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Henri Robert
Jaffar Es-Sayeh

The role of periosteal flap in the prevention of femoral widening in anterior cruciate ligament reconstruction using hamstring tendons

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H. Robert (✉) · J. Es-Sayeh
Centre Hospitalier du Nord Mayenne,
5 rue Roullois, 53100 Mayenne, France
Tel.: +33-2-43087340,
Fax: +33-2-43087656,
e-mail: henri.robert@wanadoo.fr

Abstract Tunnel widening in anterior cruciate ligament reconstruction has been reported for many years, whatever the type of plasty (allo- or autograft) or graft (patellar or hamstring tendons). Recently, the hypothesis has been formulated that widening would be responsible for later laxity of the knees. Micromobility of the graft or biological factors are classically responsible for the enlargement. In order to improve the biological conditions around the graft within the tunnel, we have developed a surgical technique using a periosteal flap. The periosteal flap is harvested at the superior and medial metaphysis of the tibia and wrapped around the proximal part of the four strands of gracilis and semitendinosus tendons near the outlet of the femoral tunnel. Forty-one patients with isolated rupture of the ACL were included in a prospective and randomized study: the first group of 20 patients had femoral fixation by Transfix and resorbable screw, the second group of 21 patients had femoral fixation by Transfix and periosteal flap. The diameters of the tunnel were measured between the sclerotic margins at the tunnel entrance and 1 cm above, and compared to the peroperative drill size. The percentage change in diameter was calculated as: (tunnel diameter–drill size)/drill size. The two groups of patients were comparable as to gender, side, age, KT-1000 side to side difference, femoral tunnel diameter and follow-up. At 2.5 months and 11 months postoperatively on average, there was a significant reduction of enlargement at the outlet of the tunnel with the use of a periosteal flap but widening was constant.

Keywords Anterior cruciate ligament reconstruction · Hamstring tendons · Bone tunnel enlargement · Periosteum · Transfix

Introduction

Bone tunnel enlargement in anterior cruciate ligament reconstruction has been initially reported with allograft of the patellar tendon, sterilized by ethylene oxide [18] as well as with patellar or hamstring autograft tendons [2, 6, 11,27]. For a long time widening has not modified the clinical results when considering a follow-up of 2 to 3 years, but this is not the case with a follow up of more than 5 years [29]. The phenomenon of widening can have mechanical or biological reasons. The persistence of micro mobility of the graft within the tunnel has been largely and extensively described and attributed to a non-anatomic fixation of the graft far from the tunnel outlet [16, 17, 23]. Such a graft conserves longitudinal and sagittal mobility leading to erosion of the bone walls. After 3 or 4 months, the widening has reached its maximum diameter and can be characterized by sclerotic margins on X-rays [6, 29]. The surgical goal should be a solid fixation [22] as close as possible to the tunnel entry, as has already been proved by animal experiments [37]. Radiological reports concern-

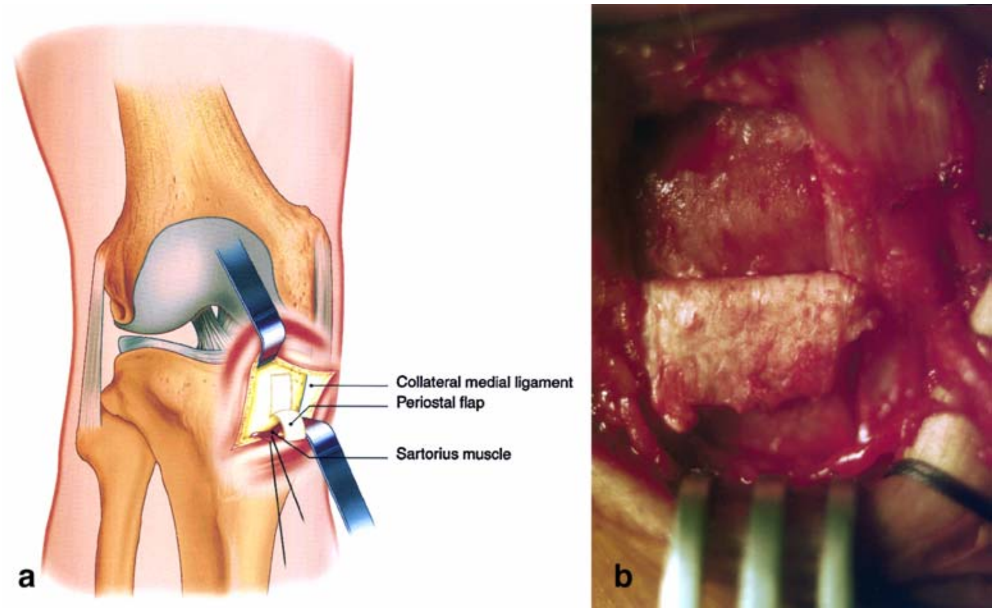

Fig. 1a, b The periosteal flap is harvested at the superior and medial metaphysis of the tibia

ing screw fixation more often mention widening with hamstrings than with patellar tendons [23, 24, 28, 36]. A recent study reported more frequent widening with non-anatomical fixation than with anatomical fixation [7]. Biological factors may act differently: immunologic response in the case of allograft [11, 14, 35], inflammatory reaction due to the rupture of the ACL [3], to the necrosis of the graft [6], to the resorption of the interference screws [9], to several components of the metallic screws [25], or to the synovial inflow within the tunnel [12]. In order to improve the biological conditions around the graft within the tunnel, we have developed a surgical technique using a periosteal flap. Michael Strobel has recently published a similar technique in his book [34]. The goal of our study is to evaluate tunnel widening in patients with or without a periosteal flap.

Material and methods

Forty-one patients (six females, 35 males; age range 15–41; mean age: 26.5 years) took part in a prospective and randomized study conducted in 2000. Inclusion criteria were isolated rupture of the ACL with a normal contralateral knee and with differential laxity inferior to 10 mm as measured with the KT-1000. Patients with greater laxity or with radiological abnormalities were excluded. One senior surgeon carried out all the operations using an endoscopic technique. A four-strand gracilis and semitendinosus autograft was harvested, and a blind femoral tunnel created through the tibial socket. The femoral tunnel was drilled to a 7 mm diameter and a depth of 3 cm then progressively dilated to the exact size of the graft.. The femoral fixation was secured by a non-absorbable cross-pin (*Transfix*, Arthrex, France) [5] in addition to either a resorbable screw or a periosteal flap. Tibial fixation was always secured by a screw or a staple. The femoral poly-L-lactic acid bio-absorbable interference screw (28 mm long) corresponded exactly to the diameter of the tunnel entry. The periosteal flap was harvested at the superior and medial metaphysis of the tibia by a sharp periosteal elevator prior to drilling. The flap was 2 cm long and 1 cm large; it was wrapped around the proximal part of the new ligament at a maximum of 25 mm from the upper end, its osseous surface faces externally (Fig. 1 and Fig. 2). When the periosteal flap was used, the femoral tunnel was dilated by another 0.5 mm. In the postoperative course, the patients wore a splint limiting flexion (0°/0°/70°) for 3 weeks but full weight bearing was allowed within the first 2 weeks. Patients were discharged from the hospital on day 2 or 3 and attended a non-aggressive rehabilitation program 3 times a week for a period of 2 months. Close chain exercises were encouraged immediately postoperatively and open exercises were allowed at 3 months. They resumed work 4 to 6 weeks postoperatively. Jogging, cycling and swimming were allowed after 3 months, but for twisting activities they had to wait for 8 to 10 months.

Forty-one patients were included: the first group of 20 patients had femoral fixation by Transfix and resorbable screw, the second group of 21 patients had femoral fixation by Transfix and periosteal flap. The patients were clinically monitored and tested with the KT-1000 arthrometer (133-N and manual maximal anteroposterior traction) at 1, 2, 3, 5, 8, 12 and 16 months postoperatively, and underwent X-rays at 10 weeks and 11 months postoperatively on average (anteroposterior and lateral weight bearing in exten-

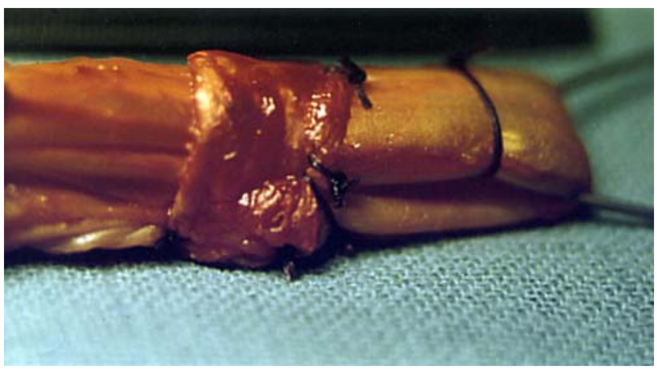

Fig. 2 The periosteal flap is wrapped around the proximal part of the four strands

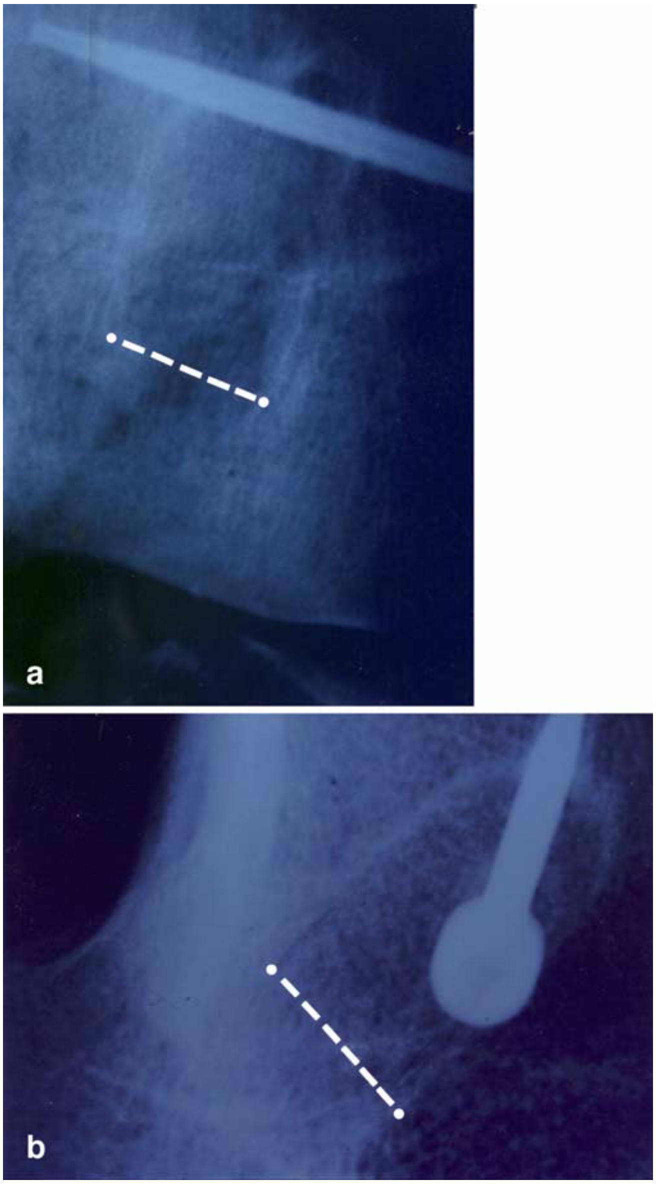

Fig. 3a, b Measurements of the enlargement at the tunnel aperture and 1 cm above. **a** Anteroposterior view. **b** Lateral view

sion). The anteroposterior and lateral diameters of the tunnel were measured between the sclerotic margins at the tunnel entrance and 1 cm above and adjusted for magnification (Fig. 3a, b). The result was compared to the peroperative drill size. The percentage change in diameter was calculated as: (tunnel diameter–drill size)/drill size. Tunnel widening was defined as any increase in comparison to the diameter of the last drill. The shape of the tunnel was classified as either "line type", "cavity type" or "cone type" (27). A senior examiner performed all the measurements. A subset of 20 X-rays was randomly selected and reviewed by a second observer to determine the interobserver variability. Femoral tunnel placement was documented by measuring the posterior aspect of Blumensaat's line to the anterior aspect of the femoral tunnel [1]. Statistical analysis was performed using the Student *t* test and the Mann-Whitney test. Statistical significance was accepted at the 95% confidence level.

Results

The two groups of patients were comparable as to gender, side, age, KT-1000 side-to-side difference, femoral tunnel diameter and follow up (Table 1).

Interobserver variability (p=0.71) and intraobserver variability (p=0.92) for measurement of tunnel enlargement was not significant. At 2.5 months postoperatively on average (1–4 months), tunnel walls were not visible in five cases of the first group, no widening was seen in two cases and the average widening at the outlet of the tunnel was 29.8% in the frontal view and 27.2% in the sagittal view. In the second group (with periosteal flap), tunnel walls were not visible in two cases, no widening was seen in four cases and the average widening at the outlet of the tunnel was 10.3% in the frontal view and 13.7% in the sagittal view. These differences were all significant. Furthermore, differences between the two groups were significant at 1 cm from the outlet of the tunnel (Table 2).

At 11 months on average (8 to 16 months), tunnel walls were always visible, and widening was constant in both groups. The average enlargement slightly increased in

Table 1 Demographics of the study population

	Group 1	Group 2
Male/female	18/3	17/3
Right/left	9/12	9/11
Age at surgery (years)	29	23.5
Side-to-side difference (mm)	7	8
Size of the femoral drill	8.5 mm	9 mm
Follow-up (months)	13.7	11.6

Table 2 Tunnel enlargement on anteroposterior and lateral views before 3 months. The differences are significant

	AP view <3 months		Lateral view <3 months	
	Tunnel aperture	+1 cm	Tunnel aperture	+1 cm
Group 1	29.83%	30.39%	27.23%	28.48%
Group 2	10.28%	10.75%	13.71%	13.71%
p	0.001	0.001	0.009	0.07

Table 3 Tunnel enlargement on anteroposterior and lateral views after 6 months. The differences are significant

	AP view after 6 months		Lateral view after 6 months	
	Tunnel aperture	+1 cm	Tunnel aperture	+1 cm
Group 1	37.38%	38.48%	31 .79%	35.31%
Group 2	18.97%	20.91%	17.67%	19.27%
p	0.0003	0.0002	0.0002	0.0002

Table 4 Types of enlargement according to Peyrache's classification

	"Line type"	"Cone type"	"Cavity type"
Group 1	13	6	2
Group 2	9	7	2

Table 5 Results of knee stability with KT-1000 arthrometer at 133 N and manual maximal anteroposterior traction

	133 N	Manual maximum
Group 1	2.1±1.5 mm	2.5±1.8 mm
Group 2	1.9±1.2 mm	2.6±1.3 mm
p	>.05	>.05

group 1 (37.4% on AP [anteroposterior] view and 31.8% on lateral view) and in group 2 (19% on AP view and 17.7% on lateral view). These differences are significant (Table 3). The "line type" tunnel was dominant in both groups (Table 4). The femoral tunnel was more anteriorly located in group 1 (58±8%) than in group 2 (65±6%). There was no significant difference in laxity between the two groups (Table 5).

Discussion

There is a wide variability in the amount of tunnel enlargement in the literature depending on the different methods of measurement employed and the minimum thresholds defined. Computed tomography or MRI are reliable methods for detecting this phenomenon and seem superior to plain radiographs in the early postoperative period [12, 19]. Due to the difficulties in orientation, there is a poor correlation between sagittal MRI and lateral X-rays [19]. We suggest that radiographic measurements are more suitable in evaluating bone tunnel dimensions in clinical practice. In the absence of a threshold, an average widening of 33% was present in all cases of Jansson's series. With a threshold of 25%, the incidence of widening was 94% (average widening is 48%), and if the threshold was 50% the incidence was 84%. In our series, without the periosteal flap, the incidence at the tunnel entry was 87.5% at 3 months and 100% after 6 months. We only referred to the enlargement at the outlet of the tunnel, as the interference screw can lead to local widening by penetration of the spongiosa. Our first group demonstrated greater widening within the tunnel than at the tunnel entry. The widening appeared within the first 3 months and then slightly increased in group 1 (7%) and in group 2 (10%); the efficacy of the periosteal flap seemed to continue.

The periosteal flap can reduce widening in two different ways: either it assists tendinous integration by contributing cells and growth factors, or it prevents synovial fluid inflow. Numerous experimental studies have dealt with the tendon–bone interface.

Kernwein et al. [21] studied this anchorage in a tunnel of long bone in rabbits and dogs using either fascia lata femoris or the extensor carpi radialis longus. The graft was gradually invaded by osteoblasts, providing osseous stability. Studies by Whiston and Walmsley [38] demonstrated the early existence of a sleeve of connective tissue around the tendon followed by infiltration of chondral cells generating an enchondral ossification. Rodeo et al. [31] studied the anchorage of an extensor tendon in the trans-tibial tunnel of dogs. After a few weeks, a fibrovascular interface developed out of the pluripotential cells of the bone marrow. Some cells underwent osteoblastic metaplasia, others developed fibroblastic metaplasia. The new collagen fibers were traction oriented, securing the tendon to bone fixation, consequently resembling Sharpey fibers. Immature bone invaded the interface and was mineralized. The quantity of collagen fibers and osteoid tissue was greater at the aperture than within the tunnel. Grana et al. [13] demonstrated an identical anchorage by fibrocellular interface in an intra-articular tunnel at 12 weeks. Weiler et al. [37] studied the Achilles tendon-bone fixation in the goat by intra-articular resorbable interference screw. This fixation depends on the different strengths of the tendon and the location of the tendon. At 6 weeks, they found a mixture of direct insertion and Sharpey fibers in contact with woven bone, within the tunnel. At 12 weeks, insertion was continuous, with alternately Sharpey fibers, fibrocartilage and bone. From 6 to 24 weeks there is an intense osteoblastic activity at the tunnel aperture. After 12 weeks, the chondral zone of the articular surface and the graft are continuous and direct fixation in four layers is complete at 24 weeks. The periosteal flap might accelerate the development by providing pluripotential cells and growth factors. This hypothesis has been confirmed by experimental work in rabbits [4]. Extratendinous implantation using a periosteal flap has been compared to a sham group: the periosteal flap accelerated the osseous integration of the fibrous interface. Moreover, several authors [15, 32] have added growth factors to the tendon bone interface to accelerate the osteoid reaction. According to Yamazaki, the periosteal flap has to be fixed at the entry of the femoral tunnel where the fixation is strongest [39].

There are five reports in the literature concerning tendon–bone biopsies of anatomical screw fixation using hamstring tendons. In Scranton's series [33], Sharpey fibers are present at 6 weeks postoperatively, whereas Pinszewsky [28] described them only at 12 weeks after operation. Eriksson et al. described the presence of Sharpey fibers between tendon and bone and a fibrochondral interface at 1 year after operation [10].

The interface between tendon and bone has been demonstrated with MRI as intermediate signal intensity on T1-weighted images [6, 19, 23]. Two reports have studied the anchorage in non-anatomic fixation: according to Petersen and Laprell [26] (femoral fixation by Endobutton and tibial fixation by cramp) indirect fixation was observed at 6 months postoperatively within the tunnel, whereas Robert et al. [30] noted fixation at the top of the socket (femoral fixation with Transfix) at 10 months. It may be possible that biopsies far from the tunnel outlet do not show the exact maturation of the interface. Anchorage at the tunnel entry seems faster and is of the direct type as has been shown by Colombet [8]. The periosteal flap appears to accelerate fixation at this site but cannot avoid widening of the tunnel.

In a second hypothesis, the periosteal flap can act as a barrier to synovial fluid inflow. Fluid leakage around the tendons in the tunnel is documented by CT arthrograms [12] or MRI [6, 11, 23] during the first weeks after surgery. Cytokines affecting bone resorption (IL-1, IL-6, IL-8, TNFa, PGE-2) have been identified in synovial fluid following ACL disruption [20] or graft necrosis [3]. In a similar way to articular prostheses, these uncontrolled cytokines (IRAPS) lead to bone resorption. Very low concentrations of particles released from the metallic screws can act on the synovial cells and macrophages to stimulate cytokine secretion [25]. Stimulation of these cells could equally be generated by thermal bone necrosis [11] or by micro mobility of the graft [6]. Individual variability in the concentration of these cytokines could account for the variable frequency of widening [3].

The periosteal flap may use either or both these mechanisms for accelerating tendinous integration at the tunnel entry to reproduce direct anchorage in four layers. It seems that its biological role is of considerable importance since we rarely find a circular periosteal cover on the graft.

References

1. Aglietti P, Buzzi R, D'Andrias S, Zaccherotti G (1992) Long term study of anterior cruciate ligament reconstruction for chronic instability using the central one third patellar tendon and a extra-articular tenodesis. Am J Sports Med 20:38–45
2. Buelow J, Siebold R, Ellerman A (2002) Tunnel widening in ACL reconstruction using 3 fixation techniques. Knee Surg Sports Traumatol Arthrosc 10:80–85
3. Cameron M, Buchgraber A, Pässler H, Vogt M, Thonar E, Fu F, Evans C (1997) The natural history of the anterior cruciate ligament deficient knee. Changes in synovial fluid cytokine and keratan sulfate concentration. Am J Sports Med 25:751–754
4. Chih-Hwa Chen, Wen-Jen Chen, Chun-Hsiung Shih, Chung-Yeung Yang (2003) Enveloping of periosteum on the tendon to enhance tendon healing in a bone tunnel, a biomechanical and histological studies in rabbits. Arthroscopy 19:290-296
5. Clark R, Olsen RE, Larson BJ, Goble EM, Farrer FP (1998) Cross pin femoral fixation: a new technique for hamstring anterior cruciate ligament reconstruction of the knee. Arthroscopy 14:258–267
6. Clatworthy MG, Anner P, Bulow JU, Bartlett RJ (1999) Tunnel widening in anterior cruciate ligament reconstruction: a prospective evaluation of hamstring and patellar tendon grafts. Knee Surg Sports Traumatol Arthrosc 7:138-145
7. Clatworthy M, Buelow J, Pinczewski L, Howell, Fowler P (2001) Tunnel widening in hamstring ACL reconstruction: a prospective clinical and radiographic evaluation of four different techniques. Presented at ISAKOS meeting, Montreux, Switzerland, 14–18 May 2001
8. Colombet P, Allard M, Bousquet V, Delavigne C, Flurin PH (2000) Histological analysis of hamstring tendons in ACL reconstruction. Presented at the French Arthroscopic Society, Annecy, France, 9–11 December 2000
9. Edwards DJ, Hoy G, Saies AD, Hayes MG (1994) Adverse reactions to an absorbable shoulder fixation device. J Shoulder Elbow Surg 3:230–233
10. Eriksson K, Kindblom L G, Wredmark T (2000) Semitendinosus tendon graft ingrowth in tibial tunnel following ACL reconstruction, a histological study of two patients with different types of early graft failure. Acta Orthop Scand 71:275–279
11. Fahey M, Indelicato PA (1994) Bone tunnel enlargement after anterior cruciate ligament replacement. Am J Sports Med 22:410–414
12. Fink C, Zapp M, Benedetto K, Hackl W, Hoser C, Rieger M (2001) Tibial tunnel enlargement following anterior cruciate ligament reconstruction with patellar tendon autograft. Arthroscopy 17:138–143
13. Grana W, Egle D, Mahnken R, Goodhart E (1994) An analysis of autograft fixation after anterior cruciate ligament reconstruction in a rabbit model. Am J Sports Med 22:344–351
14. Harner C, Jamison J, Thomson W (1994) The immunologic response to fresh frozen patellar tendon allograft anterior cruciate ligament replacement. Presented at AOSS meeting 1994
15. Hattersley G, Cox K, Soslowsky LJ (1998) Bone morphogenetic proteins 2 and 12 alter the attachment of tendon to bone: a histological and biomechanical investigation. Trans Orthop Res Soc 23:96–100
16. Höher J, Möller HD, Fu F (1998) Bone tunnel enlargement after anterior cruciate reconstruction: fact or fiction? Knee Surg Sports Traumatol Arthrosc 6:231–240
17. Ishibashi Y, Rudy T, Livesay G, Stone J, Fu F, Woo S (1997) The effect of anterior cruciate ligament graft fixation site on the knee stability. Arthroscopy 13:177–183
18. Jackson DW, Windler GE, Simon TM (1990) Intraarticular reaction associated with the use of freeze dried, ethylene oxide sterilized bone patella tendon bone allografts in the reconstruction of anterior cruciate ligament. Am J Sport Med 18:1–11
19. Jansson KA, Harilainen A, Sandelin J, Karjalainen PT, Aronen HJ, Tallroth K (1999) Bone tunnel enlargement after anterior cruciate ligament reconstruction with the hamstring autograft and endobutton fixation technique. Knee Surg Sports Traumatol Arthrosc 7: 290–295
20. Jasty M (1993) Clinical reviews: particulate debris and failure of total hip replacement J Biomater Appl 4:273–276

21. Kernwein G (1942) A study of tendon implantations into bone. J Gynecol Obstet 75:794–796
22. Kurosaka M, Yoshiya S, Andrish J (1987) A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction Am J Sports Med 15: 225–229
23. L'Insalata JC, Klatt B, Fu FH, Harner CD (1997) Tunnel expansion following anterior cruciate ligament reconstruction. A comparison of hamstring and patellar tendon autografts. Knee Surg Sports Traumatol Arthrosc 5:234–238
24. Nebelung W, Ropke M, Becker R (1998) Bone tunnel enlargement after anterior cruciate ligament reconstruction with semitendinosus cruciate fixation on the femoral side. Arthroscopy 8:810–815
25. Niki Y, Matsumoto H, Suda Y, Otani T (2001) Metal ions induce bone resorptive cytokine production through the redox pathway in rheumatoid synoviocytes and bone marrow macrophages. Presented at ISAKOS meeting, Montreux, Switzerland, 14–18 May 2001
26. Petersen W, Laprell H (2000) Insertion of autologous tendon grafts to the bone: a histological and immunohistochemical study of hamstring and patellar tendon grafts. Knee Surg Sports Traumatol Arthrosc 8:26–31
27. Peyrache MD, Djian P, Christel P, Witvoet J (1996) Tibial tunnel enlargement after anterior cruciate ligament reconstruction by autogenous bone-patellar tendon-bone graft. Knee Surg Sports Traumatol Arthrosc 4:2–8
28. Pinczewski L, Clingeleffer A, Otto D, Bonar F, Corry I (1997) Integration of hamstring tendon graft with bone in reconstruction of the anterior cruciate ligament. Arthroscopy 5:641–643
29. Pinczewski L, Stange R, Russel V, Salmon L (2001) Tibial tunnel widening after ACL reconstruction: a 2 and 5 year comparison of patellar tendon autograft and 4 strands hamstring tendon autograft. Presented at ISAKOS meeting, Montreux, Switzerland, 14–18 May 2001
30. Robert H, Es Sayeh J, Passuti N, Heymann D, Eloit S, Vaneenoge E (2003) Hamstring insertion site healing after anterior cruciate ligament reconstruction in patients with symptomatic hardware or re-rupture; a histological study in 12 patients. Arthroscopy (in press)
31. Rodeo SA, Arnocsky SP, Torzilli PA, Hidaka C, Warren RF (1993) Tendon healing in a bone tunnel: a biomechanical and histological study in the dog. J Bone Joint Surg Am 75:1795–1803
32. Rodeo S, Suzuki K, Deng XH, Wozney J, Warren R (1999) Use of recombinant human bone morphogenetic protein-2 to enhance tendon healing in a tunnel bone. Am J Sports Med 27: 476–488
33. Scranton P, Lanzer W, Ferguson M, Kirkman T, Pflaster D (1998) Mechanism of anterior cruciate ligament neovascularisation and ligamentisation. Arthroscopy 14:702–716
34. Strobel MJ (2001) Manual of arthroscopic surgery. Springer, Berlin Heidelberg New York, pp 419–420
35. Thorson E, Rodrigo JJ, Vasseur P et al (1989) Replacement of the anterior cruciate ligament. A comparison of autografts and allografts in dogs. Acta Orthop Scand 60: 555–560
36. Webster KE, Feller JA, Hameister KA (2001) Bone tunnel enlargement following anterior cruciate ligament reconstruction: a randomised comparison of hamstring and patellar tendon grafts with 2 years follow up. Knee Surg Sports Traumatol Arthrosc 9:86–91
37. Weiler A, Hoffman RFG, Bail HJ, Rehm O, Südkamp NP (2002) Histological analysis after biodegradable interference screw fixation in a model of ACL reconstruction in sheep. Arthroscopy 18:124–135
38. Whiston TB, Walmsley R (1960) Some observation on the reaction on bone and tendon after tunneling of bone and insertion of tendon. J Bone Joint Surg 42:377–386
39. Yamazaki S, Yasuda K, Tomita F, Minami A, Tohyama H (2002) The effect of graft-tunnel diameter disparity on intraosseous healing on the flexor tendon graft in anterior cruciate ligament reconstruction. Am J Sports Med 30:498–505