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Magnetic resonance imagination of the peroneus longus tendon after anterior cruciate ligament reconstruction

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Abstract Several studies report that tendons can regenerate after harvesting. These studies have been performed especially in patellar and hamstring tendons. At our institution, 10 cm length of full thickness peroneus longus tendon has been harvested to reconstruct torn anterior cruciate ligament since 1997 as a different graft source. The aim of this study was to investigate whether the peroneus longus tendon used the anterior cruciate ligament reconstruction has a regeneration potential or not. Twelve patients, who had originally undergone harvesting of the peroneus longus tendon for the primary surgery of the anterior cruciate ligament reconstruction, underwent magnetic resonance imaging (MRI). Images of both legs were acquired simultaneously with the use of the scanner's extremity coil, as we aimed to compare harvested peroneus longus tendon with the other leg's peroneus longus tendon (healthy side) for evaluation of the regeneration potential. The average age of the patients was 31 years. There were eight right and four left legs. The average time interval was 52 months between ligament surgery and MRI. In all patients, a varying amount of the regeneration of the peroneus longus tendon was seen on the MRI images. Although the extent of PLT regeneration in proximal sections seemed better than in mid- and distal sections, there was no statistical difference between sections ($P = 0.130$). These data show that the peroneus longus tendon has a regeneration potential after harvesting for anterior cruciate ligament reconstruction.

Keywords Regeneration · Tendon · Magnetic resonance imaging · Peroneus longus tendon · Anterior cruciate ligament

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Introduction

Tendon grafts have been used increasingly in many different areas of reconstructive orthopedic surgery. Due to a number of reasons autologous tendon grafts are frequently preferred, especially in the reconstruction of the anterior cruciate ligament (ACL). The most common sources of autografts are patellar tendon, semitendinosus tendon, gracilis tendon, iliotibial band and quadriceps tendon [10]. With an increasing use of these grafts, it has been observed that there is a neotendon development in the harvested area. Following the first report, by cross indicating a regeneration potential of the harvested tendons in 1992 [3], regeneration of the tendons has become a popular subject and several clinical and experimental studies reported that the tendons can regenerate [4, 5, 7, 12–15, 17, 18]. These studies have been performed especially in patellar and hamstring tendons because of the fact that utilization of these tendons in the reconstruction of the ACL has become more common during the last few years.

Although these grafts are commonly used nowadays, disagreement about the choice of the suitable graft still persists due to some disadvantages. It has been demonstrated that many complications can occur following the application of autologous patellar tendon grafts including kneeling pain, tendon shortening, patellar chondromalacia, patellar fractures, patellar tendon ruptures, patellofemoral pain syndromes and persistent quadriceps weakness [6, 8]. Hamstring tendon grafts have greater mechanical strength than a bone–patellar tendon–bone complex, and also patients treated with hamstring tendon grafts are less likely to suffer patellofemoral pain and extension loss. But using the hamstring tendons can cause a significant change in hamstring muscle strength [16]. Hamstring function is very important after ACL reconstruction in order to protect the reconstructed ACL from the anterior drawer force, which is exerted by quadriceps contraction [11].

Because of knee joint complications involving patellar and hamstring tendon grafts in ACL reconstruction, peroneus longus tendon (PLT) graft has been preferred. Additionally, we did not create a secondary injury in the knee region.

Ten centimeters length of full thickness PLT has been harvested to reconstruct torn ACL since 1997 as a different graft source [9]. Since no patient experienced ankle joint dysfunction or difficulty in sports activities due to PLT graft transfer, we hypothesized that the PLT might have a regeneration potential. Therefore, we evaluated 12 patients with magnetic resonance imaging (MRI) to confirm the regenerative ability of the PLT after harvesting for ACL reconstruction.

Materials and methods

Patients and surgical techniques

Twelve patients, who had originally undergone harvesting of the PLT for the primary surgery of ACL reconstruction, consented to be included in the study after approval by the ethical committee of the University. The indications for reconstruction of the ACL were functional instability during daily or sports activities and complete rupture or absence of the ACL as verified arthroscopically.

The operative technique was standardized in all patients. The tibial and femoral stumps of the torn ACL were excised to allow the anatomical ACL attachment sites to be seen. A 2.2-mm K-wire was inserted from the lateral femoral condyle cortex to the posterosuperior portion of the femoral ACL attachment site with the aid of a femoral drill guide. The tibial drill guide was used to insert another K-wire from the anteromedial aspect of the tibia to a point just posteromedial to the center of the tibial ACL attachment site. The K-wires were then over-drilled with a cannulated reamer according to the maximum diameter of the autograft. It was taken from the PLT of the injured leg for ACL reconstruction. A 10-cm long PLT section with its entire width was harvested from above and below the lateral malleolus with two separate incisions. The autograft was introduced into the tunnels as a single strand and was first fixed at the femoral site. The tibial site was then fixed during manual tensing of the graft [9].

MRI

All patients underwent the same MRI protocol. A radiologist knew that the PLT tendon had been harvested, but was not informed about the operated side.

MRI was performed with a 1.5-Tesla imager (Symphony; Siemens Medical Solutions, Erlangen, Germany). Images of both legs were acquired simultaneously with the use of the scanner's extremity coil, because we aimed to compare harvested PLT with the other leg's PLT (healthy side PLT, HPLT) for evaluation of the regeneration potential. The imaging protocol was as follows; images were obtained on sagittal fast-spin echo T1-weighted, axial fast-spin echo T1-weighted, and axial fast-spin echo T2-weighted. Imaging was performed from the distal cruris to the mid-portion of the metatarsals. Image parameters were obtained (repetition time 650 ms; echo time 13 ms; matrix 334×512 pixels; slice thickness 3 mm; gap between slices 0.5 mm).

One musculoskeletal radiologist interpreted all images and the presence of the PLT distal to the harvest site was recorded. Three different MRI sections, corresponding to the harvested tendon path were determined by using anatomical landmarks. The end of the posterolateral tibial tip for proximal sections, end of the lateral malleolus for mid sections, and sinus tarsi for distal sections were used as landmarks. The approximate volume of the regenerated PLT (RPLT) and HPLT in a 3-mm section were calculated separately using the formula for an ellipse [volume = length (slice thickness) $\times$ width $\times$ height $\times$ 0.52]. The extent of PLT regeneration was expressed as a percentage by dividing the volume of RPLT by the volume of HPLT (vRPLT/vHPLT). Finally, vRPLT/vHPLT was obtained in each section level separately.

Statistical analyses

Data normality was assessed by the Kolmogorov–Smirnov test. Comparisons among proximal, mid and distal of the regenerated tendons were done with analysis of variance—ANOVA (Bonferroni test as the post hoc test) for percent of volume. Pearson correlation coefficients were calculated between volume, and age and time. The results are cited as mean ± SD. A value of $P < 0.05$ was considered significant.

Results

The study group consisted of 12 male patients. The average age of the patients at the time of MRI examination was 31 ± 8 years. There were eight right and four left legs. The average time interval was 52 ± 32 months (range 18–96 months) between ligament surgery and MRI. Partial meniscectomy at the time of reconstruction was performed in five patients. The others had intact menisci at the time of surgery. When the results of ACL reconstruction were evaluated according to the IKDC scores, eight (66.6%) patients received a final rating of normal or nearly normal and four (33.4%) received a rating of abnormal or severely abnormal. The Lysholm scores of 10 (83.3%) patients were categorized as good or very good. No patients experienced any impairment in their sports activities and ankle joint dysfunction due to transplant harvest abnormality.

In all of the patients, varying amount of the regeneration of the PLT was seen on the MRI images (Fig. 1). The mean percentages of the regeneration were 59.2, 49.9 and 44.5 in proximal, mid and distal sections, respectively. The appearance of this regenerated tissue appeared to be tendinous and was present at its normal tract (Fig. 2a–c). Some of the regenerated tendons in the harvested areas were nearly similar to the HPLT, but majority of these were thinner. Although the extent of PLT regeneration in proximal sections seemed better than in mid and distal sections, there was no statistical difference between sections ($P = 0.130$).

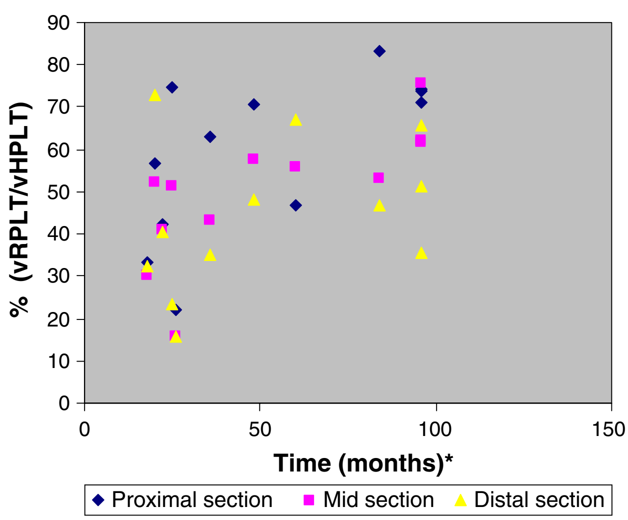

Fig. 1 In all patients varying amounts of the regeneration of the PLT were seen. The extents of PLT regeneration in proximal sections of eight patients were over 50%. It seemed better than mid and distal sections. But this situation did not reveal a statistical difference. *Asterisk* time interval between ligament surgery and MRI. *vRPLT/vHPLT* the extent of PLT regeneration was expressed as a percentage by dividingthe volume of RPLT by the volume of the HPLT

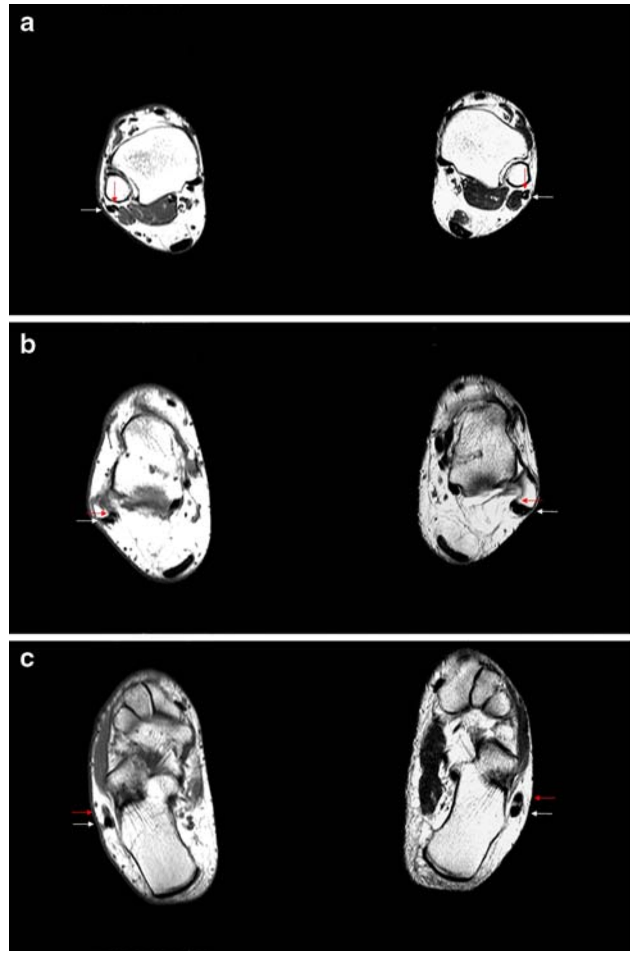

Fig. 2 Magnetic resonance images of the ankles of a 42-year-old man at 96 months after peroneus longus tendon harvest in the left leg. The RPLT (*white arrow in left image*) were nearly similar to the HPLT (*white arrow in right image*) in the proximal (**a**) and mid sections (**b**). The RPLT (*white arrow in left image*) is clearly identified in the distal section but it is thinner than the HPLT (*white arrow in right image*) (**c**). Peroneus brevis tendons (*red arrows*) are clearly identified in all images

There was a correlation between time interval and amount of regeneration in proximal and mid sections of the regenerated tendon ($r = 0.64$, $P = 0.025$ and $r = 0.73$, $P = 0.007$, respectively). However, the patient's age was not correlated with the amount of regeneration.

Discussion

The principal finding of the present study was MRI evidence for PLT tendon regeneration after harvesting for ACL reconstruction. Our results are consistent with similar studies about regeneration potential of the hamstring tendons.

Papandrea et al., using ultrasound, showed that the semitendinosus tendon may actually regenerate [14]. The regenerated bands were very similar to the normal tendons by 18 months postoperatively. However, in any case, the distal insertion of the regenerated semitendinosus tendon was not clearly identified at the anatomic site in the pes anserinus. In the present study, regenerated tendon in the distal insertion was recognizable but thinner than the proximal and mid sections. Appearance of distal regeneration might be due to longer follow-up in our study (52 ± 32 months).

Okahashi histologically studied regeneration potential of the hamstring tendons harvested for reconstruction of the ACL [13] and reported similar regeneration incidence with Eriksson et al.'s results [5]. In addition, several MRI studies also showed that the hamstring tendons could regenerate after harvesting. Eriksson et al. investigated the regeneration potential of the tendons with MRI in 11 patients in whom only the semitendinosus tendon but not the gracilis was harvested for ACL reconstruction. They reported that eight patients had regenerated tendons at 7–28 months after harvesting [5]. Later they reported results of another study about regeneration potential of the semitendinosus tendon. Similarly, in this study five of the six patients also had regenerated tendons on MRI at 6–12 months after harvesting [4]. In both studies, the semitendinosus tendon had been used in its whole length and thickness. They claimed that regeneration involves extrinsic mechanisms because of the fact that no obvious tendon material that could act as a scaffold or guide for the regenerative process was left after the complete semitendinosus tendon resection [4]. In the light of these findings, Carofino has stated that the intact gracilis may help the regenerating structure track to the pes anserinus and facilitate anatomic regeneration [2]. Similarly, in our study the regeneration of PLT might also be potentialized by intact peroneus brevis tendon within the same tendon sheath. So we had varying amounts of the regeneration of PLT in all patients.

Aforementioned studies were performed especially in patellar and hamstring tendons because of frequent use of these tendons in reconstruction of ACL. Beall et al. reported a paper about regeneration of flexor carpi radialis (FCR) tendons [1]. At least partial regeneration of the FCR tendons, harvested during ligamentous reconstruction tendon interposition of the thumb carpometacarpal joint arthroplasty, occurred in 11 of the 14 patients in their study (79%).

Many problems can occur following the application of autologous patellar tendon grafts [6, 8] and also using the hamstring tendons can cause a significant change in hamstring muscle strength [16]. Hamstring function is very important after ACL reconstruction in order to protect the reconstructed ACL from the anterior drawer force, which is exerted by quadriceps contraction [11]. So we used full thickness PLT to reconstruct torn ACL due to the knee joint complications involving patellar and hamstring tendons. Our patients did not state any complaints about the ankle joint dysfunction or any difficulty in sports activities. However, no clinical pathology was observed in our patients after harvesting tendon grafts even if they have actively made sports, walking analyses and study of muscle strength could not be performed to evaluated functional state in the ankle.

Our results about regeneration potential of the PLT support previous MRI studies. Varying degrees of tendon regeneration occurred in all subjects. The results of this study verify that the PLT tendon has a strong potential for regeneration.

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