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Anterior cruciate ligament reconstruction with fresh-frozen patellar tendon allografts: sixty cases with 2 years' minimum follow-up

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Abstract A prospective study was performed on 101 patients who underwent an arthroscopic anterior cruciate ligament (ACL) reconstruction with fresh-frozen patellar tendon allograft (bone-patellar tendon-bone). We present the results of the first 60 patients with a minimum follow-up of 2 years. Thirty-four were men and 26 women with a mean age of 23. In 45 patients, a postoperative arthroscopy was performed, and tissue biopsies of the reconstructed ACL were obtained. Patients were evaluated according to the International Knee Documentation Committee evaluation form. After a mean follow-up of 47 months, the overall results were normal or nearly normal in 85%. Under postoperative arthroscopy, the macroscopic appearance of the implant was similar to that of a normal ligament. The ACL allograft was covered with a normal, well-vascularized synovium. There were no cases of infection, disease transmission or tissue rejection. We conclude that the use of fresh-frozen patellar tendon allografts is a good method of ACL reconstruction.

Key words Anterior cruciate ligament reconstruction · Allograft

Introduction

Conservative treatment of anterior cruciate ligament (ACL) lesions often leads to recurrent episodes of giving way, meniscal damage, osteoporosis and osteoarthritis of the knee [23, 26, 27]. There is consensus that surgical treatment is convenient, but which surgical reconstructive procedure is the best is still controversial [26]. Although bone-patellar tendon-bone autograft has been considered the gold standard for ACL reconstruction, recent studies have shown no significant clinical differences in outcome in patients who received an autograft compared with those who received an allograft [15]. Besides, there are several disadvantages in the use of patellar tendon autograft, such as relative loss of flexion, limited extension, quadriceps weakness and anterior knee pain [13, 24, 38, 45]. The use of allografts eliminates donor tissue site morbidity, reduces surgical time, permits smaller incisions, is associated with a lower incidence of postoperative arthrofibrosis [15, 18, 21, 32, 38, 44]; but it raises potential disadvantages including inmunogenicity, the potential for disease transmission, possibly slower incorporation and cost effectiveness in ACL reconstruction [21]. This paper presents our experience with fresh-frozen patellar tendon allografts (bone-patellar tendon-bone) in patients who require either an ACL substitution or reinforcement.

Materials and methods

Between 1988 and 1996, 101 patients underwent ACL reconstruction at the University Clinic of Navarra using fresh-frozen, nonirradiated allograft tissue. All had ACL-deficient knees that were unstable during sports and/or activities of daily living. All the ACL reconstructions were performed by one surgeon (J.V.N.). The first 60 patients with a minimum follow-up of 2 years (range 24–78 months) were included in this prospective study. All patients were told of the origin of the graft, and then informed consent was obtained. Laboratory tests were carried out as required by current Spanish legislation [2]. Thirty-four were men and 26 women with a mean age of 23 (range 16–32) at the time of ACL reconstruction.

We performed acute surgery in 4 patients and delayed surgery in 56. All patients followed a strict protocol with preoperative evaluation and monthly postoperative review during the first 6 months, at 6 and 12 months, and then yearly. Fifty-five patients sustained their injury during sports, 25 while playing soccer, 19 skiing, 5 playing basketball, 2 during gymnastics, 2 playing handball, 1 during athletics, and 1 while practising judo. Five were injured at work, at home or during leisure. Twenty patients (33.3%) had undergone a previous arthroscopy, and 12 (20%) a previous failed ACL reconstruction.

Anterior translation was assessed manually by the same physician with the Lachman's test at 25° and anterior posterior translation at 70° flexion. Rotatary instability was examined by pivot shift and reverse pivot shift tests. Instrumented measurement of anterior translation of the knee was not done because an arthrometer was not available at the time this study was conducted. The active and passive range of motion were assessed using standard goniometric technique.

Weight-bearing radiographs were taken, and a preoperative radiographic Lachman's test was carried out. In 30 patients a magnetic resonance imaging was also undertaken. In 45 patients arthroscopy was performed 10–36 months after surgery to obtain arthroscopic assessment and biopsies of the reconstructed ligament.

Operative technique

The patellar tendon allograft (bone-patellar tendon-bone) was stored in a freezer at –90° C, changing to –40° C the day before the operation. The tendinous part of the graft was 1 cm wide. Immediately before use, a stainless steel wire suture was inserted into both ends of the graft, and the two bone plugs were shaped with a small oscillating saw. Arthroscopy was performed in every case to evaluate the ACL and to treat any associated meniscal or cartilaginous lesions. The graft was implanted by arthroscopy alone in the last 40 patients, and in the remaining 20 a miniarthrotomy was performed. We used the two-incision 'rear entry' technique [10]. We tried to preserve the remaining fibers of the ACL to help revascularisation of the graft. Fixation was achieved by tying the wire suture over a screw and washer distally. The proximal bone plug was cut into a conical shape, allowing bone-to-bone wedge fixation so that the proximal screw was unnecessary.

Postoperative care and rehabilitation

Antibiotics were given routinely with cefazolin 1 g ever 7 hours intravenously for the first 3 days and cefradoxyl every 8 hours orally for the next 4 days. A postoperative knee brace locked at 15° flexion was applied for 7 days, then active exercises were begun wearing the hinged functional brace to prevent hyperextension for 3 months. Rehabilitation was carried out for 2 months after the operation by a physiotherapist in a special centre and included active and passive exercises, electrical muscle stimulation and progressive weight-bearing as tolerated. Patients ambulated with crutches for the first 8 weeks. After 3–6 months depending on the strength of the quadriceps muscle, swimming, cycling, and jogging were permitted. After 1 year, any sport was allowed provided there was no pain or restriction of movement.

Criteria for evaluation

The follow-up evaluation was conducted according to the guidelines of the International Knee Documentation Committee [16]. The findings of the second-look arthroscopy were also assessed. The graft was considered normal when it was well oriented, with adequate thickness, tension, vascularization, and synovialization. It was considered nearly normal when there was adequate tension and at least 75% of the fibers were well oriented, with normal vascularization and synovialization. When there was inadequate tension or more than 25% of the fibers were abnormal, the graft was considered abnormal, and in the case of absence of rupture of the graft, it was considered severely abnormal.

Results

The final evaluation, following the IKDC guidelines, showed 30 normal knees (50%), 21 nearly normal (35%), 8 abnormal (13.3%), and 1 severely abnormal (1.7%) (Table 1). Subjective evaluation revealed normal knees in 36 patients (60%), nearly normal in 17 (28.3%), abnormal in 7 (11.7%), and poor in 0. The patients rated their symptoms by indicating the highest level of activity they could do before symptoms appeared (Table 2).

Thirty-three patients (55%) had undergone a meniscal repair prior to or during ACL reconstruction. The overall results of these patients are shown in Table 3.

At later follow-up evaluation, nine patients (15%) had moderate patellofemoral crepitus, and the only patient who had preoperative moderate patellofemoral crepitus developed mild patellofemoral pain.

One patient presented with 8° lack of extension, 5 patients with a lack of flexion between 6° and 15°, and one patient who developed arthrofibrosis presented with 35° lack of flexion. In three cases, manipulation of the knee under anesthesia was necessary due to lack of flexion. Two of those patients achieved a full range of motion, and one did not improve with manipulation, with a persisting lack of flexion of 35° and lack of extension of 8°. This patient underwent an open arthrolysis.

Table 1 Rating according to International Knee Documentation Committee guidelines

	n
Rating	
Normal	30 (50%)
Nearly normal	21 (35%)
Abnormal	8 (13.3%)
Severely abnormal	1 (1.7%)
Frequency of abnormal rating	
Subjective	7
Symptoms	2
Range of motion	0
Laxity	7
One patient had a severely abnormal range of motion	
Number of abnormal categories per patient	
None	51
1	3
2	3
3	2
4	0
One patient had one severely abnormal category	

Table 2 Symptoms

	n
Highest level of activity without pain	
Strenuous sports activities	41
Moderate sports activites	17
Light sports activities	2
Activities of daily living (ADLs)	0
Highest level of activity without swelling	
Strenuous sports activities	46
Moderate sports activities	12
Light sports activities	2
ADLs	0
Highest level of activity without partial giving-way	
Strenuous sports activities	45
Moderate sports activities	14
Light sports activities	1
ADLs	0
Highest level of activity without complete giving-way	
Strenuous sports activities	48
Moderate sports activities	11
Light sports activities	1
ADLs	0

Table 3 Results with and without associated meniscal lesion

IKDC rating	Intact meniscus	1/3 partial meniscectomy
Normal	15 (55.6%)	15 (45.5%)
Nearly normal	10 (37%)	11 (33.3%)
Abnormal	1 (3.7%)	7 (21.2%)
Severely abnormal	1 (3.7%)	0

Table 4 Manual ligament evaluation (– no translation, + less than 10 mm AP translation, firm endpoint, ++ less than 10 mm AP translation, soft endpoint, +++ more than 10 mm AP translation)

Preoperative		Postoperative			
Lachmann (25° flexion)		–	+	++	+++
+++	2	1		1	
++	24	14	5	5	
+	34	28	6		
Total anteroposterior translation (70° flexion)					
+++	5	2	3		
++	36	17	15	4	
+	19	13	6		
Pivot shift		Equal	Glide	Marked	Gross
Gross	2	1		1	
Marked	24	14	5	5	
Glide	34	28	6		

Table 5 Sports activity level: preoperatively vs postoperatively

Intensity (level of activity)		0	LRS	VRS	CS
Light recreational sports (LRS)	26	1	24		1
Vigorous recreational sports (VRS)	22			21	1
Competitive sports (CS)	12			3	9
Occupational	–				

The results of manual ligament evaluation and sports activity level are shown in Tables 4 and 5, respectively. Between 10 months and 3 years after surgery, 45 patients had the distal screw removed, and at the same time an arthroscopy was performed. The ACL allograft appeared to be covered with normal, well-vascularised synovium which was hypervascularised at the ends compared with the middle part of the graft. Most of the graft's bundles were well oriented and under good tension. Histologically, there were viable fibroblasts and blood vessels interspersed between well-organised collagen bundles. The overlying synovium did not show any evidence of inflammation. On this second-look arthroscopy 20 grafts were normal (44.4%), 20 nearly normal (44.4%), 5 abnormal (11.2%), and none severely abnormal. The five patients with abnormal arthroscopic findings presented with an abnormal IKDC rating. Three patients with nearly normal grafts presented with an abnormal IKDC rating. The only patient who achieved a severely abnormal result had developed a severe postoperative arthrofibrosis that required arthrolysis. None of the patients had undergone a second reconstruction of the ACL during the follow-up period, and there were no cases of infection or rejection.

Discussion

Soft-tissue allografts are an attractive alternative treatment for ligamentous lesions in the knee and other joints, provided they are available and their sterile preservation can be assured. Disease transmission must be avoided, and remodelling anticipated without loss of the ligament's mechanical properties. In our center we harvest our own bone and soft-tissue grafts from multiorgan donors under strict sterile conditions [3]. Unprotected allografting without any screening puts the risk of human immunodeficiency virus (HIV) transmission at 1:161 [5]. Use of the available screening tools lowers the estimated risk to 1:1 667 600 [5]. Nevertheless, it is important that both the donor and host be carefully selected.

The role of radiation for tissue sterilization and HIV eradication is controversial [37]. The American Association of Tissue Banks currently recommends a dose of 2.5 megarads for sterilization of soft-tissue allografts [1]. However, Fideler et al. [11] reported that 3.0 megarads are needed to completely inactivate HIV in bone-patellar ligament-bone allografts, and Conway et al. [7] postulates

the need for 3.6 megarads to kill free viruses and larger doses yet for intracellular viruses. On the other hand, gamma-irradiation alters collagen structural and tensile strength, decreasing the graft stiffness and maximum force [35] in a dose-dependent fashion [6, 12, 34]. The long-term mechanical properties of bone-patellar tendon-bone allografts after gamma-irradiation remain to be investigated [29].

Ethylene oxide sterilization produces acute and chronic synovial reaction with bone resorption, large cyst formation, and eventually complete dissolution of the graft [6, 8, 12, 19, 21, 35, 36].

Freezing and to a lesser extent freeze-drying of fresh sterile allografts do not alter the mechanical properties of the implant [8, 9, 17]. Clinical studies have shown better results with fresh-frozen allografts than freeze-dried allografts [17].

Studies reported by different authors confirm that the bone-patellar tendon-bone graft has good mechanical properties, and it is the preferred method of treating ACL lesions [50]. Its firm fixation in a bony tunnel allows as early rehabilitation as any type of synthetic implant [31]. There are very few experimental [44, 46, 47, 49] and clinical studies [15, 24, 28, 29, 44, 48] that could determine whether there is any difference in the mid- and long-term results between autografts and allografts. Harner et al. [15] found no significant differences in outcome.

Even though data obtained from animal models suggest that the phases of biologic remodelling may progress more rapidly in autografts than in allografts [21], we have found in an experimental study in lambs that 1 year after the operation there are no significant differences in mechanical properties, macroscopical and microscopical appearances, and final clinical outcome between the two groups [39].

The minimum follow-up of 2 years in our series seems adequate since graft maturity is attained 18 months after implantation [42]. Our results of fresh-frozen patellar tendon allografts are satisfactory when compared with data reported using other techniques and implants [15], particularly considering that 87% of our patients had chronic ACL lesions which have a worse outcome than acute injuries [18, 31, 38]. Our 85% normal and nearly normal results using allografts is similar to the 80% good results reported by Jackson et al. [19], the 88% reported by Shino et al. [43] and the 90% of Indelicato et al.'s series [17], even though they did not use the IKDC rating system. Our overall failure rate with the allograft was 15%, similar to the 14% reported by Noyes and Barber [30].

An instrumented arthrometer to measure anterior-posterior laxity was not available, and thus we could not perform an objective evaluation. There are inconsistencies in manual testing, but experienced clinicians have reported a high rate of accuracy in evaluation of the anterior-posterior laxity of the knee with the Lachman test [22].

In our series, only one patient had a lack of extension at follow-up. Harner et al. [13, 14] have found a statistically significant difference, with a higher incidence of loss of terminal extension in the autograft group over the allograft group. In his series, the mean loss of active extension in patients receiving an autograft was 3° compared with 1.2° for patients receiving an allograft.

Nine patients (15%) had moderate patellofemoral crepitus and one patient patellofemoral crepitation with mild pain at later follow-up evaluation. In Noyes and Barbers [30] series after a mean follow-up of 7 years, 24% of the patients had moderate crepitus and 1% severe crepitus. Patellofemoral crepitus after ACL reconstruction could be secondary to the effects of the initial injury, the operative procedure or the effects of disuse [30]. Although moderate crepitus was not associated with symptoms, it may eventually lead to pain and a reduction of the level of activity [30, 36]. Some authors have advocated the use of close-kinetic-chain exercises and avoidance of both stationary cycling and progressive resistance exercises with heavy weights to decrease patellofemoral pain [25, 30].

Even though there were more abnormal results in the group with partial meniscectomy, the statistical analysis of the percentages of abnormal knees in each group (chi-square) showed no statistically significant differences. The finding that the state of the menisci had no influence on the final outcome of our knees could be due to the fact that at least two-thirds of the meniscus were preserved in the patients who had undergone meniscectomy.

In our patients, there has been no clinical evidence of inmunological reaction to the graft. Fresh-freezing at –90° C and at –180° C in liquid nitrogen markedly dimishes cellular inmunogenicity [39, 40].

The results of the second-look arthroscopy should be interpreted with caution due to the different lengths of follow-up of the patients at the time it was performed (range 10 to 36 months). Nevertheless, there was a correlation between abnormal arthroscopic findings and abnormal IKDC score. Our arthroscopic findings of the allograft 18 months after implantation indicated that the appearance of the implant was similar to that of a normal ligament after 1 year. There was an initial slight decrease in vascularization in the middle part of the graft; this finding has also been reported by others [2, 21]. The vascular pattern becomes normal after 1 year [21]. The lack of inflammatory response found in histological specimens could be related to the freezing process, which denatures cell surface marker proteins and disrupts cell membranes, thereby reducing antigenicity [4].

The patients were assessed from a functional point of view, which is important since the aim of the procedure is to enable the patient to return to sport at the same level as before injury. Allografts are currently our graft of choice for ACL reconstruction procedure. Success is based on the principles which apply to all ACL reconstructions with autograft, namely the correct size and width of the implant, isometric placement and stable flexion with bone plugs, and early mobilization.

References

1. American Association of Tissue Banks (1987) Standards for bone banking. American Association of Tissue Banks, McLean, Virginia
2. Amiel D, Kleiner JB, Roux RD, Harwood FL, Akeson WH (1986) The phenomenon of ligamentization: anterior cruciate ligament reconstruction with autogenous patellar tendon. J Orthop Res 4:162–172
3. Amillo S, Cara JA, Valentí JR (1990) Bance de huesos del sistema musculoesquelético: aplicaciones clínicas. Rev Med Univ Nav 34:227–234
4. Arnoczky S, Warren P, Ashlock M (1986) Replacement of the anterior cruciate ligament using a patellar tendon allograft. J Bone Joint Surg [Am] 68:376–385
5. Buck BE, Malinin TI, Brown MD (1989) Bone transplantation and human immunodeficiency virus: an estimate of risk of acquired immunodeficiency syndrome (AIDS). Clin Orthop 251:249–253
6. Butler D (1991) Irradiation of 2Mrad or less is safe for sterilizing allograft ligaments; but 3 Mrad irradiation weaken tissues. Am J Sports Med 19: 7–11
7. Conway B, Tomford WW, Hirsch MS (1990) Effects of gamma irradiation on HIV-1 in a bone allograft model. Trans Orthop Res Soc 15:225–230
8. Curtis R, De Lee J, Drez D (1985) Reconstruction of the anterior cruciate ligament with freeze dried fascia lata allografts in dogs: a preliminary report. Am J Sports Med 13:408–414
9. Drez D, De Lee J, Holden J, Arnoczky S, Noyes F, Roberts T (1991) Anterior cruciate ligament reconstruction using bone-patellar tendon-bone allografts: a biological and biomechanical evaluation in goats. Am J Sports Med 19: 256–263
10. Fahey M, Indelicato PA (1994) Bone tunnel enlargement after anterior cruciate ligament replacement. Am J Sports Med 22:410–414
11. Fideler BM, Vangsness CT Jr, West HS Jr, Moore T, Li Z, Rasheed S (1994) Effects of gamma irradiation on the human immunodeficiency virus. A study in frozen human bone-patellar ligament-bone grafts obtained from infected cadavera. J Bone Joint Surg [Am] 76:1032–1035
12. Gibbons MJ, Butler DL, Grood ES, Bylski-Austrow DI, Levy MS, Noyer FR (1991) Effects of gamma irradiation on the initial mechanical and material properties of goat bone-patellar tendon-bone allografts. J Orthop Res 9:209–218
13. Harner CD, Irrgang JJ, Paul J, Dearwater S, Fu F (1992) Loss of motion after anterior cruciate ligament reconstruction. Am J Sports Med 20:499–506
14. Harner CD, Marks PH, Fu FH, Irrgang JJ, Silby MB, Mengato R (1994) Anterior cruciate ligament reconstruction: endoscopic versus two-incision technique. Arthroscopy 10:502–512
15. Harner CD, Olson E, Irrgang JJ, Silverstein S, Fu FH, Silbey M (1996) Allograft versus autograft anterior cruciate ligament reconstruction: 3-to-5 year outcome. Clin Orthop 324:134–144
16. Hefti F, Mueller W, Jacob RP, Staubli HU (1993) Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1:226–234
17. Indelicato P, Bittar E, Prevot T, Woods G, Branch T, Huegel M (1990) Clinical comparison of freeze-dried and fresh frozen patellar tendon allografts for ACL reconstruction of the knee. Am J Sports Med 18:335–342
18. Indelicato PA, Linton RC, Hueggel M (1992) The results of fresh frozen patellar tendon allografts for chronic anterior cruciate ligament deficiency of the knee. Am J Sports Med 18:335–342
19. Jackson DW, Windler G, Simon T (1990) Intraarticular reaction associated with the use of freeze dried, ethylene oxide-sterilized bone-patellar tendon-bone allografts in the reconstruction of the anterior cruciate ligament. Am J Sports Med 18:1–10
20. Jackson DW, Rosen M, Simon TM (1992) Soft tissue allograft reconstruction: the knee. In: Czitrom AA, Gross AE (eds) Allografts in orthopaedic practice. Williams and Wilkins, Baltimore, pp 197–216
21. Jackson DW, Corsetti J, Simon TM (1996) Biologic incorporation of allograft cruciate replacements. Clin Orthop 324:126–133
22. Jonsson T, Althoff B, Peterson L, Renstrom P (1982) Clinical diagnosis of ruptures of the anterior drawer sign. Am J Sports Med 10:100–102
23. Kannus P, Jarvinen M (1987) Conservatively treated tears of the anterior cruciate ligament: long term results. J Bone Joint Surg [Am] 67:1007–1012
24. Kleipool A, Van Loon T, Marti R (1994) Pain after use of the central third of the patellar tendon for cruciate ligament reconstruction. Acta Orthop Scand 65:62–66
25. Lutz GE, Palmitier RA, An KN, Chao EYS (1993) Comparison of tibiofemoral joint forces during open-kinetic-chain and closed-kinetic-chain exercises. J Bone Joint Surg [Am] 75:732–739
26. McDaniel WR, Dameron TB Jr (1980) Untreated ruptures of the anterior cruciate ligament: a follow up study. J Bone Joint Surg [Am] 62:696–705
27. Natri A, Jarvinen M, Lehto M, Kannus P (1996) Reconstruction of the chronically insufficient anterior cruciate ligament. Long term results of the Eriksson procedure. Int Orthop 20:28–31
28. Nikolau PK, Seaber AV, Gilsson RR, Ribbeck BM, Bassett FH (1986) Anterior cruciate ligament allograft transplantation: long term function, histology, revascularization and operative technique. Am J Sports Med 14:328–360
29. Noyes F, Barber S (1996) Revision anterior cruciate ligament surgery: experience from Cincinnati. Clin Orthop 325:116–129
30. Noyes F, Barber S (1996) Reconstruction of the anterior cruciate ligament with human allograft. Comparison of early and later results. J Bone Joint Surg [Am] 74:524–537
31. Noyes F, Barber S, Mangine R (1990) Bone-patellar-bone and fascia lata allografts for reconstruction of the anterior cruciate ligament. J Bone Joint Surg [Am] 72:1125–1136
32. Olson EJ (1993) Use of soft tissue allografts in sports medicine. Adv Oper Orthop 1:111–128
33. Paulos LE, France EP, Rosemberg TD (1987) Comparative material properties of allograft tissues for ligament replacement. Effect of type, age, sterilization, and preservation. Trans Orthop Res Soc 12:129–135
34. Pelker RP, Friedlander GE, Markham TC (1983) Biomechanical properties of bone allografts. Clin Orthop 174:54–57
35. Rasmussen TJ, Feder SM, Butler DL, Noyes FR (1994) The effects of 4 MRad of gamma irradiation on the initial mechanical properties of bone-patellar tendon-bone grafts. Arthroscopy 10:188–197
36. Roberts TS, Drez D, McCarthy W (1991) Anterior cruciate ligament reconstruction using freeze-dried, ethylene-oxide-sterilized bone-patellar tendon-bone allografts. Two year results in 36 patients. Am J Sports Med 19: 35–41
37. Ruwe PA, Shields CL (1995) Allograft ACL reconstruction. Orthop Int 3: 207–211
38. Sachs RA, Daniel DM, Stone ML, Garfein RF (1989) Patellofemoral problems after anterior cruciate ligament reconstruction. Am J Sports Med 17:760–765

39. Sala D (1992) Reconstrucción del ligamento cruzado anterior de la rodilla con tendón rotuliano autólogo y homólogo crioconservado en fresco. Estudio experimental en ovejas. Doctoral thesis, University of Navarra, Pamplona, Spain
40. Sanchis V, Gomar F (1993) Sustitución del ligamento cruzado anterior mediante aloinjertos tendinosos crioconservados Comportamiento biológico del implante a nivel intraarticular. Estudio experimental. Rev Ortop Traum 37 (IB): 87–97
41. Shino K, Kawasaki T, Hirose H, Gotoh I, Inuoe M, Ono K (1984) Replacement of anterior cruciate ligament by an allogenic tendon graft: a experimental study in the dog. J Bone Joint Surg [Br] 66: 672–681
42. Shino K, Inoue M, Horibe S, Nagano J, Ono K (1988) Maturation of allograft tendons transplanted into the knee. J Bone Joint Surg [Br] 70: 556–560
43. Shino K, Inoue M, Nakamura H (1989) Arthroscopic follow-up of the anterior cruciate ligament reconstruction using allogeneic tendon. Arthroscopy 5: 165–171
44. Shino K, Nakata K, Inuoe M, Horibe S, Hamada M, Nakamura N, Toritsuka Y (1992) Quantiative evaluation following arthroscopic ACL reconstruction: autograft vs allograft. Abstract of the First World Congress of Sports Trauma, Spain
45. Shino K, Nakagava S, Inoue M, Horibe S, Yoneda M (1993) Deterioration of patellofemoral articular surfaces after anterior cruciate ligament reconstruction. Am J Sports Med 21: 206–211
46. Thorson E, Rodrigo J, Vasseur P, Sharkey N, Heitter D (1987) Comparison of frozen allograft versus fresh autologous anterior cruciate ligament replacement in the dog. Trans Orthop Res Soc 12: 65–70
47. Thorson E, Rodrigo J, Vasseur P, Sharkey N, Heitter D (1989) Replacement of ACL: a comparison of autografts and allografts in dogs. Acta Orthop Scand 60: 555–560
48. Uribe JW, Hechtman KS, Kvijac JE, Tjin-A-Tsoi EW (1996) Revision anterior cruciate ligament surgery: experience from Miami. Clin Orthop 325: 91–99
49. Vasseur PB, Rodrigo UJ, Stevenson S, Clark G, Shonkey N (1987) Replacement of the anterior cruciate ligament with a bone-ligament-bone anterior cruciate ligament allograft in dogs. Clin Orthop 219: 268–277
50. Woo SL, Hollis JM, Adams DS (1991) The tensile properties of human femur-anterior cruciate ligament-tibia complex. Am J Sports Med 19: 217–225