MRI evaluation of medial hamstring tendons after harvesting for anterior cruciate ligament reconstruction

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Purpose

Reconstruction of a ruptured anterior cruciate ligament (ACL) is a commonly performed orthopaedic procedure. Several graft sources have been used, yet none has gathered full consensus approval. During the last few years, autologous hamstring tendons (semitendinosus and/or gracilis) have emerged as a popular graft source. In 1992 Cross et al. first published findings indicating a regeneration potential of the harvested tendons. However, only 4 patients were thoroughly examined. In 1997 Simonian et al. reported findings showing regeneration of the hamstrings tendons to a more proximal insertion point than normal. The purpose of our study was to evaluate the MRI appearance of semitendinosus and gracilis harvest site in a number of consecutive patients in whom both the semitendinosus and gracilis tendons were harvested for ACL reconstruction.

Methods and Materials

Forty-four patients (39 males-5 females, age range 15-49), who had previously undergone ACL reconstruction with hamstring tendons, participated in the study. 4 of them were finally excluded from the study due to technical problems. Inclusion criteria were that there was no history of hamstring injury in either leg and that there had been no previous surgery on the ipsilateral or contralateral knee. All of them were no more than recreational athletes and none was involved in competitive sports.

ACL reconstruction was performed by the same orthopaedic surgeon using the ipsilateral semitendinosus and gracilis tendons. All patients followed the same standardized rehabilitation protocol. The knee was immobilized for a week with a brace followed by continuous passive motion exercise. Active and assisted range of motion exercises were started at 2 weeks. Partial weight bearing was allowed at 3 weeks and full weight bearing was started at 4 weeks. Running was allowed at 3 months, followed by return to previous sports activity at 9-10 months.

All patients had a preoperative MRI examination of the affected knee. After the ACL reconstruction a single MRI investigation was performed on each patient using a 1,5
Thus, a total number of 40 postoperative MRI studies were performed. The time interval between surgery and MRI ranged from 1 to 24 months (4 examinations at 1 month, 8 at 3 months, 12 at 6 months, 8 at 9 months, 6 at 12 months, and 2 at 24 months).

The postoperative MR imaging protocol included T1-weighted spin-echo (SE) images of the operated knee in the sagittal and axial planes, and T1-weighted SE and short-tau inversion recovery (STIR) images in the axial and coronal planes through the thighs bilaterally from the level of the knee joint to the subtrochanteric region.

In each case, the anatomic location of semitendinosus and gracilis tendons was evaluated separately on T1-weighted MR images of the operated knee. The tendons were evaluated at 2 locations: (1) between the superior pole of the patella and the level of the joint line, and (2) distal to the joint line. The presence or absence of a structure in the normal anatomic location of each of the hamstring tendons was noted. If a structure was present in the harvest site, the morphology and T1-weighted imaging characteristics were recorded. Patients were classified as "regenerated" or "nonregenerated" based on the presence or absence of a neotendon that crosses the joint line, respectively.

Using axial T1-weighted images through the thighs bilaterally anterior-posterior and transverse diameter measurements were obtained through each of the 2 hamstring muscles separately at the mid-thigh level. Measurements were compared between the operative and nonoperative sides to evaluate for muscle atrophy. In addition, the presence of increased signal within the hamstring muscles on axial and coronal T1-weighted images was noted to document the presence of fatty atrophy on the operated versus the nonoperated side. Furthermore, the semitendinosus and gracilis muscles were carefully observed for superior muscle retraction.

Finally, STIR images were used to evaluate for abnormal signal within the muscles.

**Results**

The MRI data showed variability among patients. In all but 2 cases, the operated semitendinosus and gracilis muscles were atrophied demonstrating a decrease in cross-sectional area (Fig. 1, 2). Both the operated hamstring muscles were superiorly retracted in 20 patients (Fig. 2), whereas only the operated semitendinosus muscle showed cephalad retraction in 10 cases and only the operated gracilis muscle was centrally retracted in 6 patients. Presence of strikingly abnormal signal in the operated semitendinosus muscle and in the surgical harvest site of the semitendinosus tendon was detected in 4 cases (Fig. 3). Fatty infiltration of both the operated hamstring muscles was present in 4 patients, whereas fatty atrophy of only the operated semitendinosus muscle could be seen in 8 cases (Fig. 4, 5) and of only the operated gracilis muscle in 2 patients.
Distally, soft tissue, beginning proximally and extending distally to various distances, was seen along the path of the harvested tendons in 38 out of 40 patients. It could not be determined, with MRI criteria, to what extent this tissue represented scar tissue versus tendon regeneration, but, for the purposes of our discussion this tissue was considered to be tendon. Only a study based on histology would provide accurate information about regenerative tissue after harvesting. In 26 patients a regeneration of both hamstring tendons was observed (Fig. 6-12), whereas a regeneration of only the semitendinosus tendon was present in 6 cases (Fig. 13-15) and of only the gracilis tendon in 6 patients (Fig. 16-21). These tendons, in most cases, terminated in an abnormal location below the joint line, blending either with the semimembranosus and gastrocnemius muscles or with the sartorius fascia. We should also mention that, of all the patients in our series, there were only 2 in whom both the hamstring tendons failed to regenerate at all (Fig. 22, 23). Finally, in 2 cases the regenerated semitendinosus and gracilis muscles appeared more normal with their extensions distally, at the level of the pes anserinus, clearly seen. (Fig. 24-27). All the remarks above are listed in the table below:

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ACL reconstruction using the semitendinosus and gracilis tendons has become recently a standard technique. Previous reports in the literature have surprisingly reported that the tendon can regenerate after harvesting the semitendinosus and/or gracilis tendons.

Cross et al. evaluated the regeneration of the semitendinosus and gracilis tendons in 4 random patients out of a group of 225 by using MRI and electromyography. He clarified that the regrowth occurs from the distal cut end of the muscle belly, and follows the fascial planes to the medial popliteal fossa.
Simonian et al. found no significant hamstring atrophy after harvest when compared with the nonoperative side. However, they measured muscle dimensions at a point 10 cm above the joint line, which is distal to the main portion of the muscle bellies of semitendinosus and gracilis in many patients. At this level, the atrophy of the muscle belly may not be evident. Despite the findings of absent atrophy, in 3 of the 9 patients in their series, a semitendinosus could not be identified distally.

Papandrea et al. studied by ultrasound the process of regeneration of the semitendinosus tendon after it had been harvested for ACL reconstruction. They showed that the regenerated tissue at the harvest site appeared very similar to the normal tendon by 18 months postoperatively, and concluded that the semitendinosus tendon has the potential to regrow in a near-anatomic position.

Rispoli et al. used MRI to study the hamstring tendons after ACL reconstruction at different time periods after harvesting. In their report, they revealed an apparent regeneration of the tendons beginning proximally and extending distally with time. They found normalization of the semitendinosus tendon to the level of the knee joint, but the tendon appeared "ill-defined" in the most distal 3-4 cm.

Eriksson et al. evaluated 16 patients with MRI at a median of 7 months postoperatively using a 0.2-T scanner after harvesting of the semitendinosus alone. Twelve of the 16 showed regeneration to and below the joint line with fusing of fibers with the gracilis. They observed no signs of muscle belly retraction and the regenerated tendon had a larger cross-sectional area, although it was not quite statistically significant.

The data from our study are more in accord with the report of Fukubayashi in which no significant regeneration of the hamstrings occurred. He found in his study that the tendons attached to the medial head of the gastrocnemius.

Even though there appears to be regenerative tendon or scar tissue at the harvest site of the hamstring tendons in almost all patients on postoperative MR images, this tissue in our study reached the level of the pes anserinus insertion in only 2 patients. The neotendons, in most cases, terminated in an abnormal location at the level of the joint line, blending either with the semimembranosus and gastrocnemius muscles or with the sartorial fascia. The muscle bellies showed significant atrophy and superior retraction in most cases, even at 2 years postoperatively. The fact that 2 patients appeared a fairly normal attachment of the operative tendons demonstrates the possibility of complete "regrowth" in isolated cases and a nearly normal MRI appearance.

Potential weaknesses of this study are as follows. Although the MR images were obtained and interpreted prospectively, MR examinations at each time interval were performed on a different group of patients. It may be beneficial to examine the same group of patients sequentially at specific intervals following hamstring tendon harvest to determine the process of regeneration. Another potential weakness is that the exact histologic composition of the regenerated tendons remains unknown. There are only a few reports
in the literature speculating on this subject. According to their findings the regenerative tissue is very close histologically to a normal tendon. Finally, the functional ability of the regenerated tendons and their potential for reharvest remains uncertain. Further studies focusing on these issues are important to resolve these clinically critical questions.

**Images for this section:**

![MRI Image](image-url)

**Fig. 1:** MRI of the thighs in a 21-year-old male 3 months after harvesting the semitendinosus and gracilis tendons of his right knee for ACL reconstruction. Axial T1-
weighted MR image through midthigh. The semitendinosus muscle (ST) on the right (arrow) is half the size of the left semitendinosus. The gracilis muscle (G) is also atrophied but to a lesser degree. The semimembranosus (SM) and sartorius (S) muscles are normal in appearance on both sides. Axial images distal to this image showed that the regenerated semitendinosus tendon merges into the adjacent semimembranosus muscle fascia.

![Figure 2](image)

**Fig. 2:** Continued. Coronal T1-weighted MR image through posterior aspect of the thigh. The semitendinosus muscle on the right leg (white arrow) is atrophied and superiorly retracted. Compare with the normal semitendinosus on the left leg (arrowheads). A hypertrophied regenerated semitendinosus tendon is clearly seen in its harvest site on the right leg (grey arrow).
Fig. 3: Continued. Coronal STIR MR image through posterior aspect of the thigh. There is strikingly abnormal signal in the operated semitendinosus muscle belly (arrow) compared with the adjacent muscles on the right thigh, as well as to the contralateral semitendinosus muscle (arrowheads).
Fig. 4: MRI of the thighs in a 39-year-old male 24 months after harvesting the semitendinosus and gracilis tendons of his left knee for ACL reconstruction. Axial T1-weighted MR image through midthigh shows severe atrophy and fatty infiltration in the semitendinosus muscle (ST) (arrows). The gracilis muscle (G) is normal in appearance (arrows). Axial images caudal to this image showed regeneration of the gracilis tendon and a fairly normal attachment at the pes anserinus.
Fig. 5: Continued. Coronal T1-weighted MR image through posterior aspect of the thigh. There is severe atrophy and fatty infiltration of the left semitendinosus distally (white arrow). The muscle appears superiorly retracted and there is no regeneration of the tendon. Notice the normal semitendinosus tendon on the right leg (black arrow).
Fig. 6: MRI of the right knee of a 33-year-old male 6 months after harvesting the semitendinosus and gracilis tendons for ACL reconstruction. A T1-weighted axial MR image at the level of the upper pole of the patella shows a normal sartorius (S) and semimembranosus muscle (SM). Hypertrophied regenerated semitendinosus (ST) and gracilis (G) tendons with low signal intensity are clearly seen at this level (arrows).
Fig. 7: Continued. A T1-weighted axial MR image just below the level of the lower pole of the patella demonstrates clearly the hypertrophied regenerated semitendinosus and gracilis tendons (arrows) adjacent to the medial head of the gastrocnemius muscle (MGC).
Fig. 8: Continued. A T1-weighted axial MR image below the level of the joint line shows the hypertrophied semitendinosus tendon fading into the medial head of the gastrocnemius muscle (arrow). The gracilis tendon is clearly distinguishable (arrow).
**Fig. 9:** Continued. T1-weighted axial MR image distal to the previous image shows the regenerated semitendinosus tendon blending with the medial head of the gastrocnemius muscle (arrow). The gracilis tendon, although present, is amorphous and can not be clearly distinguished from the adjacent tissues (arrow).
**Fig. 10:** Continued. T1-weighted sagittal MR image shows the course of the hypertrophied regenerated gracilis tendon in its harvest site as a clearly seen thick band of low signal intensity (arrow). The distal end of the semitendinosus tendon fades into the medial head of the gastrocnemius muscle (arrows).
Fig. 11: Continued. A T1-weighted sagittal MR image lateral to the previous image shows the fan-shaped distal end of the regenerated semitendinosus tendon merging into the medial head of the gastrocnemius muscle (arrows). The normal semimembranosus tendon is also well-demonstrated (arrow).
**Fig. 12:** Continued. A T1-weighted sagittal MR image lateral to the previous image shows the regenerated semitendinosus tendon in its harvest site as a clearly seen thick band of low signal intensity (arrow).
Fig. 13: MRI of the left knee in a 19-year-old male 9 months after hamstring tendon harvest for ACL reconstruction. T1-weighted axial MR image at the level of the superior pole of the patella shows a normal sartorius (S) and semimembranosus muscle (SM). A regenerated semitendinosus tendon (ST) is clearly visible at this level (arrow). A regenerated gracilis tendon is not seen at this point.
Fig. 14: Continued. T1-weighted axial MR image at the level of the joint line again shows the normal appearing sartorius muscle (arrow) and the regenerated semitendinosus tendon (arrow). No distinct gracilis tendon is seen.
Fig. 15: Continued. T1-weighted axial MR image distal to the previous image, just above the level of the tibial insertion of the pes anserinus. The sartorius tendon is normal in appearance (arrow). The regenerated semitendinosus tendon (arrow) fades into the medial gastrocnemius muscle (MGC).
Fig. 16: MRI of the left knee of a 24-year-old male 12 months after harvesting the semitendinosus and gracilis tendons for ACL reconstruction. T1-weighted axial MR image just above the upper pole of the patella. The sartorius (S) and semimembranosus (SM) muscles are of normal appearance. A regenerated gracilis tendon (G) is clearly seen at this level (arrow). A regenerated semitendinosus tendon (ST) is also seen at this point (arrow).
Fig. 17: Continued. T1-weighted axial MR image at the level of the upper pole of the patella. The sartorius and semimembranosus muscles are of normal appearance. The regenerated gracilis tendon is clearly visible at this level (arrow). The semitendinosus tendon, although present, is less distinct than normal and is slightly attenuated blending with the semimembranosus muscle fascia (arrow).
Fig. 18: Continued. T1-weighted axial MR image at the level of the joint line. The sartorius muscle is of normal appearance (arrow). The regenerated gracilis tendon is clearly seen at this level (arrow). The semitendinosus tendon is totally absent at this site.
Fig. 19: Continued. T1-weighted axial MR image at the level of the tibial attachment of the pes anserinus (PES ANS) shows a normal appearing attachment (arrow).
Fig. 20: Continued. T1-weighted sagittal MR image shows the course of the hypertrophied regenerated gracilis tendon in its harvest site as a clearly seen thick band of low signal intensity (arrow).
Fig. 21: Continued. T1-weighted sagittal MR image lateral to the previous image at the level of the pes anserinus shows a normal appearing attachment (arrow).
Fig. 22: MRI of the left knee of a 28-year-old male 12 months after hamstring tendon harvest. T1-weighted axial MR image at the level of the joint line. Both the semitendinosus and gracilis tendons are totally absent. Only the sartorius muscle can be distinguished (arrow).
Fig. 23: Continued. T1-weighted axial MR image at the level of the pes anserinus. Only the sartorius tendon participates in the formation of the tibial attachment of the pes anserinus (arrow).
Fig. 24: MRI of the thighs in a 27-year-old male 1 year after harvesting the hamstring tendons of his left knee for ACL reconstruction. T1-weighted axial MR image through midthigh. The left gracilis (G) and semitendinosus (ST) muscles appear only slightly smaller than the right (arrows). The semimembranosus (SM) muscles on both thighs are of normal appearance.
**Fig. 25:** Continued. T1-weighted axial MR image at the middle of the patella. The regenerated semitendinosus and gracilis tendons, although hypertrophied, are clearly seen in their normal harvest site (arrows). The sartorius (S) muscles on both thighs are normal in appearance (arrows).
**Fig. 26:** Continued. Axial T1-weighted MR image at the level of the attachment of the pes anserinus (PES ANS). The pes anserinus on the left knee is thickened and irregular, but shows a fairly normal attachment (arrows).
**Fig. 27:** Continued. Coronal T1-weighted MR image through posterior aspect of the thigh. The semimembranosus, semitendinosus and biceps femoris (BF) muscles on both sides appear nearly normal. Neither superior retraction, nor fatty infiltration of the operated semitendinosus muscle is observed. A hypertrophied regenerated semitendinosus tendon is clearly distinguishable in its harvest site up to the level of the pes anserinus (arrow).
Conclusion

This study revealed retraction and muscle belly atrophy of both semitendinosus and gracilis muscles persisting over time. MRI demonstrated an apparent regeneration of the harvested tendons beginning proximally and extending distally. Furthermore, MRI depicted in detail the morphology of the regenerated tendons and the exact anatomic position of their insertion point distally. This tissue in the harvest site had a variable appearance fading into adjacent structures well proximal to the original tibial attachment of the operated tendons.

References


**Personal Information**