. KT-2000 showed a mean injured/uninjured difference of 2.1 mm. In all, 90% of patients resumed sports at the same level, 67.5% in 3–4 months and 27.5% in 4–6 months. The highly satisfactory results of this series with no major complications confirm the reliability of this techinque and the possibility of guaranteeing functional behaviour in the knee.

Key words Arthroscopy · Anterior cruciate ligament reconstruction · Hamstrings · Extra-articular reconstruction

Introduction

Numerous surgical procedures have been described for the correction of anterior cruciate ligament (ACL) insufficiency. They differ in terms of the graft used, surgical steps, open or arthroscopically assisted, and intra- or extra-articular reconstruction. For many years the central third of the patellar tendon has been the most common type of graft used. The numerous clinical reports [8, 10, 30, 38] citing excellent short- and long-term results and the possibility of a single incision and of strong bony fixation explain this success.

On the other hand, in the past few years some studies [14, 18, 35] have pointed out that a patellar tendon graft can cause an increased incidence of knee stiffness, pain and quadriceps weakness. Furthermore, the harvesting time may be longer than with other grafts, and carries the risk of patella fracture and damage of the extensor apparatus [4, 23].

The use of the hamstrings presents some interesting advantages: small incisions, large graft when gracilis and semitendinosus tendons are sutured together, very similar biomechanical characteristics to ACL, rapid harvest. For these reasons the use of these tendons for ACL reconstruction has been recently advocated. Pes anserinus tendons have been used in many different ways. Lindemann [19] and Puddu [32] have employed gracilis or semitendinosus, respectively, as a "dynamic" ACL intra-articular reconstruction. Cho [7], Macey [21], McMaster et al. [25], Mott [28] and Zaricznyj [45, 46] have used these grafts with double-tunnel or over-the-top techniques, with single or double loops and with different fixation methods. Zarins and Rowe [47] have used the semitendinosus tendon with the iliotibial tract to perform a combined intra-articular and extra-articular reconstruction.

The semitendinosus tendon has also been used completely detached as a triple or quadruple loop in the Rosenberg technique [34] to obtain a strength similar or even superior to the patellar tendon and with less morbidity. Recently, Morgan [27] has described a bone-hamstring-bone graft to achieve an anatomic graft fixation with an endosteal interference screw with the advantages of limited surgical exposure and low harvest site morbidity.

Each of these techniques utilizing hamstring tendons presents potential advantages and disadvantages, and the increased knowledge of the anatomy, physiology and biomechanics of the knee and of the ACL in particular has certainly played an important role in the choice of graft and operative technique used.

The purpose of this article is to describe a combined intra- and extra-articular arthroscopic reconstruction of the ACL using gracilis and semitendinosus tendons which we have developed and utilized since 1992 and evaluate the results of the first 40 patients with a minimum 2-year follow-up.

Patients and methods

Surgical technique

The patient is placed in the supine position on the operating table. A pneumatic tourniquet is placed as high as possible around the proximal part of the thigh. A support is placed laterally at the upper level of the knee to stress the joint during arthroscopic evaluation.

After preparation and draping of the leg, the arthroscopic portals are made. We normally use a superomedial portal for the inflow cannula, an anterolateral portal for the camera and a anteromedial portal for instruments.

Under arthroscopic control meniscectomies or chondroplasty are performed where necessary, and the tibial insertion area of the ruptured ACL and the intercondylar notch are prepared. When the reconstruction is performed acutely, the ruptured ACL stump is removed while trying to preserve a maximum amount of the remaining ACL. In chronic reconstruction the residual stump is removed completely. In both cases, it is important to remove carefully all the soft tissues in the posterior part of the roof to find the over-the-top position easily. Usually, no bony notchplasty is performed. Only in chronic cases when a large osteophyte of the medial edge of the lateral condyle is present do we remove the bone that narrows the intercondylar notch to avoid a possible impingement on the implanted graft.

The semitendinosus and gracilis tendons are then harvested. A figure-of-four position is used, and the pes anserinus is found by following the hamstrings tendons distally to their attachment to the anteromedial tibia at a point 2 cm distal and 1 cm medial to the tibial tubercle.

A 3–4 cm oblique or curved incision in the anteromedial aspect of the tibia over the pes anserinus is made once it has been localized. After dissecting the subcutaneous tissue, a fascial incision is made parallel to the orientation of the pes tendons. Care is taken to avoid the infrapatellar branches of the saphenous nerve. The tendon of sartorius is retracted superiorly, and the gracilis and semitendinosus tendons are bluntly freed from the surrounding soft tissue. A dissection scissor is used to isolate the tendons completely from fascial attachments to allow their complete mobilization and permit an easy placement of the tendon stripper. The superficial medial collateral ligament (MCL) lies immediately deep to the expansion of pes anserinus and should not be mistaken for it.

The tendons are then stripped separately with a blunt tendon stripper (Acufex, Microsugical, Inc. Mansfield, USA) while maintaining firm tension on the tendon distally and with the knee in more than 90 deg flexion to facilitate the detachment of the tendon. Extreme caution is necessary to try to obtain the maximum length of the tendons. Approximately 20 cm of the semitendinosus is available and usually less than that of the gracilis tendon, both being left attached distally. Distally, the attachment of the semitendinosus to the adjacent gracilis tendon is then dissected free, thus gaining 1 or 2 cm more in length. The insertion of the semitendinosus tendon into the tibia must not be disturbed nor should the gracilis tibial insertion.

The harvested tendons are sutured together using non-absorbable Flexidene no. 2 stitches (Lab. Bruneau Boulogne Billancourt, France). The sutures are tightened, especially at the free proximal tendon ends, and looped around the edges of the tendon to obtain sufficient strength for traction and to allow easy passage of the tendons through the tibial drill hole. For preparation of the tibial tunnel, it is advisable to clear an area medially and slight superior to the origin of the tendons of soft tissue with electrocautery taking care not to violate the superficial MCL or pes anserinus.

Preparation of the tibial tunnel is performed under arthroscopic visualization by drilling a 8–9 mm diameter tibial tunnel after positioning of a guide pin. The correct placement of the guide pin is verified arthroscopically, trying to position the tibial tunnel in the medio-posterior part of the ACL tibial insertion (Fig. 1).

The reaming debris of the tibial tunnel is removed with a curette, and the sharp edges of the osseous tunnel are smoothed using a shaver. Champfering of the tunnel apertures may be performed either through the osseous tunnel or through the arthroscopic portals.

A wireloop passer that will be used for graft passage is directed from the tibial tunnel into the notch and under arthroscopic visualization is brought out from the anteromedial portal.

The knee is positioned on the operating table at 90 deg flexion, and the foot is externally rotated, with the popliteal fossa free of pressure.

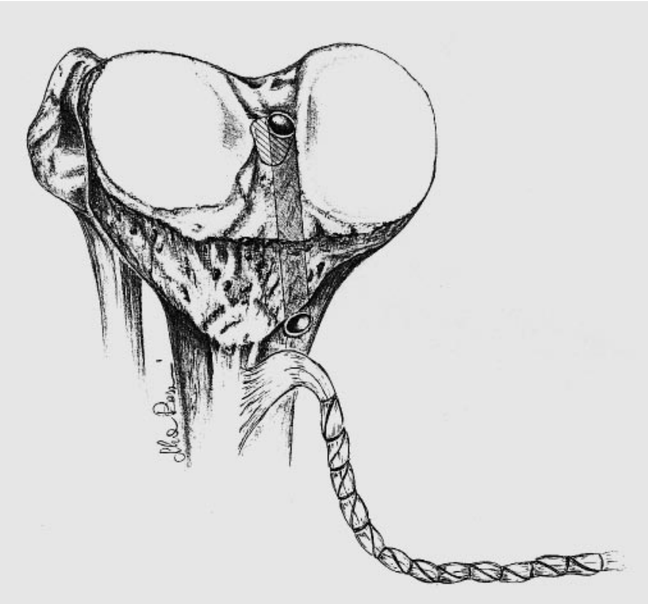


Fig. 1 After the tendons have been harvested and prepared, the tibial tunnel is drilled, trying to reproduce the posteromedial part of anterior cruciate ligament (ACL) tibial insertion. This guarantees reproduction of the more functional part of the ACL, avoiding impingement and extension deficit

A 3–5 cm longitudinal incision is then made superolaterally, just proximal to the lateral femoral epicondyle. The ileotibial band is divided sharply in its posterior third and retracted anteriorly. With electrocautery and scissors the lateral aspect of the thigh is dissected to reach the lateral intermuscular septum which inserts into the lateral femoral condyle and separates the vastus lateralis muscle (above) from the lateral head of the gastrocnemius muscle (below).

Once the lateral intermuscular septum has been clearly identified, it is possible to reach the posterior aspect of the joint capsule by passing over this structure. If is not possible to reach the posterior capsule, the septum can be divided.

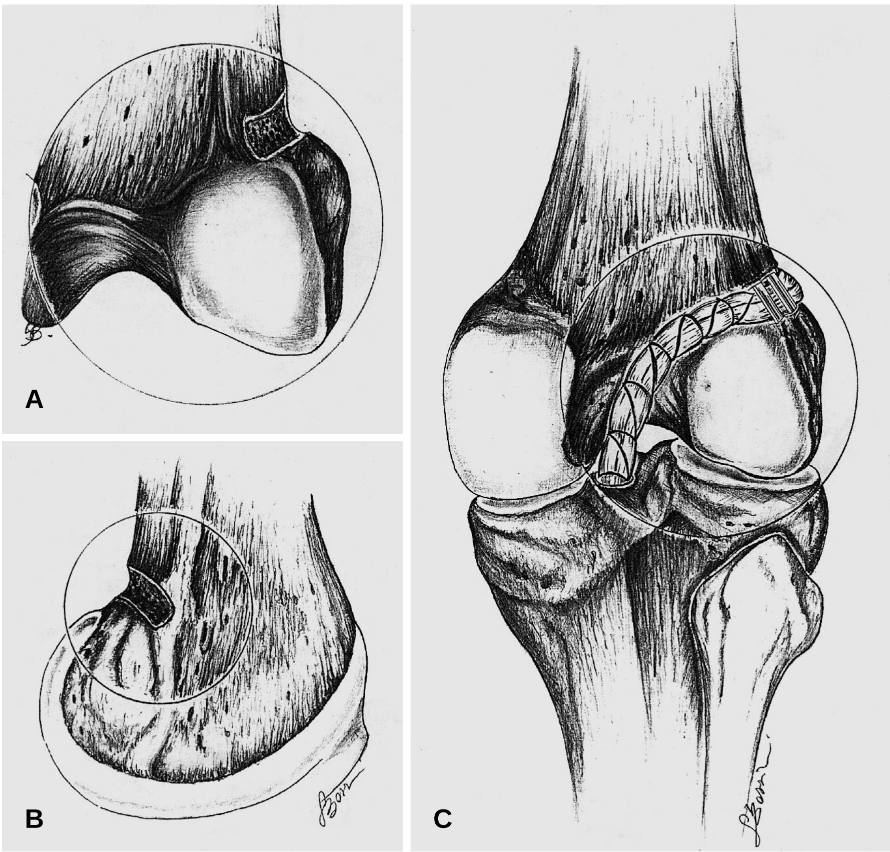
The correct placement of the over-the-top position is found by palpating the posterior tubercle of the lateral femoral condyle with a finger. This manoeuvre also leads to protection of the noble posterior structures during the next step.

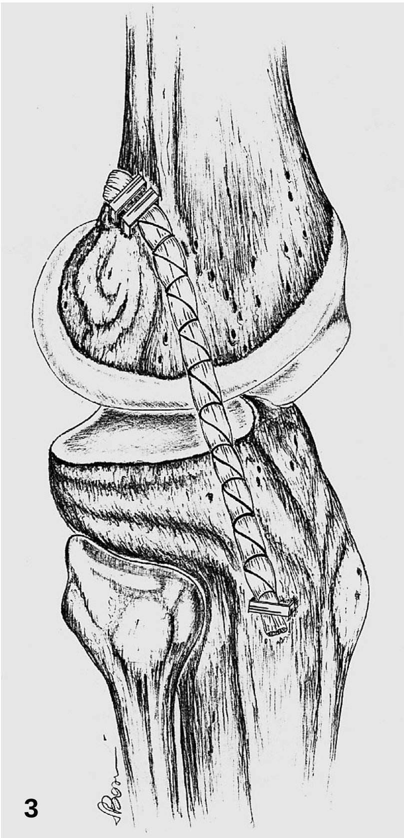
A curved Kelly clamp is passed from the anteromedial portal into the notch, and its tip is placed against the posterior part of the capsule as far proximal as possible. Once the tip of the clamp can be palpated from the lateral side of the femur, just posterior to the intermuscular septum, it is pushed through the thin posterior layer of the knee capsule to reach the posterior space previously prepared.

A suture loop is placed into the tip of the clamp, which is then pulled anteriorly through the anteromedial portal and put into the wire loop previously inserted in the portal. Pulling the wire loop from the tibial side, the suture enters the tibial tunnel and exits from the tibial incision, ready to pull the harvested graft.

The stitches on the free end of the semitendinosus and gracilis tendon grafts are tied onto the passing suture that is pulled through the knee joint.

Fig. 2 Illustration of the groove in the lateral aspect of the femur posteriorly (**A**) and laterally (**B**). This permits a slight anteriorization of the graft for a more isometric position. The graft is fixed with two staples in the groove (**C**)





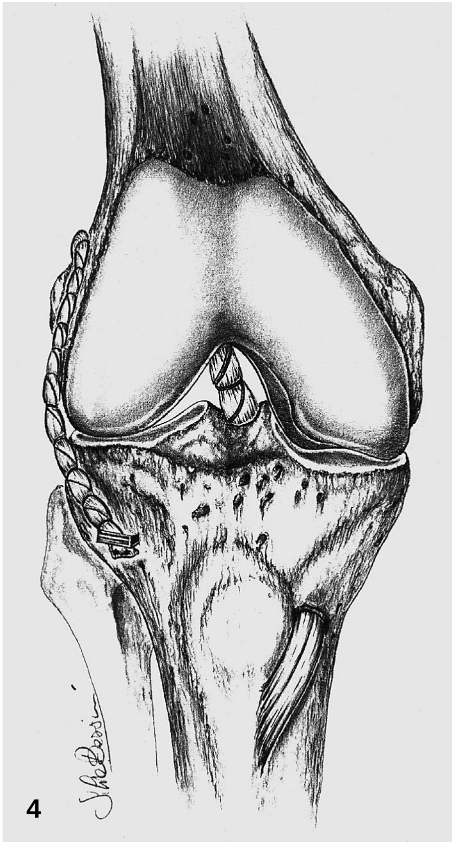


Fig. 3 The extra-articular portion of the graft is fixed with a staple to Gerdy's tubercle, ensuring isometry both in flexion and in extension

Fig. 4 Anteroposterior view of the combined reconstruction at the end of the procedure

When the graft is retrieved from the lateral incision, a groove is made in the lateral aspect of the femur just proximal to the start of the lateral condyle. In this way a more isometric position can be achieved due to the anteriorization of the grafts (Fig. 2). Once the position is satisfactory, the graft is tensioned, and the knee is cycled through a full range of motion about 20 times to check its stability. After this, the graft is tensioned with the knee at about 90 deg and the foot externally rotated, and two Richards barbed staples (Smith & Nephews, Richards Inc., Memphis, USA) are used to secure the combined gracilis and semitendinosus tendons to the lateral femoral cortex into the groove. The staples should not be driven deeply into the bone so as not to cut through the graft. The remaining part of the combined graft is then put under tension to check whether or not it is long enough to reach Gerdy's tubercle in the anterolateral aspect of the tibia.

Whenever possible, a 1–2 cm skin incision just below Gerdy's tubercle is performed as well as on the anterolateral fascia. Then a small Kelly clamp is passed below the fascia from this incision to the lateral femoral condyle where the graft is already fixed. The sutures at the end of the graft are placed in the tip of a small Kelly clamp and pulled down, emerging from the Gerdy's tubercle incision. The graft is tensioned and the knee cycled again to check the isometry of the lateral plasty and the freedom of flexion-extension.

The graft is finally fixed below Gerdy's tubercle to the lateral aspect of the tibia with barbed staples. This creates an intra-articular as well as an extra-articular reconstruction for anterior instability (Figs. 3 and 4). An intra-articular drain is threaded through the superomedial cannula, and additional drains are inserted in each wound. The iliotibial tract defect is closed, taking care to prevent lateral tilt and patellar compression. The medial fascia over the pes anserinus is not closed, however, to avoid compartmental syndrome.

Follow-up evaluation

All young patients practising sports at a high level with a positive Lachman test and pivot shift test were prospectively selected for our ACL reconstruction. These 40 patients were evaluated at a minimum of 2 years' follow-up (average follow-up 36 months). The male/female ratio was 33/7 and the ages at operation ranged from 18 to 40 years (average 25 years). Sixteen of the 40 knees underwent acute ACL reconstruction. In the remaining 24 knees, the original injury had occurred from 2 to 121 months (average 22.5 months) before the arthroscopic reconstruction was performed. No patient had previously undergone any knee operation.

Treatment for the associated injuries included partial meniscectomy and debridement of an osteochondral defect. MCL tears were never repaired.

The rehabilitation protocol allowed partial weight-bearing with no brace from the 1st week. Weight-bearing was increased to full by the 3rd week. Complete return to sports, including cutting sports, was allowed usually at 3–4 months.

Lysholm's rating scale [20] and the International Knee Documentation Committee (IKDC) [11] were used for evaluation. Anterior tibial translation was also measured instrumentally with the KT-2000 knee arthrometer (Med metric Corp., San Diego, USA). The functional knee capacity was tested by resumption of sport, time to that point and Tegner activity score [42].

Statistical analysis

Linear regression analysis and correlation coefficient were used to evaluate whether or not accelerated rehabilitation could influence knee stability and the Tegner activity score.

One way analysis of variance (Anova) was used to compare mean values between groups along with the Kruskal-Wallis test. The minimum value of significance was $P = 0.05$.

Results

IKDC and Lysholm scores demonstrated highly satisfactory results, with 92.5% normal or nearly normal knees and a mean value for the Lysholm score of 95 points (Tables 1 and 2). The range of motion was full in 38 patients (95%). A flexion deficit of between 6 and 15 deg was present in only 2 patients (5%), and no flexion contracture was found. Patellofemoral crepitus was never observed and anterior knee pain, related to extensor apparatus problems, was present in only 2 patients (5%).

The KT-2000 evaluation showed in the three tests performed a 93.3% of value between 0 and 5 mm (Table 3) with an average injured/uninjured difference of 2.1 mm (range 0–8 mm).

Regarding functional knee capacity, all patients were able to resume sports, 36 (90%) at the same level and 4 (10%) at a lower level. The time to resume high-risk sports was 3–4 months for 27 patients (67.5%), between 4 and 6 months for 11 (27.5%) and between 6 and 12 months for the remaining 2 (5%). The mean Tegner activity score was 7.2 (range 4–10). Statistical analysis demonstrated that aggressive rehabilitation with resumption of sport at 3–4 months did not significantly affect the objective knee stability and IKDC score. Moreover, patients who resumed sports earlier had a significantly increased Tegner score ($P = 0.05$), significantly less anterior knee pain ($P = 0.0008$) and lower flexion deficit ($P = 0.04$).

Table 1 Lysholm Score results

Rating	Score	No. of patients
Excellent	91–100	34 (85%)
Good	84– 90	4 (10%)
Fair	65– 83	2 (5%)
Poor	0– 64	None

Table 2 IKDC Score results

Rating	No. of patients
Normal (A)	16 (40%)
Fairly normal (B)	21 (52.5%)
Abnormal (C)	3 (7.5%)
Severe abnormal (D)	None

Table 3 KT-2000 Score results

Rating	Manual	Lachman	Quadriceps active test
< 3 mm	22 (55%)	30 (75%)	24 (60%)
3–5	15 (37.5%)	8 (20%)	13 (32.5%)
> 5 mm	3 (7.5%)	2 (5%)	3 (7.5%)

Discussion

The rationale for using our combined gracilis and semitendinosus technique was: (1) to combine intra- and extra-articular procedures, (2) to use double tendon for both procedures to increase the tensile strength of the reconstruction, (3) to develop an easy procedure which reproduces the more functionally important part of the ACL, (4) to allow faster rehabilitation of the graft, leaving a blood and nerve supply distally, (5) to avoid the anterior knee pain and increased risk of stiff knee frequently observed with the bone-patellar tendon technique, and finally (6) to ensure a good soft-tissue fixation of the graft which allows an accelerated rehabilitation program with resumption of sport after 3–4 months.

The combination of an intra- and extra-articular reconstruction has the theoretical advantages of repairing the primary lesion and at the same time strengthening lateral tissues in a line parallel to the intra-articular route of the ACL. Furthermore, lateral reconstruction has the theoretical mechanical advantage over an intra-articular procedure of preventing anterior subluxation of the lateral tibial plateau by being located further from the centre of rotation, resulting in an increased rotational moment arm [6]. Thus, because of the interplay between anterior and posterior forces as well as rotatory components, we believe combined intra- and extra-articular repair is a valid combination to control anterior instability.

Regarding the strength of the reconstruction, studies by Kennedy et al. [15] and Noyes et al. [29] using different techniques demonstrated that the semitendinosus fails at between 70% and 75% of the normal ACL strength, and the gracilis tendon fails at between 50% and 70% of the normal ACL. A combination of these two tendons should, therefore, meet the strength requirement for a replacement. Moreover, as suggested by Woo et al. [43], factors other than strength, such as biomechanical characteristics, that would ideally match those of the ACL may be of greater importance. A stronger but stiffer graft such as the patellar tendon does not match the normal ACL in compliance and may be a cause of failure. Gracilis and semitendinosus tendons present higher tensile properties (104 and 113 MPa, respectively) with respect to the patellar tendon (79 MPa) and close to the normal ACL value, as demonstrated by McKernan et al. [24].

The association of the extra-articular portion transformed our graft into a quadrupled (two intra and two extra) hamstring, ensuring a higher ultimate failure with respect to the patellar tendon. Friedman [9], in fact, has obtained a peak load for quadrupled hamstring of 1159 N vs 1082 N for 10 mm wide patellar tendon.

The position of our tibial tunnel is determined by trying to reproduce the major functional bands of the ACL. Takai et al. [41] demonstrated that the posterior part of the anteromedial portion of the ACL carries 75% of the in situ force developed in the ligament, and Sapega et al. [36] has found that the anteromedial portion shows the least strain or length changes. Therefore, the posterior position of our tunnel attempts to reproduce this functionally important portion. Moreover, utilizing an over-the-top technique is fundamental to constructing a tibial tunnel slightly posterior to avoid any impingment problem as suggested by Yaru et al. [44].

We prefer the over-the-top method because it locates the graft close to the anatomical origin of the ACL, is easy to position, and allows the graft to pass over a round, smooth surface compared with the sharp edge of a femoral drill hole. Moreover, with this method the graft becomes tight in extension, which is the position where instability is usually manifested, allowing the achievement of functional stability.

Melhorn and Henning [26] and Penner et al. [31] have shown that creating a groove in the lateral femoral condyle at the junction with the roof (11 or 1 o'clock position) led to a modified over-the-top position with approximation to an isometric placement. We normally create a groove that places the graft anteriorly to improve its isometry. This effect can be obtained not only if the groove is made in the posterior part of the lateral condyle, which is already smooth, but also by making the groove just at the beginning of the lateral cortex posterior to the edge of the lateral condyle. At the same time, after fixation of the graft with double staples on the groove performed at this level, we reach the ideal proximal insertion of the extra-articular portion. This band is isometric when passed over the lateral collateral ligament, to avoid any conflict problem, and is fixed to Gerdy's tubercle as demonstrated by Krackow and Brooks [16].

The composition of the graft with the tendons sutured together and fixed by staples allows during the first postoperative period automatic achievement of the correct tension with a spontaneous balance between the intra- and extra-articular portion of the tendons. The adequate fixation of the graft is guaranteed initially by the staples and definitely by the scar tissue of the posterior capsule.

Intra-articular and extra-articular graft fixation with staples ensures a good primary mechanical stability. Steiner et al. [40] has demonstrated that doubled gracilis and semitendinosus tendons secured with a soft-tissue washer presents a mechanical failure similar to patellar tendon fixed with 9 mm interference screws. Kurosaka et al. [17] obtained superposable results, confirming that staples fixation guarantees a valid initial fixation of the tendon graft that, along with the features of the surgical technique, permits an extremely accelerated rehabilitation program. Rodeo et al. [33] has suggested from an experimental study in dogs that bone-tendon healing can be obtained from 8 to 12 weeks, but the concerns arising from this study on the application of an accelerated rehabilitation program are identical when considering bone to bone healing.

We have never used staples on the tibial portion to avoid possible avulsion of the graft. In fact, the hole of the tibial tunnel is made more medially with respect to the normal execution so that the tendons lie, in the first part, normally, avoiding avulsion stress that may occur with a tunnel more superiorly and laterally positioned (Fig. 5).

Regarding remodeling or ligamentization of the graft, we believe that saving the tibial periosteal insertion of both tendons ensures a sort of neurovascular supply to this structure that can accelerate this process. The remodeling process of the graft is one of the more controversial issues. In fact, many considerations must be taken into account when discussing this topic. Undoubtedly, the semitendinosus and gracilis tendons are smaller in structure with respect to the patellar tendon, but this is advantageous because animal models [12, 13, 39] have shown that the graft swells in the first 6–9 months, and a large graft could be more susceptible to notch wear. Another consideration is that the ingrowth rate depends on the surface area. Amiel et al. [2] has shown that with larger grafts, the

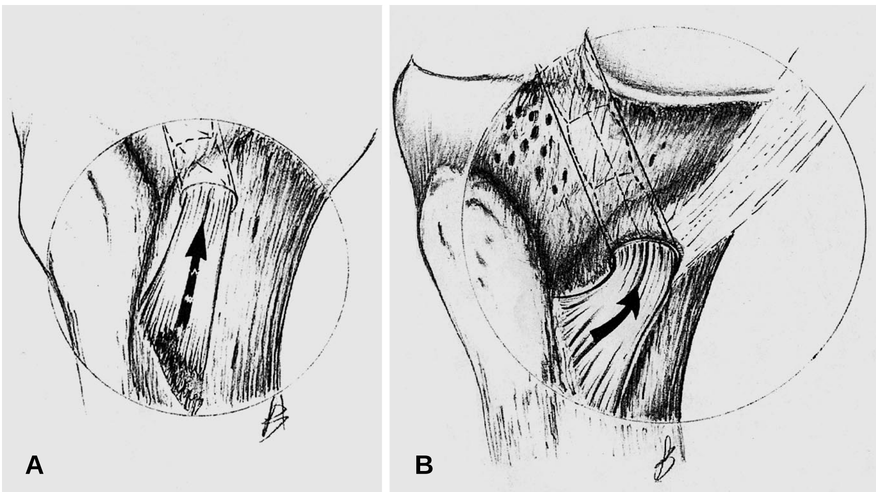


Fig. 5 The tibial tunnel positioned too vertically and superiorly (**A**) would damage the insertion of the tendons due to the different directions of stress. By drilling the tunnel slightly medially and superiorly (**B**), the tendons and its insertion are stressed in the normal direction, avoiding avulsion stress

centre is further from the revascularization process. For this reason, a multiply stranded graft which maintains part of the neurovascular supply may remodel more quickly than a single width graft.

Graft selection is certainly one of the more important and controversial issues in ACL reconstruction. Bone-patellar tendon-bone is probably the most popular ACL graft, and most series report 85%–90% good-excellent results. The results obtained in our 40 patients are highly satisfactory, with 93% of normal or nearly normal knees according to the IKDC score. Resumption of sport and activity level were very high as well.

Moreover, anterior knee pain appears to be a significant problem related to the patellar tendon. Friedman [9] compared patellar tendon, allograft and hamstring reconstructions at 4 years' follow-up and showed a significant incidence of anterior knee pain (26%–47%) only in the patellar tendon group. Callaway et al. [5] in acute reconstructions alternating hamstring and patellar tendon found 14% anterior knee pain in the hamstring group vs 42% for the patellar tendon group. Our results confirm the lower morbidity of hamstrings, with no stiffness and only 5% anterior knee pain.

Hamstring ACL reconstructions seem to achieve better results when performed in acute cases, as suggested by Sgaglione et al. [37] and Barber et al. [3]. In contrast, Marder et al. [22] found no significant differences between patellar tendon and hamstring reconstructions in chronic patients. Aglietti et al. [1] noted higher objective stability with the patellar tendon, but he observed 47% extension deficit in this group compared with 3% in the hamstring group.

In our series there was no significant difference between acute and chronic cases. Interestingly, the cases with associated MCL tears had the worst objective stability.

Our technique combining intra- and extra-articular procedures leads to satisfactory stability in acute and chronic patients and avoids concurrently the higher morbidity related to the harvest of the patellar tendon, with minor surgical trauma and very satisfactory results combined with reduction of the postoperative rehabilitation phase.

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