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Differences in the rehabilitation period following two methods of anterior cruciate ligament replacement: semitendinosus/gracilis tendon vs. ligamentum patellae

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Abstract This study compared patient outcome during the early rehabilitation phase following two different methods of anterior cruciate ligament (ACL) reconstruction: ligamentum patellae (LP) and semitendinosus/gracilis tendon (SG) based reconstruction. The study included 50 consecutive patients treated by each method, examined 6 weeks and 3, 6 and 12 months after surgery. Patients in the SG group showed significantly better Lysholm scores at 6 and 12 months, Tegner Activity Scale scores at 3 months, and pain profile assessments at 6 weeks and 3 months than those in the LP group. Significant advantages were observed in LP group in the Overall Knee Score at 6 weeks and in range-of-motion at 6 weeks and 3 and 6 months post-surgery. Stability tests revealed no significant differences between patients in the two groups. SG-based reconstruction of the ACL thus demonstrates advantages over LP-based reconstruction regarding pain and function, while LP-based reconstruction was associated with an earlier return of motion.

Keywords ACL reconstruction · Rehabilitation period · Semitendinosus/gracilis tendon · Ligamentum patellae

Introduction

The use of autologous material to perform arthroscopic reconstruction of the anterior cruciate ligament (ACL) following acute rupture or in cases of chronic anterior instability has become standard procedure, although alleged advantages of arthroscopic vs. open reconstruction remain subject to debate [19]. Autologous, arthroscopically assisted ACL reconstruction is currently the most commonly performed using either the semitendinosus/gracilis (SG) tendons or the central third of the ligamentum patellae (LP) [24]. Various studies indicate that each of these methods has produced good to very good clinical results at medium-term follow-up (at least 24 months) [5, 10, 11, 12, 20, 23, 29, 32] and long-term follow-up (at least 4 years) [2, 14, 21, 34]. However, several authors [7, 37] have observed that SG-based reconstruction often leads to decreased postoperative pain profile, more rapid return to functionality of the quadriceps muscle, and less trauma associated with harvest of the transplant while effecting the same functional result as LP-based reconstruction.

Because of the relatively young and active population of patients who typically undergo ACL reconstruction the promotion of fast rehabilitation with early social reintegration and complete return of knee functionality is integral to treating anterior knee instability. The rehabilitation program prescribed to patients following ACL reconstruction varies with the study. Marder et al. [29] endorsed relatively early functional treatment with protected weight-bearing up to 6 weeks postsurgery for both procedures; return to normal activity was permitted 10–12 months after the surgery. Alternatively, MacDonald et al. [26] favored an accelerated postoperative treatment program with full weight-bearing following SG-based surgery. In addition, they favored immediate, full range of motion coupled with wearing a knee brace for a maximum of 2 weeks. A return to sports activity was allowed after 4 (most sports) or 6 months (sports that involve pivoting).

The two main factors used to evaluate the success of an ACL operation are long-term results and reintegration into professional and sporting life; the accurate evaluation of outcome in clinical studies requires a minimum follow-up of at least 2 years [39]. To date very few studies have focused on the rehabilitation phase following ACL reconstruction, and most of the studies that have been conducted have evaluated only a single time point. Carter and Edinger [9], who assessed the hamstring and quadriceps isokinetic capacity of patients 6 months after the patients underwent ACL reconstruction via the LP or the SG method, found no statistically significant differences in regard to knee extension or flexion strength when evaluating the two different tissue sources. However, Eriksson et al. [13] concluded that the SG-based technique offers some advantages during the early rehabilitative phase at a mean follow-up of 26.8±3.5 weeks postsurgery. They hypothesized that the use of the hamstrings as reconstructive material leads to less morbidity and shorter rehabilitation following ACL reconstruction. Feller et al. [15] documented early postoperative morbidity following ACL reconstruction using both LP and SG autografts at 2 weeks, 4 weeks, and 4 months. They also observed less morbidity with the SG graft during.

The postsurgery rehabilitation phase is a continuous process during which patients should be evaluated at different time points to identify specific differences between these two methods of ligament repair. Consequently our study was designed to compare objectively and subjectively in the outcome using the use of SG vs. LP for ACL reconstruction at different time points during the rehabilitation phase.

Materials and methods

Surgical technique

Semitendinosus/gracilis tendon graft (SG group)

The pes anserinus was identified via a longitudinal incision to the center of the tibial tuberosity in patients undergoing the SG procedure. After separation of the semitendinosus and gracilis tendons, the tendons were harvested with a tendon stripper (Arthrex, Naples, Fla., USA). Both tendons were prepared using the four-strand method. All tendons were of sufficient length to make quadruple grafts. The graft was placed using the single-channel method and fixed using bioresorbable interference screws (Arthrex) on the femoral and tibial sides. The tibial fixation was performed with the leg fully extended under manual tensioning.

Patellar tendon graft (LP group)

The central third of the patellar tendon and a bone block (length 2.5 cm) were harvested from the patella and tibia, respectively, through a longitudinal incision. The reconstructive procedure was performed arthroscopically in all patients using the single-channel method and Arthrex guides for tunnel placement. Notchplasty was carried out if necessary. The graft was fixed using bioresorbable interference screws (Arthrex) on the femoral and tibial sides. The tibial fixation was performed with the leg fully extended under manual tensioning.

Postoperative and rehabilitative care

The same postoperative rehabilitation protocol was used for patients in both treatment groups. Full weight-bearing was allowed from the first day postsurgery. In the phase immediately following surgery (days 1–4) continuous passive motion (CPM) was performed using a motorized CPM device. Analgesic treatment was applied when necessary in combination with local cooling and anti-inflammatory medication. From the 5th day the CPM device was used to obtain up to 90° flexion and full extension of the knee. Knee protection was provided by a knee brace (Artrocare CTS, Ormed, Freiburg, Germany) that was fitted and worn until week 6 postoperation without limitation of extension or flexion. More intensive training therapy aimed at specific muscle development was initiated in the third week using muscle sequences and closed-chain exercises. Beginning at week 7 postsurgery coordination exercises were introduced to improve proprioception. Sports activity (e.g., running and open chain exercise) was permitted after 12 weeks of rehabilitation; however, sports involving contact and/or pivot shifting were not allowed for 6 months following surgery.

Details of evaluation

All patient cases were selected using a consecutive comparison method. Exclusion criteria included signs of infection, reduced general condition, prior reconstruction, and concomitant injury to the posterior cruciate ligament. A total of 57 patients with an ACL reconstruction using the central third of the LP with two blocks of bone were thus included between December 1997 and July 1998. Between August 1998 and January 1999 we enrolled 58 patients with the four-strand method of ACL reconstruction using the SG graft. The first 50 patients in each group to complete a 12-month follow-up were analyzed. Patients in the LP group, consisting of 33 men and 17 women, had a median age of 29.5 years (range 17–45). The median age of the 29 men and 21 women patients in the SG group was 29 years (range 15–55). All operations were performed by the same surgeon, who had extensive experience in both procedures prior to the study period. Patients in each group were examined at 6 weeks and 3, 6, and 12 months; at each time point the following assessment instruments and measurements were used or acquired: (a) overall Knee Score, as established by Orthopädische Arbeitsgruppe Knie of the Swiss Orthopedic Association (OAK) [30]; (b) Lysholm Knee Scoring Scale [25]; (c) Tegner Activity Scale [38]; (d) Lachmann and pivot-shift stability test; (e) measurement of anterior translation of the tibia with manual maximum force using the Aircast Rolimeter device (only after 12 months; for comparison the stability evaluation compared the recovering knee to the healthy knee with the knee joint at the 60° position; and (f) range of motion measurement using a protractor.

All questionnaires were completed by the patients without supervision. Two independent examiners, neither of whom was the operating surgeon, conducted the clinical examinations and patient consultations. Anterior translation was measured three times by one examiner to determine the intrareliability for this examiner at the current patient. Knee extension evaluated by range of motion was compared to the extension angle of the healthy knee joint. Cases in which the period between injury and reconstruction of the ACL was less than 6 weeks were classified as acute ruptures. Cases involving longer time periods were classified as chronic instability injuries. The minimum acceptable time periods between injury and operation was 10 days. The Lysholm knee scoring scale was used for pain scoring. Six weeks after surgery the pain could be assessed only from the close chain exercise, because of the rehabilitation protocol.

Statistical analysis

Data are presented by descriptive statistics (i.e., mean, standard deviation, median, range). The ordinal variables (i.e., join stability, range of motion, pain level) were examined using the χ^2 test. The nonparametric Mann-Whitney *U* test was used to assess variance in the performance scores used to identify possible differences between the two surgical procedures (OAK score, Lysholm score, Tegner score), and the nonparametric Wilcoxon test was used to evaluate differences over time. All significance tests were two-tailed, and statistical significance was set at 0.05.

Results

The SG group comprised 31 cases of acute injury and 19 cases of chronic instability. The cases of acute injury and chronic instability in the LP group were 34 and 16, respectively. Lysholm and OAK scores revealed no significant differences between the patients with chronic instability injuries and those with acute ruptures (Table 1). In the SG group concomitant intra-articular injuries included 7 injuries to the medial meniscus, 4 injuries to the lateral meniscus (6 refixed, 5 resected), and 7 chondral lesions (2 behind the patella and 5 on the femoral condyle; grade II, 4; grade III, 2; grade IV, 1). There were 12 cases of concomitant injury to the medial meniscus in the LP group (5 refixed, 7 resected), 3 cases of injury to the lateral meniscus, and 5 cases of chondral lesions to the femoral condyle (grade II, 1; grade III, 3; grade IV, 1)

Graft laxity

During the clinical stability examination conducted 12 months after the operation 6 patients in each group (12%) showed a positive result for the pivot-shifting phenomenon. In all of the postoperative follow-up periods (6 weeks and 3, 6, and 12 months postsurgery), the Lachmann test returned positive results for 3 patients in the SG group (6%) and 6 patients in the LP group (12%; Table 2). The

Table 1 Lysholm and OAK scores. Scores did not differ as to whether ACL reconstruction was performed due to acute injury or chronic instability

Score	Acute	Chronic	*P*
Lysholm			
6 weeks	75 (18–90)	73 (44–88)	0.73
3 months	79 (55–100)	81 (36–100)	0.85
6 months	88 (62–100)	88 (36–100)	0.93
12 months	88 (56–100)	90 (56–100)	0.30
OAK			
6 weeks	72 (42–86)	69 (55–84)	0.42
3 months	79 (42–97)	78 (58–96)	0.60
6 months	86 (48–100)	84 (62–96)	0.23
12 months	92 (62–100)	92 (75–100)	0.14

Table 2 Evaluation of stability 12 months postsurgery. Functional knee stability tests (Lachmann and pivot-shift tests) and the translation test (difference between the healthy side and the reconstructed side, using Rolimeter) revealed similar results in the two treatment groups 12 months postsurgery

Test	SG	LP	*P*
Lachmann			0.49
0 (0–2 mm)	47	44	
+1 (3–5 mm)	3	6	
Pivot-shift			–
0	44	44	
+1 (trace)	6	6	
Rolimeter (mm)	1.9±1.6	1.3±1.3	0.30

Table 3 Range of motion evaluation. Loss of extension was significantly higher in the SG than the LP group at 6 weeks, although the flexion deficit persisted in the LP group for 6 months postsurgery; there was no significant difference between the groups 12 months postsurgery

Range-of-motion	SG (*n*)	LP (*n*)	*P*
6 weeks			
Extension deficit			0.05
<3	29	43	
3–5	16	7	
>5	5	0	
Maximal flexion			0.05
>120	14	42	
90–120	36	8	
<90	0	0	
3 months			
Extension deficit			0.26
<3	43	46	
3–5	7	4	
>5	0	0	
Maximal flexion			0.05
>120	42	50	
90–120	8	0	
<90	0	0	
6 months			
Extension deficit			0.18
<3	42	46	
3–5	7	4	
>5	1	0	
Maximal flexion			<0.05
>120	42	50	
90–120	8	0	
<90	0	0	
12 months			
Extension deficit			–
<3	50	50	
3–5	0	0	
>5	0	0	
Maximal flexion			0.12
>120	45	50	
90–120	5	0	
<90	0	0	

Lachmann test was carried out in combination with additional Rolimeter measurements to improve the stability evaluation. In the SG group an overall mean anterior-posterior translation of 7.7±2.1 mm [3] was measured at the recovering knee joints and compared to the overall mean healthy-knee measurement of 6.6±1.3 mm. In the LP group the mean anterior translation on the knee joint that had been operated upon was 7.2±1.4 mm while that on the healthy knee was 6.5±1.5 mm. No significant differences between the healthy and the recovering knee were identified in either group (LP group: P=0.64; SG group: P=0.06). Similarly, no statistical differences between the two reconstruction methods were detected based on Rolimeter measurements (difference between the reconstructed knee and healthy knee) used to evaluate anterior translation (P=0.30). The most marked difference in translation movement between the reconstructed knee joint and the healthy knee joint was 5 mm (three patients in the SG group and two in the LP group).

Range of motion

In the 6-week to 12-month rehabilitation period there was a clear improvement in knee joint mobility in both groups. Twenty-one patients in the SG group had an extension deficit of at least 3° in the repaired knee (relative to the healthy knee) at 6 weeks and in the LP group (Table 3). All patients were able to extend the repaired knee fully at 12 months. In the SG group a mean increased flexion of 111±11° was measured at 6 weeks; flexion had increased to an average of 128±7° at 12 months. In the LP group the average increased flexion of 123±8° improved to an average of 133±5° during the same period. Extension was significantly (P<0.05) better after 6 weeks and flexion significantly (P<0.05) better after 6 weeks and 3 and 6 months in the LP group than the SG group.

Pain evaluation

Pain intensity was evaluated using the Lysholm Knee Scoring Scale. At 6 weeks 20 patients in the SG group had inconstant or no pain during heavy exertion, compared to only 3 in the LP group (Table 4). At 12 months 42 patients in the SG group and 34 in the LP group reported inconstant or no pain during heavy exertion. Patients in the SG group reported less pain than those in the LP group at the 6-week and 3-month time points.

Activity level

The degree of activity was determined using the Tegner Activity Scale (maximum score 10 points). No significant differences between the two treatment groups were found at 6 weeks (P=0.33), 6 months (P=0.89), or 12 months (P=0.79) after surgery (Table 5). Three months after the operation patients in the SG group displayed significantly higher activity scores (P<0.05) than those in the LP group (SG 2.1±1.2, LP 1.5±1.3). The average preinjury activity score, determined retrospectively, was 5.3±2.0 in the SG group and 4.9±1.9 in the LP group (P=0.22). At 1 year 22 patients in the SG group and 19 in the LP group reported that they had resumed a level of activity that was equal to or higher than their activity level prior to the surgery (P=0.34). However, there were significantly (P<0.05)

Table 4 Pain score evaluation using the Lysholm Knee Scoring Scale. Significantly more pain was reported in the LP than the SG group 6 weeks and 3 months postsurgery, but there were no differences between the groups after 12 months. (pain score: *25* none, *20* inconstant and slight during heavy exertion, *15* marked during heavy exertion, *10* marked on or after walking more than 2 km, *5* marked on or after walking less than 2 km, *0* constant)

Pain score	SG (*n*)	LP (*n*)	*P*
6 weeks			<0.05
20–25	20	0	
10–15	27	42	
0–5	3	5	
3 months			<0.05
20–25	31	16	
10–15	16	30	
0–5	3	4	
6 months			0.09
20–25	39	29	
10–15	10	18	
0–5	1	3	
12 months			0.12
20–25	42	34	
10–15	8	14	
0–5	0	2	

Table 5 Results of Tegner Activity Scale. No preinjury differences were found in the grade of activity between patient in the two groups, but activity was significantly higher in the SG than the LP group 3 months postsurgery; more patients in the SG group than in the LP group had reached their previous or a higher activity level at the end of the follow-up, although the difference was not significant

	SG	LP	*P*
Score			
Preinjury	5.3±2.0	4.8±1.9	0.22
6 weeks	0.7±0.9	0.5±0.8	0.33
3 months	2.1±1.3	1.5±1.2	<0.05
6 months	3.2±1.6	3.3±1.8	0.89
12 months	4.3±2.2	4.0±2.1	0.79
Comparative level (*n*)			
Lower	28	31	0.34
Same or higher	22 (44%)	19 (38%)	

Table 6 Results of OAK Knee Score. The score was significantly higher in the LP than the SG group at 6 weeks; no differences were detected at the other time points

OAK score	SG	LP	*P*
6 weeks	68 (42–86)	74 (55–85)	<0.05
3 months	78 (42–97)	79 (64–94)	0.41
6 months	85 (48–100)	85.5 (69–96)	0.82
12 months	92 (62–100)	93 (76–100)	0.94

Table 7 Results of Lysholm Knee Scoring Scale. The score was significantly higher in the SG than the LP group at 6 and 12 months; no differences were detected at the other time points

Lysholm score	SG	LP	*P*
6 weeks	75 (18–90)	74 (44–88)	0.89
3 months	82.5 (36–100)	78 (43–95)	0.09
6 months	90 (62–100)	81.5 (36–95)	<0.05
12 months	90 (56–100)	84.5 (56–95)	<0.05

lower activity scores in both groups at 12 months (SG 5.3± 2.0, LP 4.8±1.9) than the preinjury activity score (SG 4.3± 2.2, LP 4.0±2.1).

OAK score and Lysholm score

The OAK score recorded 6 weeks after the operation revealed a significantly better result ($P<0.05$) for patients in the LP group than for those in the SG group (Table 6). At the other postoperative examinations there were no significant differences detected between the groups (3 months, $P=0.41$; 6 months, $P=0.82$, 12 months, $P=0.94$). In contrast, the Lysholm scores were significantly better in the SG group than in the LP group at the 6-month ($P<0.05$) and 12-month ($P<0.05$) time points (Table 7). No significant differences in Lysholm score were detected at the 6-week ($P=0.89$) and 3-month ($P=0.09$) examinations. At the end of the follow-up 45 patients in the SG group had good or very good results according to the OAK score while 41 patients attained similar results according to the Lysholm score. In the LP group 44 patients showed good or very good results according to the OAK score and 36 patients according to the Lysholm score. No correlations were found between functional scores (Lysholm, OAK, Tegner) and clinical variables (pain, range of motion, stability).

Discussion

This study compared two standardized techniques for ACL reconstruction under similar circumstances and conditions. During the early rehabilitation phase patients were evaluated prospectively 6 weeks and 3, 6, and 12 months after surgery. Our findings indicate some advantage to the LP method regarding range of motion. The greater pain in the LP group than in the SG group proved to disadvantage LP patients throughout the entire follow-up period and perhaps explains the better activity level results in the SG group at 6 weeks and 3 months and the improved Lysholm scores recorded at 6 and 12 months. Because long-term results were not addressed in this study, no conclusions can be drawn regarding long-term advantages to one technique over the other.

This prospective study evaluated patient recovery following ACL reconstruction. Very few reported studies have compared the outcome of two different methods of ACL reconstruction during the early postoperative phase [9, 13, 15]. The postoperative rehabilitation program is known to play an important role in clinical outcome and patient satisfaction following ACL reconstruction. The use of early physical therapy, including muscle training (particularly training based on discrete muscles sequences), can help to prevent atrophy development in fast type II muscle fibers (musculus vastus medialis) [33]. A knee brace can prevent uncontrolled anterior-to-posterior and torsional movement while the intra-articular proprioception remains impaired [16]. With these techniques in mind, all of the patients in our study wore a knee brace during the first 6 weeks after surgery and participated in similar training programs under the supervision of a physical therapist. Thus any differences in outcome between the two treatment groups are attributable to the different reconstruction methods.

Carter et al. [9] found that the PL, SG, and semitendinosus tendon methods of reconstruction resulted in no significant differences in the extension and flexion strength of the knee joint as assessed by isokinetic examination at 6-month follow-up. However, results obtained by Eriksson et al. [13] during the early postoperative period (mean 26.8±3.5 weeks) indicate that reconstruction using hamstrings affects quadriceps muscle strength and proprioception less than reconstruction using bone-tendon-bone grafts. Feller et al. [15] also observed a higher quadriceps torque deficit in the LP group after 4 months.

Marcacci et al. [28] reported that patients who undergo early reconstruction of the ACL (≤15 days after injury) can return to sports activity earlier and show better clinical results and higher knee joint stability than patients who undergo delayed reconstruction; therefore we distinguished between acute ACL rupture and chronic anterior instability by the period between injury and ACL reconstruction (i.e., <6 weeks postinjury vs. longer periods). Our clinical results did not confirm the findings of Marcacci et al. The main reason for the difference could be the different definition of acute trauma (14 days vs. 6 weeks). However, neither the Lysholm scores nor the OAK scores indicated any significant differences in recovery between cases of acute injury and chronic instability (according to our definition) at any of the tested time points. We were thus able to exclude the onset of instability as a factor influencing operative outcome.

Graft laxity

The primary goal of ACL reconstruction is to obtain sufficient stability of the knee joint; therefore joint stability is an important criterion by which to assess operative outcome. We observed a positive pivot-shift phenomenon in 6 patients (12%) from each group and soft joint contact upon extension according to the Lachmann test (3 patients in the SG group; 6 in the LP group), results that closely paralleled the findings reported by Aglietti et al. [2] who detected grafting failure in the form of a positive pivot shift or a lateral difference according to the KT 1000 measurement in 10% of patients treated using the SG method.

Eriksson et al. [13] observed more manual laxity (according to the Lachmann test) after treatment using the semitendinosus tendon rather than the LP, whereas they found no significant differences in the pivot-shift test or Stryker side-to-side laxity. Additional, Beynnon et al. [5] reported after 3 years of follow-up that the bone–patellar tendon–bone autograft was superior to replacement with a two-strand SG graft with regard to knee laxity and pivot-shift grade. The meta-analysis by Freedman et al. [17] summarized the significantly lower rate of graft failure and the better static knee stability with patellar tendon autografts. Further comparable studies [1, 10, 29, 32] were combined in a meta-analysis by Yunes et al. [39], which revealed a significant stability difference at 20 lb force in favor of LP-based reconstruction according to KT analysis. O'Neill et al. [32 observed more stiffness associated with the LP as measured with the KT 2000arthrometer at maximum force. Aglietti et al. [1] reported a side-to-side difference in anterior displacement greater than 5 mm at 30 lb in 13% of knee joints reconstructed with LP and in 20% of those reconstructed with SG. However, there was no statistical difference between the groups at maximum manual force. The latter finding was confirmed by our results based on Rolimeter readings obtained while at the maximum force. The used Rolimeter device to quantify anterior translation is easy to use and is comparable to the KT arthrometer in terms of diagnostic specificity and sensitivity [4, 18]. The results that we obtained with the Rolimeter device accorded closely with those reported by Marder et al. [29], which showed comparably good results between PL and SG grafting methods using the KT-1000 (average contralateral difference in the SG group, 1.9±1.3 mm; LP group, 1.6±1.4 mm) 24 months after surgery. Similarly, several studies [10, 11, 23] also detected no significant differences in knee joint stability between those two therapy methods as assessed by KT arthrometer.

However, Röpke et al. [35] found that stability measurements of knee joints reconstructed with either PL or SG did not necessarily reflect the clinical result, a finding indicating that factors other than knee joint stability affect clinical outcome. As with Sernert et al. [36] and Eriksson et al. [13], we found no correlation between functional outcome and stability factors.

Range of motion

Recovery of full extension in the knee joint is necessary for a satisfying postoperative functional result. Aglietti et al. [1] reported a slight loss of extension (≤3°) in 48% of patients in their LP group and 3% of patients in their SG group in a study of 60 patients at an intermediate follow-up of 28 months; this difference between treatment groups was significant. In contrast Buss et al. [8] detected minimal range-of-motion loss in 63 of 68 patients with knees reconstructed via the PL method (follow-up: 2 years minimum) while Eriksson et al. [13] found only a few deficits in extension and flexion at an early time point postsurgery (mean 26.8±3.5 weeks) with no differences attributable to reconstruction technique. This was confirmed by Feller et al. [15], who also observed no differences between the two groups at 2weeks, 4 weeks, or 4 months postoperative regarding the range of motion. Our results do not completely confirm these prior findings. During the early rehabilitation phase (6 weeks after operation) patients from the SG group displayed significantly lower range of motion that affected joint extension and limited flexion for 6 months postsurgery. We hypothesize that harvesting the SG more severely affected the function of the lower extremity (particularly the flexion) than did harvesting the LP. The examination of motion at the end of the follow-up period (12 months post-surgery) revealed full extension capacity in all patients when comparing the reconstructed knee to the healthy knee.

Pain evaluation

Corry et al. [10] determined that ACL reconstruction involving the SG resulted in less pain than did the PL-based reconstruction; they hypothesized that excising the transplant tissue from the hamstring tendons is less traumatic than excising the PL. The study by Feller et al. [15] found more severe anterior knee pain in the LP group after 2 weeks, but no differences were seen after 8 weeks or 4 months. During the early rehabilitation phase (6 weeks and 3 month after surgery) we found that the pain profile in the SG group was significantly lower than that in the LP group. This pain differential may also be attributable to the higher incidence of retropatellar pain associated with the PL method [35, 35]. Eriksson et al. [13] and Shaieb et al. [37] also reported that patellofemoral pain and donor site pathology were more common in the LP group than in the SG group. These findings support our observations and similar results obtained in studies conducted by Aglietti et al. [1] and Muneta et al. [31], which also found a higher incidence of patellofemoral pain in the LP group.

Activity level

Recovery of knee joint function and the patient's ability to perform pre-injury activities are decisive factors in assessing surgical outcome. Marder et al. [29] reported that 64% of their patients (n=72) had returned to their previous level of activity within a follow-up period of at least 24 months postoperation (range 24–40 months). Similar results were recorded by Maeda et al. [27], who reported that 23 of 41 patients had returned to their previous level of activity within 24–48 months following surgery. Aglietti et al. [2] evaluated 68 patients with anterior instability, of whom 67% were previously active in a sport that involves pivoting. After ACL reconstruction using the SG 54% of the patients had resumed playing this type of sport when evaluated at the 60-month follow-up. The return to levels of activity equal to or higher than preinjury levels was attained by only 41% of our patients, with no significant differences between the two groups of patients. This relatively low figure may be due to the short follow-up of 12 months and probably will increase in time. Severe studies [5, 11, 13] similarly detected no differences in patients' ability to resume activity based on the method used for ACL reconstruction. In contrast, O'Neill [32] found that patients in the LP group returned to a higher level of activity than patients in the SG group. This conclusion was underscored by the Yunes et al. meta-analysis [39] which indicated a significant return to activity advantage for patients in the LP groups at a minimum follow-up of 2 years. Conflicting findings obtained by Röpke et al. [35] suggested improved functional results in patients who had received semitendinosus tendon treatment compared with those who underwent LP treatment after follow-up of up to 24 months. Feller et al. [15] observed a higher activity level in the LP group despite a lower IKDC score and a greater pain in general in this group 4 months postoperatively. In contrast, we found a significantly greater level of activity in the SG group at the 3-month follow-up. In our opinion, the lower degree of pain reported by patients in the SG group at 6 weeks and 3 months into the rehabilitation phase may have enabled earlier mobilization and heightened rehabilitation capacity of patients in this group than those in the LP group.

OAK and Lysholm scores

Total assessment scores have been demonstrated to be useful in creating a common basis for comparing individual surgical outcomes [6]. We utilized the OAK assessment and the Lysholm Knee Scoring Scale for general outcome evaluation. Breitfuss et al. [6] reported good to very good postoperative results in 80% of patients (n=41) based on OAK assessment following ACL reconstruction using LP. In a study comparing the two reconstruction techniques Feller et al. [15] observed a significant higher scoring in the SG group than in the LP group using the IKDC score at the early follow-up of 4 months. Corry et al. [10] confirmed equally good results at 24-month follow-up according to the Lysholm and IKDC scores. Similar results were described by Jansson et al. [23] using IKDC and Lysholm scores after a minimum follow-up of 21 months. Pinczewski et al. [34] found similar results in the two groups using the Lysholm score after a longer follow-up of 5 years.

The assessments used in our study (Lysholm and OAK) revealed partially conflicting results. The Lysholm score showed better results in the SG group than the LP group at 6 and 12 months, but the benefit of the SG reconstructive technique was not confirmed by the OAK assessment, which indicated that patients in the LP group showed significantly better results than patients in the SG group at 6 weeks. The reason for these conflicting results can be traced to differences in the scoring criteria used in the two assessment techniques. The movement deficit in extension and flexion is given high priority in the OAK evaluation. Thus the initially worse freedom of movement in extension and flexion of patients in the SG group 6 weeks after surgery lowered these patients' OAK score at this time point, although the patients' Lysholm score, based on self-evaluation, did not support this OAK result. Freedom from pain and the associated raised activity level resulted in a better Lysholm score since the Lysholm Knee Scoring Scale strongly emphasizes these criteria. Essentially the Lysholm score is correlated more strongly with the subjective evaluation of the patient, whereas the OAK score provides a differentiated evaluation [22]. The lower pain profile in the general follow-up for patients in the SG group could be attributed to the lower trauma associated with excising the transplant tissue when using this technique; this reduction in pain would lead to a subjectively improved evaluation of the operational result and could explain the increase in the Lysholm score observed 6 and 12 months after surgery. The decreased pain profile also could explain the significantly decreased occurrence of thigh atrophy in the SG group 1 year after surgery, a finding reported by Corry et al. [10].

Conclusion

A return to pain-free function of the knee joint is of major importance to patients who undergo ACL reconstruction. This function is best achieved via use of the surgical method that causes the least trauma possible and allows the fastest possible rehabilitation. Patients are able to tolerate the slight inconvenience of graft stiffness, which does not exert any negative effect on surgical outcome. The temporarily decreased range of motion also is well tolerated by patients. When operating on patients who are young and active in sports, both the subjective recovery and the objective surgical outcome are important to ensure early reha-

bilitation and social reintegration. This study demonstrates that ACL reconstruction using the SG technique results in advantages regarding pain and function during the rehabilitation phase compared to LP-based reconstruction. Therefore this technique can be recommended when performing ACL reconstruction for young, active patients as well as athletes. However, the contradictory results that we obtained regarding the ability to return to preinjury levels of activity following ACL reconstruction by these two methods should be explored further in additional studies designed to evaluate correlations between results in the rehabilitation phase and results at long-term follow-up.

References

1. Aglietti P, Buzzi R, Zaccherotti G, De Biase P (1994) Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. Am J Sports Med 22: 211–217
2. Aglietti P, Buzzi R, Menchetti PM, Giron F (1996) Arthroscopically assisted semitendinosus and gracilis tendon graft in reconstruction for acute anterior cruciate ligament injuries in athletes. Am J Sports Med 24:726–731
3. Aune AK, Ekeland A, Cawley PW (1998) Interference screw fixation of hamstring vs patellar tendon grafts for anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 6:99–102
4. Balasch H, Schiller M, Friebel H, Hoffmann F (1999) Evaluation of anterior knee joint instability with the Rolimeter. A test in comparison with manual assessment and measuring with the KT-1000 arthrometer. Knee Surg Sports Traumatol Arthrosc 7:204–208
5. Beynnon BD, Johnson RJ, Fleming BC, Kannus P, Kaplan M, Samani J, Renstrom P (2002) Anterior cruciate ligament replacement: comparison of bone-patellar tendon-bone grafts with two-strand hamstring grafts. A prospective, randomized study. J Bone Joint Surg Am 84:1503–1513
6. Breitfuss H, Frohlich 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 3:194–198
7. Brown CH Jr, Steiner ME, Carson EW (1993) The use of hamstring tendons for anterior cruciate ligament reconstruction. Technique and results. Clin Sports Med 12:723–756
8. Buss DD, Warren RF, Wickiewicz TL, Galinat BJ, Panariello R (1993) Arthroscopically assisted reconstruction of the anterior cruciate ligament with use of autogenous patellar-ligament grafts. Results after twenty-four to forty-two months. J Bone Joint Surg Am 75:1346–1355
9. Carter TR, Edinger S (1999) Isokinetic evaluation of anterior cruciate ligament reconstruction: hamstring versus patellar tendon. Arthroscopy 15:169–172
10. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA (1999) Arthroscopic reconstruction of the anterior cruciate ligament. A comparison of patellar tendon autograft and four-strand hamstring tendon autograft. Am J Sports Med 27:444–454
11. Ejerhed L, Kartus J, Sernert N, Kohler K, Karlsson J (2003) Patellar tendon or semitendinosus tendon autografts for anterior cruciate ligament reconstruction? A prospective randomized study with a two-year follow-up. Am J Sports Med 31:19–25
12. Eriksson K, Anderberg P, Hamberg P, Lofgren AC, Bredenberg M, Westman I, Wredmark T (2001) A comparison of quadruple semitendinosus and patellar tendon grafts in reconstruction of the anterior cruciate ligament. J Bone Joint Surg Br 83:348–354
13. Eriksson K, Anderberg P, Hamberg P, Olerud P, Wredmark T (2001) There are differences in early morbidity after ACL reconstruction when comparing patellar tendon and semitendinosus tendon graft. A prospective randomized study of 107 patients. Scand J Med Sci Sports 11:170–177
14. Feagin JA Jr, Wills RP, Lambert KL, Mott HW, Cunningham RR (1997) Anterior cruciate ligament reconstruction. Bone-patella tendon-bone versus semitendinosus anatomic reconstruction. Clin Orthop 341:69–72
15. Feller JA, Webster KE, Gavin B (2001) Early post-operative morbidity following anterior cruciate ligament reconstruction: patellar tendon versus hamstring graft. Knee Surg Sports Traumatol Arthrosc 9:260–266
16. Fleming BC, Renstrom PA, Beynnon BD, Engstrom B, Peura G (2000) The influence of functional knee bracing on the anterior cruciate ligament strain biomechanics in weightbearing and nonweightbearing knees. Am J Sports Med 28:815–824
17. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr (2003) Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. Am J Sports Med 31:2–11
18. Ganko A, Engebretsen L, Ozer H (2000) The Rolimeter: a new arthrometer compared with the KT-1000. Knee Surg Sports Traumatol Arthrosc 8:36–39
19. Harilainen A, Sandelin J, Osterman K, Vanhanen I (1993) Prospective preoperative evaluation of anterior cruciate ligament instability of the knee joint and results of reconstruction with patellar ligament. Clin Orthop 297:17–22
20. Harter RA, Osternig LR, Singer KM (1989) Instrumented Lachman tests for the evaluation of anterior laxity after reconstruction of the anterior cruciate ligament. J Bone Joint Surg Am 1: 975–983
21. Holmes PF, James SL, Larson RL, Singer KM, Jones DC (1991) Retrospective direct comparison of three intraarticular anterior cruciate ligament reconstructions. Am J Sports Med 19: 596–599
22. Hoser C, Fink C, Benedetto KP, Gabl M (1996) Knee scoring systems. Arthroskopie 9:196–201
23. Jansson KA, Linko E, Sandelin J, Harilainen A (2003) A prospective randomized study of patellar versus hamstring tendon autografts for anterior cruciate ligament reconstruction. Am J Sports Med 31:12–18
24. Johnson RJ, Beynnon BD, Nichols CE, Renstrom PA (1992) The treatment of injuries of the anterior cruciate ligament. J Bone Joint Surg Am 74:140–151
25. Lysholm J, Gillquist J (1982) Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 10:150–154
26. MacDonald PB, Hedden D, Pacin O, Huebert D (1995) Effects of an accelerated rehabilitation program after anterior cruciate ligament reconstruction with combined semitendinosus-gracilis autograft and a ligament augmentation device. Am J Sports Med 23:588–592

27. Maeda A, Shino K, Horibe S, Nakata K, Buccafusca G (1996) Anterior cruciate ligament reconstruction with multistranded autogenous semitendinosus tendon. Am J Sports Med 24:504–509
28. Marcacci M, Zaffagnini S, Iacono F, Neri MP, Petitto A (1995) Early versus late reconstruction for anterior cruciate ligament rupture. Results after five years of followup. Am J Sports Med 23:690–693
29. Marder RA, Raskind JR, Carroll M (1991) Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction. Patellar tendon versus semitendinosus and gracilis tendons. Am J Sports Med 19: 478–484
30. Muller W, Biedert R, Hefti F, Jakob RP, Munzinger U, Staubli HU (1988) OAK knee evaluation. A new way to assess knee ligament injuries. Clin Orthop 232:37–50
31. Muneta T, Sekiya I, Ogiuchi T, Yagishita K, Yamamoto H, Shinomiya K (1998) Effects of aggressive early rehabilitation on the outcome of anterior cruciate ligament reconstruction with multi-strand semitendinosus tendon. Int Orthop 22:352–356
32. O'Neill DB (1996) Arthroscopically assisted reconstruction of the anterior cruciate ligament. A prospective randomized analysis of three techniques. J Bone Joint Surg Am 78:803–813
33. Pässler HH, Shelbourne KD (1993) Biological, biomechanical and clinical concepts of after-care following knee ligament surgery. Orthopade 22:421–435
34. Pinczewski LA, Deehan DJ, Salmon LJ, Russell VJ, Clingeleffer A (2002) A five-year comparison of patellar tendon versus four-strand hamstring tendon autograft for arthroscopic reconstruction of the anterior cruciate ligament. Am J Sports Med 30:523–536
35. Röpke M, Becker R, Urbach D, Nebelung W (2001) Semitendinosus tendon vs. patellar ligament. Results of a prospective randomized study after anterior cruciate ligament reconstruction. Unfallchirurg 104 312–316
36. Sernert N, Kartus J, Kohler K, Stener S, Larsson J, Eriksson BI, Karlsson J (1999) Analysis of subjective, objective and functional examination tests after anterior cruciate ligament reconstruction. A follow-up of 527 patients. Knee Surg Sports Traumatol Arthrosc 7:160–165
37. Shaieb MD, Kan DM, Chang SK, Marumoto JM, Richardson AB (2002) A prospective randomized comparison of patellar tendon versus semitendinosus and gracilis tendon autografts for anterior cruciate ligament reconstruction. Am J Sports Med 30:214–220
38. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop 198:43–49
39. Yunes M, Richmond JC, Engels EA, Pinczewski LA (2001) Patellar versus hamstring tendons in anterior cruciate ligament reconstruction: a meta-analysis. Arthroscopy 17:248–257