Knee Surg, Sports Traumatol, Arthrosc
(1999) 7 : 20–24

Jüri Kartus
Sven Lindahl
Kristina Köhler
Ninni Sernert
Bengt I. Eriksson
Jon Karlsson

Serial magnetic resonance imaging of the donor site after harvesting the central third of the patellar tendon

A prospective study of 37 patients after arthroscopic anterior cruciate ligament reconstruction

Received: 3 March 1998
Accepted: 28 May 1998

J. Kartus (✉) · K. Köhler · N. Sernert
Department of Orthopaedics,
Northern Älvsborg/Uddevalla Hospital,
SE-46185 Trollhättan, Sweden
e-mail: juri.kartus@trollhattan.mail.telia.com
Fax: +46-520-917 01

S. Lindahl
Department of Diagnostic Radiology,
Northern Älvsborg/Uddevalla Hospital,
Trollhättan, Sweden

B. I. Eriksson · J. Karlsson
Department of Orthopaedics,
Sahlgrens University Hospital,
Göteborg, Sweden

Abstract The aim of this prospective study was to follow the development of repair tissue in the donor-site area using serial magnetic resonance imaging (MRI) evaluation and to assess whether the MRI findings were correlated with donor-site morbidity. Thirty-seven consecutive patients with unilateral anterior cruciate ligament injuries undergoing elective reconstruction of the ligament were included in the study. They were aged 27 (range 14–50) years. The graft was harvested through two 25-mm vertical incisions with the aim of protecting the infrapatellar nerve and sparing the paratenon. The tendon defect was left open. The patients underwent MRI evaluation at 6 weeks, 6 months and 27 months postoperatively. A final clinical follow-up was made 25 (range 23–29) months postoperatively. MRI demonstrated that the donor-site gap, i.e. the area corresponding to a pathological non-tendinous-like tissue signal, was 9 (range 4–18) mm at 6 weeks, 5 (range 2–14) mm at 6 months and 2 (range 0–5) mm at 27 months. The size of the donor-site gap had significantly decreased at 6 months compared with 6 weeks ($P = 0.0001$), as well as at 27 months compared with 6 months ($P = 0.0001$). We conclude that the patellar tendon at the donor site healed gradually, as expressed by a decrease in the area of non-tendinous-like tissue signal on the serial MRI evaluations.

Key words Donor site morbidity · Anterior cruciate ligament · Magnetic resonance imaging

Introduction

Donor-site morbidity is the most common problem after anterior cruciate ligament (ACL) reconstruction using patellar tendon autografts [7, 11, 13]. Local tenderness, loss of sensitivity and inability to kneel or knee-walk is present in 40%–60% of these patients [2, 6]. We have previously reported that donor-site morbidity as assessed by the knee-walking test is correlated with a loss of anterior knee sensitivity as well as a deficit in the full range of motion (ROM) [5, 6]. In a magnetic resonance imaging (MRI) analysis of 31 patients assessed 2 years after ACL reconstruction using patellar tendon autograft, we found that only one patient demonstrated a completely healed donor-site area with a tendinous-like tissue signal [6]. Rosenberg et al. [10] have shown using both MRI (5 patients) and computed tomography (CT; 10 patients) that the donor site 12–24 months after harvest evidenced a persistent defect and significant scar formation. Nixon et al. [8] made single MRI evaluations of 14 patients between 6 weeks and 2 years postoperatively and found that the size of the defect and the intensity of the signal in the central third of the tendon decreased over time. In their study, two patients underwent MRI 2 years postoperatively. Their study revealed that the defect was indistinguishable from normal tendon.

In our previous MRI study, all the grafts were harvested through a central 70-mm-long skin incision, splitting the paratenon along its entire length [5]. In a previous

dissection study, we showed that it is possible to harvest the central third of the patellar tendon through two 25-mm vertical incisions, leaving the infrapatellar nerve and the major part of the paratenon intact (Kartus et al., manuscript submitted). Weinstabl et al. [15] have shown that blood vessels supplying the patellar tendon pass through the paratenon. An intact paratenon could thus be beneficial to the healing of the donor site. Our hypothesis was that by sparing the paratenon, the healing of the donor-site area is enhanced, so that it gradually regains the appearance of tendinous-like tissue signal on MRI. The aim of this study was to follow the development of the repair tissue in the donor-site area using serial MRI evaluations and to assess whether the MRI findings were correlated with donor-site morbidity.

Patients and methods

Thirty-seven patients (25 men and 12 women) with unilateral ACL rupture underwent elective reconstruction of the ligament using patellar tendon autograft and interference screw fixation. The age of the patients at the time of the reconstruction was 27 (range 14–50) years, and the index operation was performed 12 (range 2–192) months after the injury. The preoperative evaluation, as well as the final follow-up, was performed by an independent observer 25 (range 23–29) months after the reconstruction. The preoperative evaluation and the final follow-up were based on the Lysholm score, Tegner activity level and the IKDC evaluation system [4, 14]. Functional performance was evaluated with the one-leg hop test [4]. Special attention was paid to donor-site morbidity, which was evaluated with the knee-walking test and measurement of loss of sensitivity [5, 6].

MRI examination

Apart from one woman who was pregnant at the 6-month assessment, all the patients underwent three serial MRI evaluations at 6 (range 5–10) weeks, 6 (range 6–8) months and 27 (range 24–29) months after the index operation. The contralateral non-harvested patellar tendon was only assessed at 6 (range 5–10) weeks. The examination was performed with a Siemens Magnetom 1.0 Tesla using a flexible knee-coil method. A three-dimensional DESS sequence was employed, with TR 26.8, TE 9.0 ms. The field of view was 200 × 200, with a matrix of 256 × 256. A three-dimensional reconstruction program was used to obtain axial reconstructions from which a value for the width and thickness was calculated through the mid-point along the length of the patellar tendon from the apex of the patella to the tibial tubercle. On the operated side, the same mid-point of the patellar tendon was then evaluated for gap size (area corresponding to non-tendinous-like tissue signal) in the axial dimension. All measurements were made using a Siemens evaluation unit with the help of computerized distance measurements during the standardized setting of window level and window centre. All the MRI assessments were made by an experienced, unbiased radiologist. The intraobserver variation was ± 1 mm, as assessed by re-evaluating 10 randomly selected examinations without knowledge of the primary result. There was no (± 0 mm) intrapatient variation as assessed by comparing 10 randomly selected contralateral normal patellar tendons examined at 6 weeks and 6 months postoperatively.

Surgical procedure

One experienced arthroscopic surgeon performed all the reconstructions, using the all-inside technique, bone-patellar tendon-bone autograft and interference screw fixation. A 10-mm-wide central third of the patellar tendon was consistently harvested from the ipsilateral knee through two 25-mm vertical incisions using a subcutaneous tunnelling technique, in order to spare the infrapatellar nerve and the paratenon, as described in our dissection study [Kartus et al., manuscript submitted]. The donor-site gap was left open, and the two 25-mm vertical incisions in the paratenon and the skin were closed. All associated intra-articular injuries such as meniscal ruptures were addressed at the time of the index operation.

Rehabilitation

The patients were rehabilitated following a standardized protocol [12]. Early weight-bearing was encouraged, as well as full range of active motion training. Running was permitted after 3 months and contact sports after approximately 6 months. No rehabilitation brace was used.

Statistical analysis

Median (range) values are presented. Wilcoxon's rank sum non-parametric test was used for comparisons between the longitudinal observations in the cohort. Spearman's rank correlation test was used to test the correlations between the parameters. A *P*-value of less than 0.05 was considered statistically significant. The changes in the donor site as shown on the serial MRI evaluations were considered as the primary variables.

Results

At the 2-year follow-up, the Lysholm score, Tegner activity level, one-leg hop test, objective stability as measured with the KT-1000 and the IKDC evaluation system all revealed a significant improvement compared with the preoperative values (Table 1).

MRI revealed that the donor-site gap was 9 (range 4–18) mm at 6 weeks, 5 (range 2–14) mm at 6 months and

Table 1 Using the standard evaluation systems at the 2-year follow-up, a significant improvement was registered compared with the preoperative values

	Preoperative	Two-year follow-up	Significance
Lysholm score	69 (52–86) points	88 (44–99) points	$P = 0.0001$
Tegner activity level	3 (2–8)	7 (2–9)	$P = 0.0001$
One-leg hop test	85% (0%–110%)	96% (68%–132%)	$P = 0.0001$
KT-1000 total side-to-side difference	4 (–2.5–8.5) mm	3 (–7–10)mm	$P = 0.05$
IKDC normal/nearly normal	0/37 patients	24/37 patients	$P < 0.001$

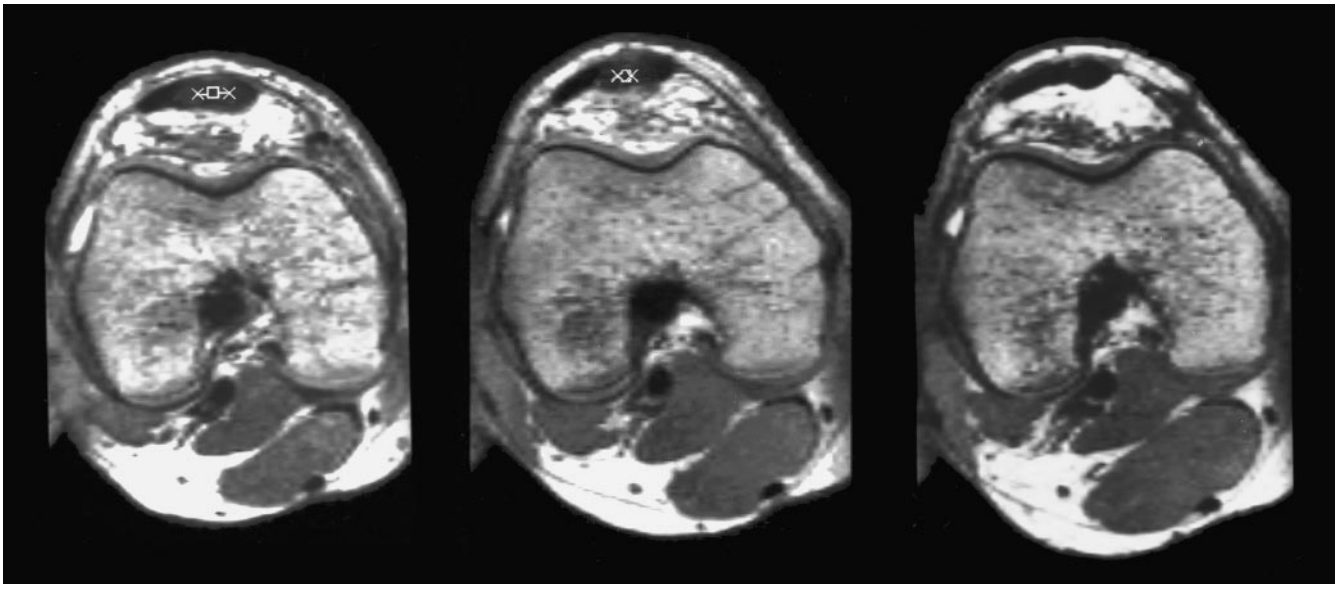

Fig. 1 Serial magnetic resonance imaging evaluations of the patellar tendon in the axial dimension demonstrating the donor-site gap at 8 weeks (7 mm), at seven months (2 mm) and at 24 months (completely healed) in this 19-year-old male patient

Table 2 The donor-site gap decreased significantly with time (P = 0.0001, 6 weeks vs 6 months; P = 0.0001, 6 months vs 27 months). The thickness of the donor site decreased with time (P = 0.008, 6 weeks vs 6 months; P = 0.0006, 6 months vs 27 months). The width of the donor site decreased with time (P = 0.02, 6 weeks vs 6 months; P = 0.004, 6 weeks vs 24 months). The width and thickness of the index side increased significantly compared with the normal contralateral side, regardless of whether the MRI assessment was made at 6 weeks, 6 months or 27 months after reconstruction ($P \leq 0.0002$)

	Contralateral side at 6 weeks (mm)	Index side at 6 weeks (mm)	Index side at 6 months (mm)	Index side at 27 months (mm)
Gap	No gap	9 (4–18)	5 (2–14)	2 (0–5)
Thickness	5 (3–8)	8 (5–12)	7 (6–12)	6 (4–9)
Width	29 (20–35)	33 (23–44)	32 (23–48)	31 (24–38)

2 (range 0–5) mm at 24 months. The size of the donor-site gap had significantly decreased at 6 months compared with 6 weeks (P = 0.0001), as well as at 27 months compared with six months (P = 0.0001) (Fig. 1). The thickness and the width of the donor-site patellar tendon decreased compared with baseline (6-week assessment), although both had significantly increased compared with the non-harvested contralateral patellar tendon (Table 2).

The median loss of anterior knee sensitivity was 0 (range 0–285) cm^2, excluding four patients with concomitant or previous incisions in the anterior knee region. No loss of sensitivity (0 cm^2) was registered in 19/33 (58%) patients.

When the knee-walking test was used at the 2-year follow-up, 8/37 patients classified this test as normal, 14/37 as unpleasant, 3/37 as difficult and 12/37 as impossible. The knee-walking test showed no correlation with loss of anterior knee sensitivity, size of the donor-site gap, or width or thickness of the patellar tendon on the donor side.

Discussion

The principal finding in this study is that the area of the donor site corresponding to non-tendinous-like tissue signal gradually decreased in size on the serial MRI evaluations. Furthermore, the thickness and width of the patellar tendon at the donor site increased significantly compared with the contralateral normal patellar tendon during the first 2 postoperative years.

The strengths of the present study are that it included 37 consecutive patients who were followed with serial MRI evaluations for a minimum of 24 months, that only one MRI evaluation was missed (due to pregnancy) and that the MRI evaluation, as well as the final clinical follow-up, were performed by independent observers.

The results at the 2-year follow-up in terms of the Lysholm score, Tegner activity level, IKDC evaluation system and functional performance were all significantly improved compared with the preoperative values, and the results were on par with those of other studies [1].

The present study revealed that donor-site morbidity, as evaluated with the knee-walking test, correlated with neither the MRI findings nor the loss of anterior knee sensitivity. Since the median loss of anterior knee sensitivity in the present study was 0 cm^2, this implies that residual donor-site morbidity is multifactorial and is not only explained by injury to the infrapatellar nerve or to the patellar tendon itself. Loss of motion is probably one of these

factors, as shown in our previous study of 604 patients [5]. The number of patients in the present study was, however, too small to test the correlation between the loss of motion and the knee-walking test.

In terms of the loss of sensitivity and inability to knee-walk, we have previously made observations contradicting the results of the present study, in two studies of 90 and 604 patients [5, 6]. However, these patients had their patellar tendon harvested through a 70-mm central vertical incision, and no effort was made to spare the infrapatellar nerve. Since the nerve-sparing technique was used in the present study and more than half the patients had no loss of sensitivity at all, we feel that the results are not fully comparable.

Our finding that the thickness of the patellar tendon at the donor site increased significantly compared with the non-harvested contralateral side has previously been reported by Coupens et al. [3], using MRI 18 months after the harvesting procedure, as well as Wiley et al. [15] after 12 months using ultrasonography. These findings indicate that there was an inflammatory reaction, representing ongoing tissue repair, which was still present at the donor site.

The finding that the donor-site gap gradually decreased in size up to the assessment at 27 months might imply that the patellar tendon has a chance to regenerate if the period between the harvest and the MRI evaluation is long enough. In a previous MRI study focusing on the donor site in patients who had the central third of their patellar tendon harvested through a single vertical paratenon-splitting incision, we have shown that the median donor-site gap was 5 mm, and only 1/31 tendons was completely healed after 2 years [6]. In the present study, the median donor-site gap size was 2 mm, and 6/37 had healed completely after 2 years. This might indicate that the patellar tendon regenerates more completely if the paratenon and its blood supply are left intact. This seems reasonable, since Weinstabl et al. [15] have shown that the blood supply to the patellar tendon passes through the paratenon. Rosenberg et al. [10] demonstrated a persistent defect and significant scar formation 12–24 months after harvesting the central third on both MRI (5 patients) and CT (10 patients). Nixon et al. [8] have shown a homogeneous low-intensity MRI signal almost throughout the entire tendon, indicating complete healing after 2 years in 2 patients. They also reported that a biopsy taken 2 years after central patellar tendon harvest was ‘indistinguishable in appearance from normal tendon’ under polarized light microscopy, but the cells were still increased in number compared with normal tendon. Proctor et al. [9] showed in a goat model that the tendon after central third harvest appeared normal on MRI at 21 months, but transmission electron microscopy revealed abnormal tissue composition with an increase in the number of collagen fibrils of small diameter. Furthermore, the maximum force to failure for the repair tissue was significantly decreased compared with normal patellar tendon [9]. We are aware that MRI does not show the quality of the tissue examined and that biopsies are needed to obtain valuable information on the healing of the repair tissue. The present study reveals that the area corresponding to non-tendinous-like tissue signal gradually decreased during the first 2 years after the harvest. This supports our hypothesis that the healing of the donor-site area is enhanced by sparing the paratenon.

Acknowledgements This study was supported by grants from the Research and Development Department of Northern Älvsborg and the Swedish National Centre for Research in Sports.

References

1. Bach BR, Jones GT, Sweet FA, Hager CA (1994) Arthroscopy-assisted anterior cruciate ligament reconstrucion using patellar tendon substitution. Two- to four-year follow-up results. Am J Sports Med 22: 758–767
2. Breitfuss H, Fröhlich R, Povacz P, Resch H, Wicker A (1996) The tendon defect after anterior cruciate ligament reconstruction using the midthird patellar tendon – a problem for the patellofemoral joint? Knee Surg Sports Traumatol Arthrosc 3: 195–198
3. Coupens SD, Yates CK, Sheldon C, Ward C (1992) Magnetic resonance imaging evaluation of the patellar tendon after use of its central one-third for anterior cruciate ligament reconstruction. Am J Sports Med 20: 332–335
4. Hefti F, Müller W, Jakob RP, Stäubli HU (1993) Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1: 226–234
5. Kartus J, Magnusson L, Stener S, Brandsson S, Eriksson BI, Karlsson J (1999) Complications following arthroscopic anterior cruciate ligament reconstruction. A 2–5-year follow-up of 604 patients with special emphasis on anterior knee pain. Knee Surg Sports Traumatol Arthrosc 7: 2–8
6. Kartus J, Stener S, Lindahl S, Engström B, Eriksson BI, Karlsson J (1997) Factors affecting donor-site morbidity after anterior cruciate ligament reconstruction using bone-patellar tendon-bone autografts. Knee Surg Sports Traumatol Arthrosc 5: 222–228
7. Kleipool AE, Loon T van, Marti RK (1994) Pain after use of the central third of the patellar tendon for cruciate ligament reconstruction, 33 patients followed 2–3 years. Acta Orthop Scand 65: 62–66
8. Nixon RG, Segall GK, Sax SL, Cain TE, Tullos HS (1995) Reconstitution of the patellar tendon donor-site after graft harvest. Clin Orthop 317: 162–171
9. Proctor CS, Jackson DW, Simon TM (1997) Characterization of the repair tissue after removal of the central one-third of the patellar ligament. J Bone Joint Surg [Am] 79: 997–1006

10. Rosenberg TD, Franklin JL, Baldwin GN, Nelson KA (1992) Extensor mechanism function after patellar tendon graft harvest for anterior cruciate ligament reconstruction. Am J Sports Med 20: 519–526
11. Sachs RA, Daniel DN, Stone ML, Garfein RF (1989) Patellofemoral problems after anterior cruciate ligament reconstruction. Am J Sports Med 17: 760–765
12. Shelbourne KD, Nitz P (1990) Accelerated rehabilitation after anterior cruciate ligament reconstruction. Am J Sports Med 18: 292–299
13. Shelbourne KD, Trumper RV (1997) Preventing anterior knee pain after anterior cruciate ligament reconstruction. Am J Sports Med 25: 41–47
14. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop 198: 43–49
15. Weinstabl R, Wagner M, Schabus R, Firbas W (1986) Anatomical bases of patellar tendon grafts used in anterior cruciate ligament reconstruction. Surg Radiol Anat 8: 163–167
16. Wiley JP, Bray RC, Wiseman DA, Elliott PD, Ladly KO, Vale LA (1997) Serial ultrasonographic imaging evaluation of the patellar tendon after harvesting its central one third for anterior cruciate ligament reconstruction. J Ultrasound Med 16: 251–255