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A comparison of clinical and radiological parameters with two arthroscopic techniques for anterior cruciate ligament reconstruction

P. Aglietti, G. Zaccherotti, P. P. M. Menchetti, P. De Biase

First Orthopaedic Clinic, University of Florence, Largo Piero Palagi 1, I-50139 Florence, Italy

Abstract. We performed a comparative study of two series of 25 patellar tendon arthroscopic reconstructions of isolated chronic anterior cruciate ligament injuries, alternating between a double-incision (using a rear-entry guide) or single-incision technique (using a transtibial approach). The patients were reviewed to assess the clinical, KT-2000 and radiological differences at an average follow-up of 14 months (range 8–18 months). For the clinical evaluation the International Knee Documentation Committee Form was used. The following radiographic parameters were measured: (1) the direction of the femoral and tibial tunnels in the antero-posterior (AP) and lateral (LL) views; (2) the location of the anterior border of the intra-articular exit hole of the femoral tunnel in the LL radiologic view; (3) femoral interference screw divergence with the bone block. An extension loss ≤ 5° was detected in 40% of the double-incision and 36% of the single-incision patients (NS). A flexion loss ≤ 10° was present in 8% of the double-incision and 16% of single-incision group (NS). There were no differences in terms of pivot shift test between the two groups (pivot glide in 12% of both groups). The average side-to-side KT-2000 differences at the manual maximum test were 1.98 mm in the double-incision and 2.64 mm in the single-incision group. With the double-incision technique the femoral and tibial tunnels were divergent in the AP plane and crossed the joint at an angle of 37° and 72°, respectively. With the single-incision technique the bone tunnels were almost parallel and crossed the joint at an average angle of 68°. The location of the intra-articular exit of the femoral tunnel was posterior in both techniques (63% and 66%, respectively). Screw divergence (≥ 20°) on the femoral side was absent in the double-incision and present in 12% in the single-incision group (NS). In conclusion, even without straight line tunnels, satisfactory results in terms of stability may be obtained. Despite our similar results, we feel that the single-incision technique is perhaps preferable because there is less postoperative pain and swelling, and it is preferred by the patients. The single-incision technique has a long learning curve.

Correspondence to: P. Aglietti

Key words: Anterior cruciate ligament – Arthroscopy – Ligament reconstruction

Introduction

Arthroscopically assisted anterior cruciate ligament (ACL) reconstruction has become the technique of choice for many surgeons. The patella tendon (PT) autograft has been widely used and is considered by some to be preferable in particular in terms of strength [2, 3, 5, 7, 9, 20, 22, 23, 28]. Fixation is usually achieved with interference screws and is similar to the strength and stiffness of the normal ACL [4, 14, 17, 18, 28].

There are different operative techniques to implant the graft, especially concerning the method of femoral tunnel production. This can be performed with two incisions from outside-in or with one incision from inside-out and through the tibial tunnel.

It is the purpose of this paper to compare at 1 year follow-up two series of ACL reconstructions performed with the two techniques in order to study clinically the range of motion and the stability, and radiographically the differences in tunnel position and angulation and interference screw divergence.

Materials and methods

Between January 1993 and July 1993, 50 chronic "isolated" ACL injuries without previous surgery were operated on in the First Orthopaedic Clinic of the University of Florence using autologous PT grafts and an arthroscopically assisted technique. Patients with preoperative medial or lateral joint opening greater than 5 mm and any degree of posterior cruciate ligament or postero-lateral injury were excluded from the study. The opposite knee had to be normal for use in comparison.

The surgical technique alternated between two forms differing in the manner by which the femoral tunnel is produced. Twenty-five patients were operated on with the double-incision technique (group A) and 25 with the single-incision one (group B). Their average ages were 23 (range 16–35) and 25 (range 16–35) years, respectively. The majority of the patients were male (60% and 72%,

Table 1. Preoperative assessment according to IKDC knee ligament standard evaluation form

Group qualification	Subjective		Symptoms		ROM		Stability		Final	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
A (normal)										
Group A	0	–	0	–	25	100	0	–	0	–
Group B	0	–	0	–	25	100	0	–	0	–
B (nearly normal)										
Group A	0	–	9	36	0	–	5	20	0	–
Group B	0	–	12	48	0	–	4	16	0	–
C (abnormal)										
Group A	23	92	14	56	0	–	15	60	19	76
Group B	20	80	10	40	0	–	15	60	15	60
D (severely abnormal)										
Group A	2	8	2	8	0	–	5	20	6	24
Group B	5	20	3	12	0	–	6	24	10	40

IKDC, International Knee Documentation Committee; ROM, range of motion

respectively), and the interval from injury to surgery was 25 months (range 6–96) and 30 months (6–92), respectively.

The activity level was recorded as proposed by the International Knee Documentation Committee (IKDC) [12]. Four activity levels were defined. Class I includes sports involving jumping, pivoting and cutting (i.e. football and soccer). Class II is heavy manual work and agility sports without cutting and pivoting (i.e. skiing and tennis).Class III is light manual work or sport (i.e. jogging and running). Class IV involves activities of daily living or sedentary work. The two groups were similar in terms of pre-injury activity level in that 72% of group A and 76% of group B were class I or II. The preoperative evaluation according to the IKDC form is given in Table 1.

Meniscal associated surgery consisted of 5 partial medial meniscectomies, 6 partial lateral meniscectomies, 1 repair of the medial meniscus and 1 repair of the lateral meniscus in the patients of group A. Five partial medial meniscectomies and 10 partial lateral meniscectomies were done in group B.

Surgical technique

The two series of operations were performed by one surgeon (P.A.) after an adequate learning curve for each technique. This involved over 50 cases with the single-incision and 245 with the double-incision (25 with the rear-entry guides) type. The details of the surgical technique have been given elsewhere [2]. Here we describe just a few points.

Graft harvest was performed at the beginning of the operation through a short antero-medial incision. The middle third (9–11 mm of width) of the PT with bone blocks at each end was taken. The bone blocks measured approximately 22 × 10 × 6 mm. Sutures were passed at each end through the bone blocks.

A *limited notch plasty* was performed under arthroscopic control in order to achieve an anterior notch width of at least 18–20 mm and a smooth lateral wall. The posterior end of the lateral wall at the junction with the roof and the "over the top" position were identified.

The *tibial tunnel* was then created from outside-in using the "Pinn-ACL cruciate" guide (Linvatec, Largo, Fla.). The starting point in the antero-medial tibial metaphysis was placed at the level of the mid-point of the tibial tuberosity and approximately 2.5 cm medial to it at an angle of 45°–50° with the tibia. We tried to place the pin, after complete removal of the ACL stump, at a point near the antero-medial spine and about 7 mm anterior to the posterior cruciate ligament (Morgan, personal communication, 1993). As an additional reference we followed the imaginary line between the antero-medial tibial spine and the posterior aspect of the anterior horn of the lateral meniscus; the ideal exit point is approximately in the middle. The position of the pin was checked through range of motion (ROM) and in full extension. In extension it had to be in the centre of the notch, with adequate space to the roof and the lateral wall. The pin was overdrilled with a cannulated tibial reamer (Acufex Microsurgical, Mansfield, Mass.) of appropriate size. The final position and orientation of the tibial tunnel were checked with an 8 mm trocar. To be acceptable there could not be any impingement with the roof or the lateral wall in extension with free movement of the trocar. No intra-operative roentgenograms were taken.

There were two methods of preparing the *femoral tunnel*. In *group A* a second incision was performed over the lateral femoral metaphysis, and with a special hook introduced through the antero-lateral portal and passed through the notch, a "rear-entry" drill guide (Acufex Microsurgical) was pulled into the joint from the femoral incision [25]. The tip of the guide was placed well posteriorly in the lateral wall of the notch, 6 mm from its posterior limit and at the junction with the roof (11 o'clock for the right knee and 1 o'clock for the left one). A tunnel was then created, overdrilling the pin from outside-in with a cannulated reamer of appropriate size (Acufex Microsurgical). In *group B* the femoral tunnel was prepared from the same single antero-medial incision, through the tibial tunnel [6]. A guide pin was placed through the tibial tunnel, with the knee at 90°, at the same posterior point of the lateral wall of the notch as described for group A. The tunnel was produced by overdrilling the pin from inside with a special atraumatic and calibrated reamer (Acufex Microsurgical), usually with a diameter 1 mm less than the tibial tunnel. The length of the tunnel was the same as the bone block to be used (usually 22 mm).

In no instance in group A or B was isometry measured during surgery before drilling the femoral tunnel. No intra-operative radiographs or fluoroscopic control was used.

The intra-articular exit holes of the tunnels were chamfered and smoothened with full radius shavers (Smith & Nephew Dyonics, Andover, Mass.) and bone curettes. The grafts were passed in the joint in group A from femur to tibia and in group B from tibia to femur. In this latter case a pin (suture passer) was inserted in the femoral tunnel and drilled through the femoral shaft. It was used to pull and hold the graft in place.

Fixation of the grafts was achieved with interference screws on both sides of the joint. In group A 7–9 mm Kurosawa cannulated screws (DePuy, Warsaw, USA) were introduced through the incisions, from outside-in, under direct visual control. The femur was fixed first, and the tibia second. The graft was stretched before fixation in the tibia with approximately 1 kg of force and with the knee near full extension. In group B the femoral cannulated 7 × 20 mm

Table 2. KT-2000 average side-to-side difference (expressed in millimetres) (differences not significant)

	Preoperative		Postoperative	
	Group A	Group B	Group A	Group B
15 lbs	4.2	4.1	1.50	2.20
20 lbs	5.3	5.2	1.56	2.20
30 lbs	5.3	6.0	1.60	2.30
Manual maximum	7.4	7.3	1.98	2.64

screw was introduced in the joint with the knee at 120° of flexion through a small "low" antero-medial capsulotomy. After femoral fixation, the graft was stretched with 1 kg of force and then fixed in the tibia near full extension with another interference screw.

Postoperatively, all the patients used an Extension Lock System brace (DonJoy, Carlsbad, Calif.) for 3–4 weeks. The brace was kept locked in full extension at night and for walking and unlocked for motion exercises, which were begun the day after surgery. Before being discharged home, the patients had to achieve full extension and at least 90° of flexion. Partial weight-bearing was begun on the second postoperative day, and the crutches were usually discontinued at 4 weeks. The patient was discharged home after an average of 4 days, without differences between the two groups. There were no postoperative complications in the two groups. The principles of an accelerated rehabilitation with emphasis on closed, kinetic, chain, strengthening exercises were followed in an identical manner in both groups and are outlined elsewhere [21, 27]. No patients used a functional knee brace for rehabilitation. They returned for weekly controls during the first 6 weeks and every 2 weeks thereafter up to 6 months.

Methods of study

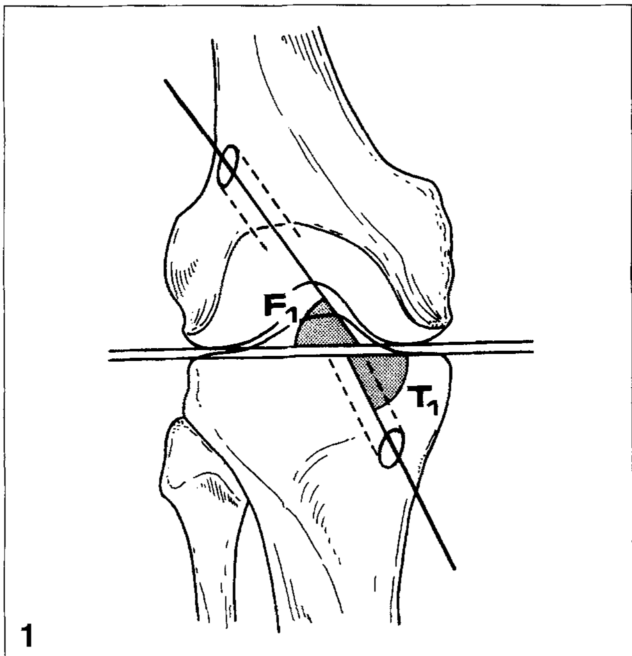
Clinical subjective

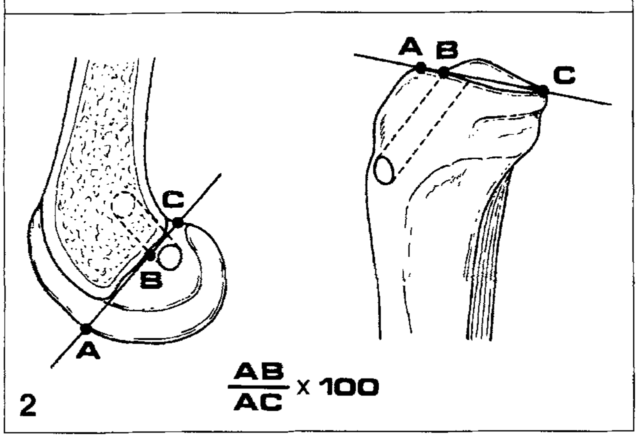
The question "How does your knee function?" was asked of all the patients at follow-up with four possible answers: normal, near normal, abnormal, severely abnormal [12]. The question "In a scale from 0 to 3 how does your knee affect your activity level?" was also asked.

The symptoms of pain, swelling and giving-way were evaluated according to the IKDC [12]. The absence of significant symptoms at the highest activity level possible at follow-up was determined and recorded.

Clinical objective

ROM was measured in comparison with the opposite normal knee according to published work [26]. In particular, extension was





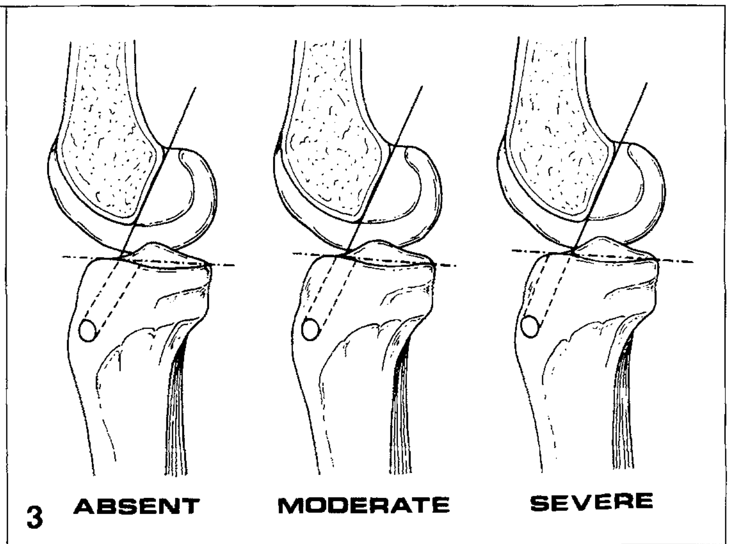


Fig. 1. Method of measurement of the angulation of the femoral and tibial tunnel in antero-posterior (AP) radiographic view

Fig. 2. Method of measurement of the intra-articular position of the exit of femoral and tibial tunnels in lateral (LL) radiographic view and expressed as percentage

Fig. 3. Method of evaluation of the impingement of the graft with the intercondylar notch in LL radiographic view with the knee in full extension according to Howell and Taylor [13]

measured as the heel-height difference with the patient in a prone position and expressed in degress.

Anterior tibial translation was measured with the KT-2000 knee arthrometer (MEDmetric, San Diego, Calif.) according to Daniel and Stone [8]. The side-to-side difference was measured with at 15–20–30 lbs and maximum manual anterior force with the knee in 25° of flexion (Table 2). Anterior laxity was classified according to the IKDC [12]: 0–2 mm (normal), 3–5 (near normal), 6–10 (abnormal), more than 10 (severely abnormal).

The knees were evaluated clinically with the pivot-shift functional test which was performed according to the Lyon School [10]. It was graded according to the IKDC [12] into: negative, grade 1+ (glide), 2+ (clunk) and 3+ (gross).

Compartment findings were evaluated at follow-up according to the same scale [12], in particular, the presence of patellofemoral crepitation which was classified as absent (equal), moderate, painful and severe (with pain and swelling).

Radiographic evaluation

The knees were radiographed at follow-up with a standing anteroposterior (AP) view in full extension and a lateral (LL) view in full passive extension (the heel was raised off the table with a support). Both images were obtained with an image amplifier to centre the beam.

In the AP view the angulation of the femoral (F1) and tibial (T1) tunnels with the line tangent to the femoral condyles or to the tibial plateau, respectively, was measured (Fig. 1).

In the LL view the angulation of the two tunnels with the axis of the femoral shaft and the tangent to the tibial plateau was measured. In the same view the intra-articular position of the exit of both tunnels was measured according to our published method [2]. For the femur the position of the anterior border of the exit hole was measured as the percentage from the front of the length (along the Blumensaat line) of the condyles. For the tibia the position of the anterior border of the exit hole was calculated as the percentage from the front (along the tangent to the plateaus) of the sagittal length of the tibial plateaus (Fig. 2).

In the LL view in extension, impingement of the graft with the notch was calculated according to a published method [13]. Lines were drawn along the Blumensaat line and the tibial plateaus. If the intersecting point of the Blumensaat line was located posterior to the tibial tunnel with the knee in full extension, the impingement was severe; if it was within the anterior and posterior limits of the tunnel, the impingement was defined as moderate; and if it was anterior to the tibial tunnel, impingement was considered absent (Fig. 3).

The divergence of the screws with the graft bone blocks was measured according to published work [19]. It was considered significant if equal to or more than 20° [16]. Divergence was measured in AP and LL views of both the femoral and tibial screws.

All the results were stored in a database and investigated for statistical significance using the chi-square test and student's t-test. The minimum level of significance was $P = 0.05$.

Results

There were no significant intra-operative or postoperative complications in both series.

The results were evaluated at a follow-up of an average of 14 months (range 8–18 months) by a single independent examiner (G.Z.).

Clinical subjective

In group A 72% of the patients judged their operated knee to be normal, 24% nearly normal and 4% abnormal. In group B 72% said that the knee was normal and 28%, nearly normal.

To the question about how much the operated knee affected their activity level, in group A 40% of the patients expressed no restrictions, 44% minimal restrictions from the knee and only 16% moderate restrictions in their activity level caused by the knee. In group B 36% had no restrictions, 52% minimal and 12% moderate problems in their activities.

There were no statistical differences between the two groups. The two groups were also similar in terms of activity level [12] in that 56% of group A and 48% of group B were level I or II. The low activity level was due to the short period of follow-up.

Clinical objective

ROM was similar in the two groups. A flexion loss (≤ 10°) was present in 8% of group A and 16% of group B (difference NS). No patient lost more than 10° of flexion. The average flexion loss was 5.7° and 6.5° in groups A and B, respectively. An extension loss (≤ 5°) was detected in 40% of group A and 36% of group B, and the average loss was 3.5° and 3.7°, respectively (difference NS). No patient lost more than 5° of extension.

The KT-2000 average side-to-side differences (preoperative and postoperative) are reported in Table 2, where it can be seen that at the manual maximum, they are 1.98 in group A and 2.64 in group B. The postoperative side-to-side differences are classified in Table 3. The differences were not significant. The preoperative laxity was also similar in the two groups.

In terms of pivot shift, the preoperative and postoperative results are detailed in Table 4. There were no differences between the two groups, although the only pivot shift grade 2+ (clunk) was present in group A.

Table 3. KT-2000 postoperative side-to-side differences according to IKDC

Difference (mm)	Group A		Group B	
	n	%	*n*	%
0– 2	13	52	11	44
3– 5	11	44	14	56
6–10	1	4	0	–

Table 4. Preoperative and postoperative pivot shift (%) (differences NS)

	Preoperative		Postoperative	
	Group A	Group B	Group A	Group B
Absent	–	–	20 (80%)	21 (84%)
Glide	3 (12%)	5 (20%)	4 (16%)	4 (16%)
Clunk	22 (88%)	20 (80%)	1 (4%)	–
Gross	–	–	–	–

Table 5. Postoperative results according to IKDC knee ligament standard evaluation form

Group qualification	Subjective		Symptoms		ROM		Stability		Final	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
A (normal)										
Group A	18	72	19	76	18	72	17	68	4	16
Group B	18	72	20	80	17	68	15	60	5	20
B (nearly normal)										
Group A	6	24	5	20	7	28	7	28	18	72
Group B	7	28	5	20	7	28	10	40	19	76
C (abnormal)										
Group A	1	4	1	4	0	–	1	4	3	12
Group B	0	–	0	–	1	4	0	–	1	4
D (severely abnormal)										
Group A	0	–	0	–	0	–	0	–	0	–
Group B	0	–	0	–	0	–	0	–	0	–

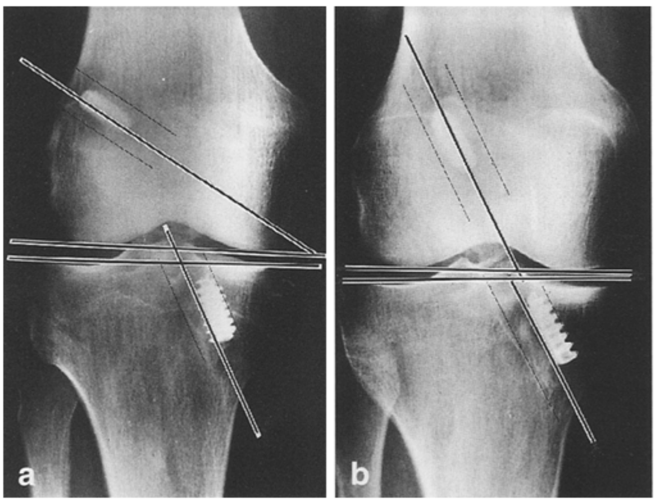


Fig. 4 a, b. Measurement of the tunnel angles in AP view. In this example the femoral tunnel angulation is 33° for the patient of group A (**a**) and 73° for group B (**b**). The tibial tunnel angulation is 70° (**a**) and 68° (**b**), respectively

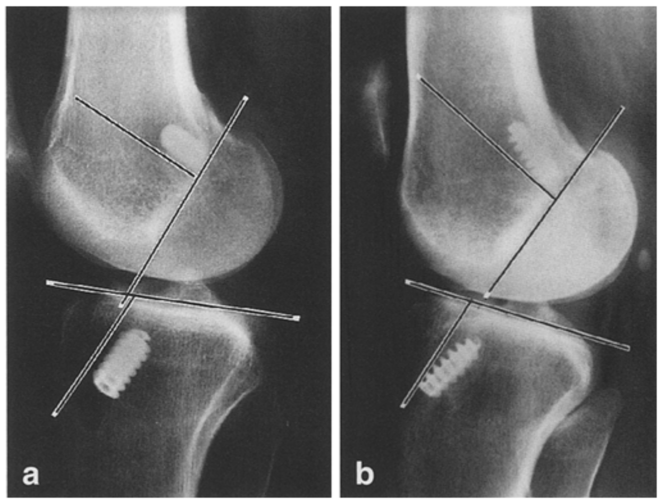


Fig. 5 a, b. Measurement of the position of the femoral tunnels (anterior border of the exit holes). In this example the position of the femoral tunnel is 63% (**a**) and 68% (**b**) for groups A and B, respectively. The tibial tunnel is placed at 25% (**a**) and 26% (**b**) for groups A and B, respectively

The final result according to the IKDC form is reported in Table 5, in terms of subjective evaluation, symptoms, motion, stability and final evaluation. There were no significant differences between the two groups.

Radiographic evaluation

The femoral tunnel angulation in the AP view (Fig. 4) was 37° (range 16°–63°) in group A and 68° (range 50°–88°) in group B. The difference was statistically significant ($P < 0.01$).

The tibial tunnel angulation in the AP view (Fig. 4) was 72° (range 60°–80°) in group A and 69° (range 58°–81°) in group B. The difference was of borderline significance ($P = 0.03$).

The angulation between the femoral and tibial tunnels was 19.6° ± 8.3° (range 4°–30°) in group A and 5.1° ± 5.8° (range 0°–17°) in group B. The difference was statistically significant ($P < 0.001$).

The femoral tunnel angulation in the LL view was 152° (range 136°–168°) in group A and 144° (range 136°–161°) in group B (NS).

Tibial tunnel angulation in the LL view was 55° (range 40°–78°) in group A and 59° (range 35°–80°) in group B (NS).

The position of the femoral tunnels (anterior border of the exit holes) relative to the anterior to posterior length of the femoral condyles (Fig. 5) was 63% (range 56%–76%) in group A and 66% (range 58%–80%) in group B. The difference is not significant ($P = 0.07$).

The position of the anterior border of the exit hole of tibial tunnels relative to the sagittal length of the tibial plateaus (Fig. 5) was 28% (range 19%–42%) in group A and 27% (range 17%–38%) in group B (NS).

The impingement of graft with the roof of the notch was studied only in those patients with full passive extension (without extension loss): 14 patients of group A (56%) and 15 of group B (60%). The impingement was classified as absent in 50% and 71% and moderate in 50% and 29%, respectively. No patient had severe impingement. The difference between the two groups was not significant.

Screw divergence (< 20°) on the femoral side was 12% in group A and 4% in group B. Screw divergence ≥ 20° was absent in group A and 12% in group B. The difference was not significant.

Discussion

The clinical results of these two prospectively studied, simultaneous and comparable series of arthroscopically assisted ACL reconstructions with PT in chronic knees are nearly the same (without statistically significant differences).

Before the comparative study a sufficient familiarity was acquired with both techniques. One (group A) involves the creation of an outside-in femoral tunnel, independent of the tibial tunnel, through a second incision and using specialized guides of considerable precision such as the "rear-entry" guides. The other (group B) requires drilling of the femoral half-tunnel from the inside, through the single antero-medial incision and through the tibial tunnel using specialized atraumatic reamers.

It is therefore possible, with sufficient experience, to obtain the same clinical results using the more difficult single-incision technique that we were used to obtaining with the more traditional and perhaps more straightforward double-incision technique. At 1 year, a short-term follow-up, the stability was satisfactory in both groups. The average side-to-side difference at the manual maximum was 1.98 and 2.64 mm in groups A and B, respectively, and only 4% of the patients in both groups of chronic knees had a difference greater than 5 mm. Similar results were also obtained in terms of motion or of motion loss.

A relatively high number of cases (40% of group A and 36% of group B) had an extension loss of up to 5°, but it must be remembered that this was measured in comparison with the opposite normal knee (which might be in recurvatum) as the heel-height difference, as defined by Sachs et al. [26], and not relative to the "zero" position as recently accepted by the IKDC [12]. The reason for being more stringent is that we believe that even a few degrees of asymmetry can be important and that a full symmetrical extension is required for the feeling of a normal gait. Flexion loss was minor in both groups (no patient had more than 10° loss).

The radiographic study did show some differences between the two groups. The most important difference, based on the technique by which the femoral tunnel is produced, is the angulation of the femoral tunnel in the AP view. The angle with the line tangent to the condyles was 37° in group A and 68° in group B ($P < 0.01$). This is also reflected in the angulation between the tibial and femoral tunnels, which is 19.6° in group A and 5.1° in group B ($P > 0.001$). There were no differences in the angulation of the tunnels in the LL view. One would expect that the objective stability results of the group B knees (where the tunnels were more in a straight line) would have been superior to group A due to the fact that, at least experimentally, "straight-line" tunnels cause less wear damage and failure at the femoral tunnel exit hole [11], but this was not the case in practice in our series. The exit holes of the femoral and tibial tunnel were smoothened and chamfered.

Not only the angulation of the tunnels was unimportant but also the angle which the femoral tunnel makes with the plane of the lateral wall of the notch. One would expect that when the reamer hits the lateral wall at a considerable angle (such as with the single-incision technique), the intra-articular exit hole would be oval and larger than desired and perhaps also more anterior (Clancy, personal communication, 1994). This was not the case.

In the lateral view the position of the anterior border of the femoral and tibial tunnel exit holes was calculated relative to the sagittal length of the projection of the femoral condyles and of the tibial plateaus, respectively. For the femoral tunnel exit hole our study demonstrated that we can arrive sufficiently posteriorly with both techniques. The position of the femoral tunnel was 63% in group A and 66% in group B (NS). In a previous long-term study of PT reconstructions [2], we could demonstrate that return of laxity and failure of the graft was more frequent for the more anterior femoral positions.

Concerning the position of the tibial tunnel exit hole in the LL view (in full extension), we could show no significant differences between the two techniques. The anterior border of the exit hole was at a point located at 28% and 27% in groups A and B, respectively. The same view allowed us also to study the impingement with the roof according to Howell and Taylor [13]. We did see a relatively high number of moderate impingements, 50% and 29% in the two groups, respectively. The difference was not statistically significant, but the high absolute values must certainly remind us of the importance of the tibial tunnel being well posterior [15, 24]. The number of cases of moderate impingement measured radiographically did not correlate in our series with the clinical results in terms of stability and ROM. Although we believe that severe impingement probably has more clinical relevance, we make every effort during surgery to avoid any degree of impingement by following closely all the steps outlined in the technique and taking great care with all the specific checks (position of the K-wire, use of the trocar, etc.).

The final radiographic point is that of interference screw divergence. The femoral interference screw with the single-incision technique was found to be frequently divergent by Lemos et al. [19], although divergence was defined as equal or more than only 5°. Recent work by Jomha et al. [16] considered that there was no significant difference in tensile strength provided by interference screw fixation for angles of up to 10°, but there was a significant weakening of fixation for angles over 20°. In our series screw divergence on the femoral side was 12% in group A and 4% in group B for less than 20° and absent in group A and 12% in group B for over 20°. Overall, there was no statistical difference, although the greater angulations (> 20°) were more frequent with the single-incision technique.

In conclusion, the clinical 1-year results of this comparative study of two techniques are very similar. We personally prefer the single-incision technique because there is less pain and swelling and also the cosmetic result is better, although these parameters are very difficult to prove and were not the object of our study. The single-incision technique is more difficult and is associated with a considerable learning curve. For this reason we have recently changed to a modified single-incision type in which the femoral tunnel is prepared first through the anteromedial portal with the knee fully bent, and the same approach and knee flexion are used for introduction of the femoral cannulated interference screw. The advantages of the modified technique are that the femoral and tibial tunnels are independent of each other, the position of the femoral tunnel exit hole is more reproducibly ideal, and femoral screw divergence is absent.

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