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Patellar tendon length after anterior cruciate ligament reconstruction: a comparative magnetic resonance imaging study between patellar and hamstring tendon autografts

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Abstract Patellar tendon shortening after anterior cruciate ligament reconstruction may be associated with anterior knee pain or patellofemoral arthritis. The present study was designed to compare postoperative changes in patellar tendon length after anterior cruciate ligament reconstruction between patellar tendon and hamstring tendon autograft. Magnetic resonance images of both knees (operated and healthy) and functional outcome were documented at least 1 year postoperatively in 16 patellar tendon harvested patients and in 32 hamstrings harvested patients. Patellar tendon length, patella length and Insall–Salvati ratio were measured. The operated knee values were compared to the respective values of the non-operated control knees. A significant 4.2 mm or 9.7% patellar tendon shortening in patellar tendon group and a non-significant 1.14 mm or 2.6% shortening in hamstrings group was detected. No significant difference was detected in terms of major shortening—patella baja—(6% for the patellar tendon group vs. 0% for the hamsting group). There was no significant difference in anterior knee problems between the two groups as evidenced by the Shelbourne score (94 for the patellar tendon group vs. 98 for the hamsting group). Harvesting of the patellar tendon for anterior cruciate ligament reconstruction resulted in a significant shortening of the remaining tendon. In contrast harvesting of the hamstring tendons did not affect significantly the patellar tendon length. However, the incidence of patella baja and overall functional outcome was not significantly different between the two groups.

Keywords Anterior cruciate ligament · Patellar tendon length · Patellar tendon graft · Hamstring tendon graft

Introduction

The bone patellar tendon bone (BPTB) autograft and the four-strand band hamstrings (HS) tendon autograft are the most popular used grafts for anterior cruciate ligament reconstruction (ACL). Harvesting of central third of the patellar tendon affects the length of the remaining tendon by inducing local scarring and compromising the tissue elasticity [1, 2, 4, 5, 8–10, 18, 20, 21, 23, 27, 28]. Shortening of the patellar tendon varies from 0.3 to 9.8% [6, 20] and leads when it is excessive to patella baja and consequent anterior knee pain [2, 6, 8, 12, 16, 17, 23, 25]. On the other hand harvesting of hamstrings tendons does not interfere with the patellar tendon site but there are no reports of any effect on the length of the ipsilateral patellar tendon or on the position of the patella.

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All previous studies have been based on plain lateral radiographs [6, 7, 9, 18, 28] of the knee to measure the patella length, the patellar tendon length and the Insall–Salvati ratio [15] after ACL reconstruction with BPTB graft. Only one study has utilized Roentgen Stereometric Analysis to overcome inaccuracies caused by different magnifications and projections of the knee and the authors reported a 3.2% decrease of patellar tendon length after BPTB harvesting [1]. Moebius et al. [20] used ultrasound evaluation to evaluate patellar tendon length postoperatively and found a 9.2% shortening. Another study tried to determine the Insall–Salvati ratio for patella alta and baja using magnetic resonance imaging (MRI) on 245 preoperative patients with various diagnoses [26]. Although they did not study knees with ACL reconstruction, the authors reported that Insall–Salvati < 0.74 is the MRI criterion for patella baja.

The primary goal of this study was to measure the length of the patellar tendon after ACL reconstruction with either BPTB or HS autograft harvested from the ipsilateral knee. Our hypothesis was that harvesting of the BPTP produces more shortening of the patellar tendon in comparison to HS tendon.

The magnetic rersonance images (MRI) was chosen as the most accurate imaging modality for depicting and measuring the soft tissue knee elements. The timing of the study was over 1 year postoperatively so that the tissue fibrosis and the tendon elastic properties were established. Secondary aims were to investigate if harvesting of BPTB or HS results in patella baja and if patellar tendon shortening correlates to compromised functional outcome.

Materials and methods

Demographics

Forty-eight patients who admitted in our institution from January 2002 to March 2004 with ACL deficient knees were enrolled in this study. This cohort of patients underwent arthroscopic ACL reconstruction by a single surgeon with either a BPTB or a four-strand band HS tendon autograft. The inclusion criteria were: (a) no pre-existing patellofemoral problems or evidence of arthritis of the patellofemoral joint during arthroscopy (b) no previous surgery in the affected knee and (c) a normal contralateral knee joint. Two distinct patient groups were defined. HS group included 32 patients and BPTB group had 16 patients. Graft selection was decided by the surgeon according to demands and activities of the patients. Patients with occupational activities require kneeling or prolonged period of sitting (masons, plumbers) received a four-strand band HS tendon autograft and recreational athletes received a BPTB graft.

Institutional review board approval was obtained before initiating the study and each patient provided informed consent for study participation.

Harvesting techniques

The central third of the patellar tendon with attached patellar and tibial bone plug was harvested from the ipsilateral knee through a 5 to 6 cm long single central longitudinal incision. The skin innervation was not specifically considered during the approach. At the completion of surgery the tendon defect was closed, with three absorbable sutures (No. 2-0). A re-approximation of the tendon edges was performed and not a tight closure of the defect. The paratenon was carefully sutured over the tendon. No bone chips were placed in the patella or in the tibial tubercle area defect.

Hamstrings graft harvesting is performed through a 2.5-cm longitudinal incision 3 cm medial and distal to the tibial tubercle, with the knee flexed to 90°. The sartorius fascia is incised along the course of the gracilis and semitendinosus. Both tendons are mobilized using blunt finger dissection. Once the tendons are free from their adhesions, they are harvested using a tendon stripper.

Rehabilitation

Rehabilitation protocol was the same for all patients. Free active knee motion without limitation of flexion was permitted after surgery. The patients were recommended to use crutches for 2–3 weeks postoperatively. Weight bearing was allowed as tolerated. Intensive physiotherapy including isotonic and closed chain exercises was started after 2 weeks. Running was permitted after 3 months and contact sports after 6 months.

Imaging protocol and measurements

All patients agreed to participate in this study, had MRI study on both the operated and the non-operated knee within 2 weeks after their latest follow up (over 1 year postoperatively). Both legs were positioned in the gantry. MRI was performed with a 1.0-T MR imager (Philips Intera; Philips Medical Systems, Best, The Netherlands) by using a quadrature coil. The examined knee was placed in the coil with 15° of flexion and 10–15° of external rotation with a supporting device to assure comfort and immobilization. The MRI protocol included one pulse sequence (T1-w Spin Echo) in sagittal, coronal and transverse planes and the parameters were as follows: 550/15 (TR ms/TE ms), matrix of 304 × 512, field of view 16 cm × 14 cm, four signal excitations, 4 mm slice thickness for the coronal and sagittal acquisitions and 500/20 (TR msec/TE msec), matrix of 304 × 512, field of view 16 cm × 14 cm, three signal excitations, 3 mm slice thickness for the transverse acquisition. The sagittal images were obtained at a level parallel to the lateral femoral condyle assessed from the axial images. No fat suppression was applied to avoid susceptibility artifacts from the previous operation (ACL reconstruction).

The patella length was measured on each knee (operated and non operated) at a single sagittal image from the superior articular margin (excluding osteophytes) to the distal anterior tip (excluding enthesophytes) [19, 26]. This single sagittal image (which was selected for measurement) was the image with the longest longitudinal axis of the patella in order to establish same circumstances for all patients. On the same image the length of the patellar tendon was also documented by measuring the distance between the patellar and tibial attachments along the inner margin of the tendon [19, 26]. The Insall–Salvati ratio [15] was determined for each knee and values <0.74 were considered as patella baja (Fig. 1). The length of the patellar tendon, the patella, and their ratio at least 1 year after harvesting of the BPTB or HS autograft (operated knees) were compared to the respective values of the non-operated control knees. All measurements were performed utilizing a PACS workstation (Merge eFilm 2.0, Milwaukee, WI, USA). Reproducibility error for MRI measurements was assessed in 10 patients (20 knees). Measurements were performed in both the operated and the contra lateral non-operated knee at two different times in random, on the same examinations within 1 week from each other. The names of the patients were not known in either session to the examiner.

Fig. 1 MRI protocol showing the method of measurement of the patella length and patellar tendon length and calculation of the Insall–Salvati ratio

Outcome measures

All patients have been clinically and radiographically evaluated at least 1 year after the index procedure. At the latest follow up the functional outcome was documented in a data collection form. The outcome measures utilized were the Lysholm knee score and, the International Knee Documentation Committee (IKDC) Standard Evaluation Form [14]. Joint laxity was assessed with the KT1000 arthrometer (Medmetric, San Diego, California). The Shelbourne score [29] which has been designed to determine the incidence and severity of anterior knee pain as it relates to sporting or daily living activities, prolonged sitting, stair climbing, and kneeling was used to evaluate anterior knee problems.

Statistics

The distribution of the continuous variables for each knee (operated and non-operated) was plotted. The independent samples t test was utilized for continuous variables with symmetric distribution. For ordinal non-parametric variables or when an asymmetric curve without Gaussian distribution was obtained, the Mann–Whitney U test was used to detect significant differences. For comparison of proportions, Pearson's chi-square and Fisher's exact tests were used. The level of significance was set at $P < 0.05$. The P values were always two-tailed with exact significance. The data were analyzed with the SPSS statistical package (SPSS ver.12, Chicago, Illinois).

We used one-tailed, two group t test for equal group sizes and equal sigma, post hoc power analysis to estimate the probability of the study to detect differences of patellar tendon length. Alpha was set at 0.05 and the sample size was 16 for the BPTB group and 32 for the HS group. The software used for power analysis was GPower v2.0.

Results

The mean follow up period from the date of surgery to the latest clinic office evaluation and the MRI study was 19.3 months (range 14–26) for the BPTB group and 16.4 months (range 13–22) for the HS group. Overall the outcome measures as well as the MRI study measurements have been documented over the first 12 postoperative months. The groups were comparable in terms of age, sex distribution, patella length, patellar tendon length and Insall–Salvati ratio of the non-operated knees (Table 1).

Patellar tendon length measurements

The precision of patellar tendon measurements in 20 knees by the same observer was excellent exhibiting a coefficient of variation of 1.5%. The contra lateral normal knee served as a control since there are no differences between the right and left knees regarding patellar tendon length and Insall–Salvati ratio according to some morphometric studies. [11, 24]. In the BPTB group the length of the patella had as expected no statistical difference between the operated and the non-operated knee. The patellar tendon length and the Insall–Salvati ratio of the operated with BPTB autograft knees were significantly different compared to the non-operated knee values (Table 2). The patellar tendon length at the operated with BPTB autograft knees was at average 39.25 mm whereas the non-operated knees had a mean patellar tendon length of 43.45 mm (Fig. 2). This is a patellar tendon difference of 4.2 mm (9.7%) compared to the contralateral non-operated knee which was statistically significant ($P = 0.006$). In the HS group the patella length, the patellar tendon length and the Insall–Salvati ratio of the operated knees had no statistical significant difference from the respective non-operated knee control values (Table 2). The patellar tendon length at the operated with hamstrings autograft knees was measured 1.14 mm (2.6%) shorter than the contralateral non-operated knees which was statistically not significant ($P = 0.230$) (Fig. 3).

Post hoc power analysis with the data available revealed that the study was able to detect a statistical significant difference of patellar tendon length (alpha 0.05) with 69% probability [power ($1-\beta$): 0.6948] for the BPTB and 32% probability for the HS group [power ($1-\beta$): 0.3228]. The slight difference of 1.14 mm between operated and healthy knees was the reason that the study was underpowered in the hamstring group even though there were twice as many patients compared to the patellar tendon group.

Table 1 Comparison of variables between groups

	BPTB ($n = 16$)	Hamstrings ($n = 32$)	P value
Age	29.75 (19–43)	28.75 (16–45)	0.665[a]
Gender M/F	15/1	26/6	0.398
Non-operated (control) knees			
Patella (mm)	43.95 (35.6–48.3)	42.59 (33.4–47.8)	0.134
Patellar tendon (mm)	43.45 (34.2–53.5)	42.84 (31.9–56.6)	0.850
Insall/Salvati ratio	0.99 (0.75–1.22)	1.011 (0.71–1.36)	0.737

Mann-Whitney-U test was used for all other variables (not truly normal distribution)

[a] Independent values t test (age had normal Gaussian distribution)

Patella baja

Harvesting of BPTB and hamstrings graft in our series have resulted in patella baja in one patient (6%) from BPTB group and none patient from HS group according to patella baja MRI criteria [26] (Insall–

Table 2 Comparison of variables between operated and control knees within groups

	Non-operated (control) knee	Operated knee	Difference (95% CI) lower/upper	P value
BPTB ($n = 16$)				
Patella (mm)	43.95 (35.6–48.3)	44.58 (34.2–50)	0.625 (–2.03/3.28)	0.596
Patellar tendon (mm)	43.45 (34.2–53.5)	39.25 (30.8–50.7)	–4.2 (–7.83/–0.57)	0.006
Insall/Salvati ratio	0.99 (0.75–1.22)	0.89 (0.67–1.23)	–0.106 (–0.21/–0.001)	0.047
Hamstrings ($n = 32$)				
Patella (mm)	42.59 (33.4–47.8)	42.58 (33.7–49.1)	–0.003 (–1.7/1.69)	0.902
Patellar tendon (mm)	42.84 (31.9–56.6)	41.69 (30.3–52.2)	–1.14 (–4.12/1.03)	0.230
Insall/Salvati ratio	1.011 (0.71–1.36)	0.97 (0.66–1.27)	–0.036 (–0.1/0.03)	0.451

The Mann–Whitney U test was used to detect differences for all variables (no variable had true normal distribution)

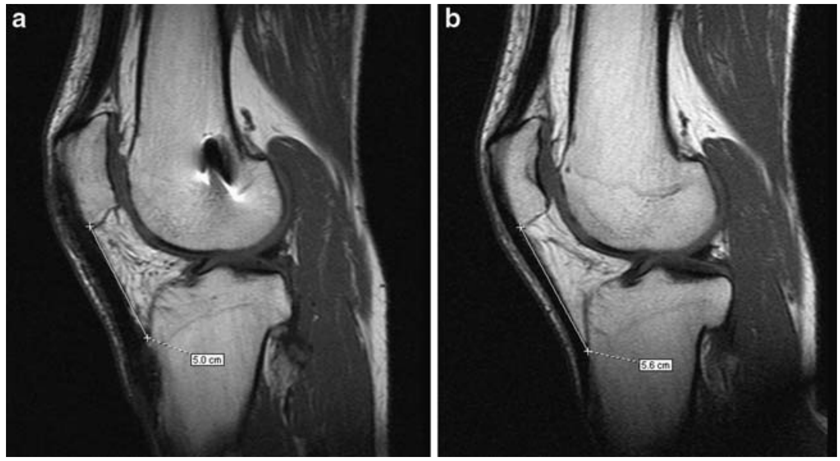

Fig. 2 **a** Measurement of the patellar tendon length in a sagittal MRI of a knee 17 months after ACL reconstruction with BPTB graft. **b** Sagittal MRI of the contralateral healthy knee (6 mm difference or 12%)

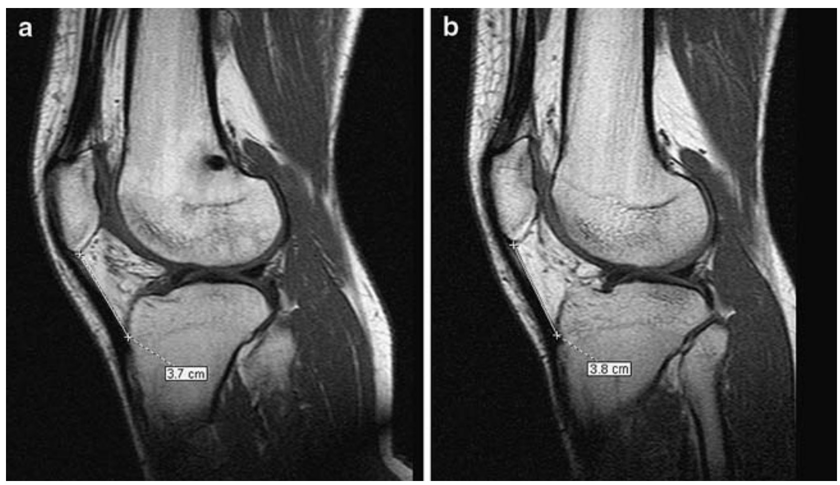

Fig. 3 **a** Measurement of the patellar tendon length in a sagittal MRI of a knee 14 months after ACL reconstruction with HS graft. **b** Sagittal MRI of the contralateral healthy knee (1 mm difference or 2.6%)

Salvati < 0.74). The proportion of patients with patella baja after harvesting either BPTB or hamstrings graft was not statistically different (Pearson's chi-square and Fisher's exact test, *P* value: 0.316).

Functional outcome

One IKDC fair result (grade C: abnormal) per group was documented in this study. The patient from BPTB group had 25% shortening of the patellar tendon and consequent patella baja (Insall–Salvati = 0.67). The fair result from HS group had 2.9% patellar tendon shortening, no patella baja and KT1000 side to side difference of 6 mm.

Overall the functional outcome of the operated knees (Lysholm score, IKDC, and KT1000 arthrometer side to side difference) was not statistically different between the BPTB and the HS group (Table 3). The Shelbourne score was slightly better in the HS group but this difference was not statistically significant.

Discussion

The primary objective of this study was to compare postoperative changes in the patellar tendon length

Table 3 Outcome comparison between groups

	BPTB (n = 16)	Hamstrings (n = 32)	P value
Lysholm score	97.25 (81–100)	97.34 (85–100)	0.669
IKDC AB/CD	15/1	31/1	1.00[a]
Shelbourne score	93.94 (55–100)	98.4 (70–100)	0.184
Total KT1000 side to side difference	1.12 mm (0 to 4)	1.47 mm (1 to 7)	0.996
Stratified KT1000 side to side difference			
0 to 3 mm	87.6%	84.4%	0.888[a]
3–5 mm	12.4%	12.5%	
>5 mm	0%	3.1%	

The Mann–Whitney U test was used to detect differences for all other variables

[a] Pearson Chi-square and Fisher's exact test

after ACL reconstruction between PT and HS tendon autografts using MRI. In our series we have used the MRI as an established imaging modality for knee pathology diagnosis [4, 13, 26] and accurate soft tissue measurements. Different magnifications and projections at the plain radiographs resulting in measurements errors at least of 10% were solved with calibrated measurements made on MR images. In addition we performed simultaneously a control study in the contralateral non-operated knee of each patient to estimate the intraindividual variable difference. The contralateral control knee patella and patellar tendon length reflected each patient's normal anatomic values.

Based on this assumption, our series demonstrated a significant patellar tendon shortening of a mean 9.7% after harvesting BPTB graft compared to the contralateral non-operated control knee. In contrast harvesting of HS tendons results in a non-significant shortening of the patellar tendon of 2.6%. Therefore, our initial hypothesis was confirmed. To our knowledge, this is the first report which compares the effect of BPTB and HS tendon grafts harvesting in patellar tendon length and had demonstrated less shortening for the hamstring tendon group.

Harvesting of bone patellar tendon bone has been reported to result in shortening of the remaining patellar tendon. Major patellar tendon shortening was found by two authors in their series [6, 9]. In a study of 40 patients after ACL reconstruction using the medial third of the patellar tendon as a graft, Dandy and Desai [9] found at average 6% patellar tendon shortening. Ten of 40 patients (25%) had more than 10% shortening. Breitfuss et al. [6] in their series of 41 patients after ACL reconstruction with BPTB graft reported 9.8% patellar tendon shortening on 23 patients (56%). Eleven patients (27%) in their series demonstrated exactly equal patellar tendon length in both knees. From a clinical point of view the vast majority of their patients (80%) had good or excellent results.

Non significant patellar tendon shortening, less than 1%, was reported by Shelbourne et al. [28] in a series of 71 patients who had undergone an identical autogenous patellar tendon ACL reconstruction, by the same surgeon, and followed the same postoperative accelerated rehabilitation program. Patellar tendon shortening of only 0.51% was also found by Krosser et al. [18] in a group of 55 patients underwent arthroscopically assisted ACL reconstruction using mid-third bone-patellar tendon-bone autograft and had the defect sutured closed. The maximum shortening in their series was 4.3%.

The great diversity of aforementioned results could be explained by inaccuracies of radiographic measurements, caused by different magnifications and projections of the radiographs. Neyret et al. [22] in a comparative study between lateral X-rays and MRI found that MRI is more sensitive and accurate to measure the patellar tendon length. A study utilized Roentgen Stereometric Analysis tried to overcome these inaccuracies, with measurements based on radiographic calibration and tantalum beads as landmarks [1]. The authors reported at average 3.2% patellar tendon shortening on 10 patients after ACL reconstruction with removal of its central one-third and open tendon defect. Two patients (20%) had over 5% shortening. Probably, the operative procedure (closing the patellar tendon defect or not) is another factor which might contributes to patellar tendon shortening. However, Charrois et al. [7] reported that after harvesting the BPTB for ACL reconstruction there are no differences in patellar height irrespectively of closing the tendon defect or not. Similar to our study, Bernicker et al. [3] using MRI found 8% shortening of the patellar tendon 1 year after harvesting the middle third but without closing the tendon defect. Therefore, comparison of the above studies with our study is not always possible, because we used a different evaluation system and different surgical technique. Nevertheless, a possible explanation of our high amount of shortening, in the BPTP group, is the accurate definition of patellar and tibial attachments of the tendon, the lack of different magnifications and projections and the inherit MRI calibration. Futhermore, these MRI properties help us to identify an average 2.6% patellar tendon shortening in patients with harvesting of hamstrings tendons.

We found that even without direct trauma to patellar tendon, like ACL reconstruction with HS tendons, a small amount of shortening of the patellar tendon occurs. Like in our study, Dandy and Desai [9] found a 2.4% shortening of the patellar tendon after ACL reconstruction with an artificial ligament which was less than the reconstruction with a BPTB autograft (6%). A possible explanation for this is the retropatellar fat pad fibrosis secondary to the surgical trauma, contraction of the scar that develops in the gap created after patellar tendon harvesting due to diminished elastic components and the decreased strength of quadriceps contributing to patella baja which stresses patellofemoral joint. Moreover quadriceps inhibition weakness causes delayed rehabilitation with subsequent extension deficit and abnormal patellofemoral joint forces.

Shabshin et al. [26] determined the MRI criteria for patella alta and patella baja after they have reviewed

262 consecutive MRI studies of the knee. They set Insall–Salvati ratio <0.74 as the MRI criterion for patella baja diagnosis. According to this cutting point we found 6% of the patients in the BPTB group and 0% of the patients in the HS group to develop patella baja after surgery. A similar rate of patella baja after harvesting of BPTB graft have been reported by many authors [2, 6, 8, 9, 21, 23, 25]. Only Tria et al. [30] found a high rate (76%) of patella baja after ACL reconstruction with BPTB.

Shortening of the patellar tendon is associated with anterior knee pain according to many authors [2, 6, 12, 16, 21, 23, 25]. However, this was not the case in our series. Similarly to our study, other studies [1, 3, 30] also reported no correlation of patellar tendon shortening with patellofemoral pain. Nevertheless, all these studies, like our study, have a short-term follow-up period. Thus, further studies with long-term follow-up period are needed to determine if this shortening is of clinical importance or not.

This study was designed to overcome the limitations of previous studies in terms of assessment the patellar tendon length using MRI. All patients, operated by a single surgeon with the same arthroscopic technique. The effect of HS tendon grafts harvesting for ACL reconstruction, on patellar tendon length was also evaluated. However, the lack of randomized treatment assignment is a limitation of this study. Finally, a power analysis before the initiation of the study was not executed. Post hoc power analysis detected a non-significant shortening of the ipsilateral patellar tendon in HS group with compromised power (32%) and a significant patellar tendon shortening in BPTB group with adequate power (69%).

In conclusion, our study suggests that harvesting a BPTB autograft results in approximately 10% shortening of the patellar tendon. In contrast harvesting of HS has minor effect the length of the patellar tendon. Although without clinical symptoms in the short-term follow-up, the clinical impication of this ‘‘complication'' needs to be determined by studies with long-term follow-up especially after harvesting the BPTB.

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