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Regeneration of the Semitendinosus Tendon Harvested for Anterior Cruciate Ligament Reconstruction

Evaluation Using Ultrasonography*

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ABSTRACT

In a prospective study, 40 consecutive patients who underwent anterior cruciate ligament reconstruction with doubled semitendinosus and gracilis tendon autografts were examined pre- and postoperatively by ultrasound to investigate the anatomy of the donor site before and after the harvest of the tendons. The patients underwent ultrasonography at 2 weeks and 1, 2, 3, 6, 12, 18, and 24 months postoperatively. A total of 298 postoperative sonographic evaluations were performed. The semitendinosus tendon was imaged in the sagittal and axial planes: structure and margins were evaluated with the sagittal views; thickness and width were measured with the axial views. In all cases the following sequence of healing was documented: 2 weeks after surgery the semitendinosus tendon site was occupied by an area of increased thickness and decreased echogenicity, suggesting the presence of traumatic edema of the soft tissue surrounding the tenotomy. At 1 month, an irregular hypoechoic structure appeared in a near-anatomic position; at 2 months after surgery, thickness, width, and cross-sectional area of this structure were significantly greater than preoperatively. The amount of regenerated tissue increased up to that seen in the tissue of the 6-month examinations, which also showed a more uniform echostructure. The scans performed at 1 year showed distinct edges and reduction in thickness and width. At 18 and 24 months the echogenicity of the structure occupying the donor site was very similar to that of the normal semitendinosus tendon. However, this structure was clearly identified about 4 cm proximal to the pes anserinus, revealing a more proximal insertion of the regenerated semitendinosus tendon.

The ACL contributes significantly to the normal kinematics of the knee. Various intraarticular substitutions for the ACL have been attempted in cases of ACL tear or insufficiency. At present, autologous grafts continue to be accepted as the standard treatment for ACL-deficient knees. The two most common sources for autologous grafts are the central third of the patellar tendon and the semitendinosus and gracilis tendons. Many studies have reported excellent functional results for arthroscopically assisted ACL reconstruction performed with autogenous patellar tendon or combined double-looped semitendinosus and gracilis tendons.[1,6,8,18,20,23,24] Reconstruction of the ACL using the tendons of the semitendinosus and gracilis muscles involves division of these tendons from the muscle at the musculotendinous junction. During routine postoperative physical examination it is apparent that on resisted flexion there is a "string" on the posteromedial aspect of the knee, suggesting the presence of a regenerated semitendinosus tendon.[5]

The purpose of this paper was to study by ultrasound the sequence and nature of the process of regeneration of the semitendinosus tendon after it had been harvested for ACL reconstruction. The capability for accurate diagnosis of musculoskeletal conditions has dramatically increased in recent years. Ultrasonography has clearly taken its place as one of the imaging modalities that has expanded our knowledge of tendinous diseases.[9–12]

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MATERIALS AND METHODS

Patients

In this prospective study, 40 consecutive patients who underwent ACL reconstruction with doubled semitendinosus and gracilis tendons were examined pre- and postoperatively with ultrasonography to investigate the anatomy of the donor site before and after the harvest of the tendons. Preoperative ultrasound examination was performed in all 40 patients on the involved and noninvolved sides. The average age of our patients was 28 years (range, 20 to 42); 29 were men and 11 were women. The patients underwent ultrasonography preoperatively and at 2 weeks, 1, 2, 3, 6, 12, 18, and 24 months postoperatively. A total of 298 postoperative sonographic evaluations were performed (see Fig. 1).

Surgical Technique

All patients underwent arthroscopically assisted ACL reconstruction using the same technique.[7] After arthroscopic treatment of meniscus tears, the semitendinosus and gracilis tendons were harvested using a commercially available slotted stripper (Acufex, Mansfield, Massachusetts) that strips all the tendon tissue from the muscle. After meticulous cleaning and removal of all muscle remnants, the graft was double-looped and the autograft was passed through the tibial drill hole and then through the lateral femoral condyle.

Postoperative Care

Postoperatively, all patients followed the same rehabilitation program. The postoperative rehabilitation program began immediately. Active range of motion was started at 2 days. The knee immobilizer was discontinued at 4 weeks, and full weightbearing was allowed. During the first 4 to 6 postoperative weeks, rehabilitation activity remained constant, with an emphasis on improving range of motion and quadriceps and hamstring muscle strengthening. A gradual running program was begun at 3 months. Return to sports participation began as early as 5 months.

Ultrasonographic Imaging

A 7.5-MHz real-time linear array transducer was used to investigate the posteromedial aspect of the knee and the medial border of the popliteal fossa up to 12 cm above the medial joint margin. The knee was positioned in 30° of flexion, which places the semitendinosus tendon in it most superficial position, making it easily visible during ultrasound investigation. The tendon was imaged in the sagittal and axial planes. Structure and margins were evaluated with the sagittal views and thickness and width were measured with the axial views. For each knee, the axial image obtained at 4 cm above the medial joint margin was used to calculate the cross-sectional area of the regenerated tissue. This allowed comparison of the cross-sectional area of both the normal and the operated knee at the same level above the joint. Statistical analysis was done with a paired t-test. All the patients were examined by the same author (PP) to ensure a uniform evaluation.

RESULTS

The longitudinal sonogram of a normal semitendinosus tendon shows a well-delineated, echoic linear structure in a subcutaneous position. Collagen fibers of the tendon appear as an echoic longitudinal pattern. The edges are distinct and regular, and echostructure is uniform. The paratenon is seen as a hyperechoic line surrounding the tendon (Fig. 2). In the transverse sonogram, the semitendinosus tendon has an oval cross-sectional profile, characterized by a spotted appearance (Fig. 3). The mean width, thickness, and cross-sectional area of the normal semitendinosus tendon shown here measured 5.2 mm, 3.5 mm,

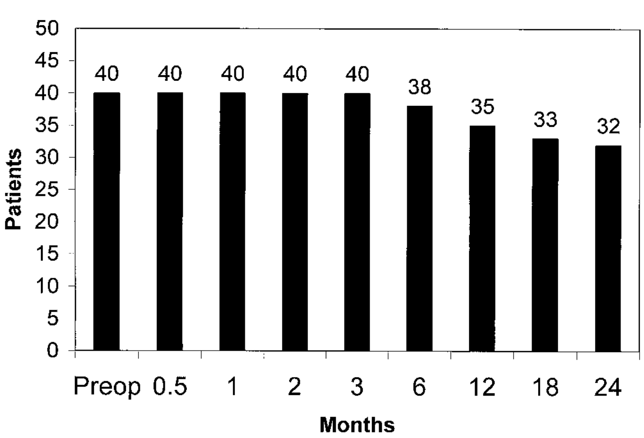

Figure 1. Number of patients who underwent prospective sonographic evaluation.

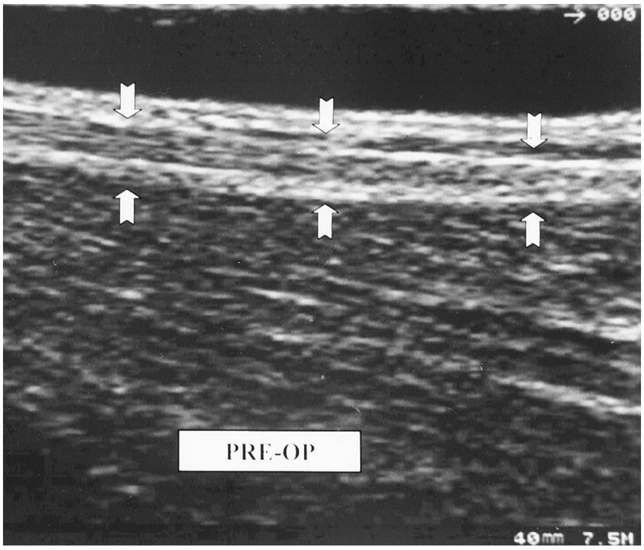

Figure 2. Longitudinal sonogram of a normal semitendinosus tendon (outlined by arrows).

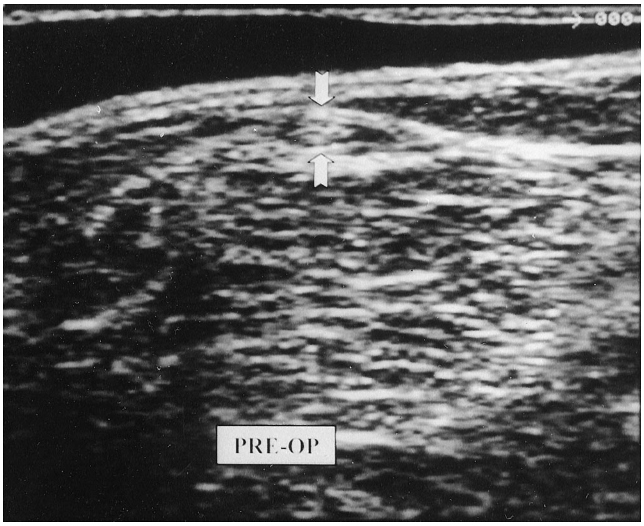

Figure 3. Transverse sonogram of a normal semitendinosus tendon (outlined by arrows).

and 13.1 mm^2, respectively. Preoperatively, no significant difference was found between the involved and noninvolved knees.

Two weeks after surgery, the semitendinosus tendon was absent in all cases. The donor site was occupied by an area of increased thickness and decreased echogenicity, suggesting the presence of a traumatic edema of soft tissue surrounding the tenotomy (Fig. 4). At 1 month after surgery, an irregular hypoechoic structure appeared in a near-anatomic position. The presence of the echoic spots and lines was variable in number and size but was well documented in all cases. Two months after surgery, the thickness and width of this structure, and therefore its cross-sectional area, were significantly greater than preoperatively (5.9 mm, 7.6 mm, and 30.7 mm^2, respectively). The edges were still sometimes irregular and the structure was hypoechoic as compared with the preoperative sonograms (Fig. 5).

At 3 months, an alternation of hypoechoic zones and echoic zones appeared in the regenerated tissue. At 6 months, the echostructure was more uniform. Although irregularities were still evident, fibrillary structure could be distinguished again, as revealed by an echoic linear structure in the longitudinal sonograms and by a spotted appearance in the transverse sonograms. Despite a progressive decrease in size, the mean width and cross-sectional area were still significantly greater than normal, measuring 5.8 mm and 16.2 mm^2, respectively (Fig. 6 and Table 1). The scans performed on the patients at 1 year after the surgery showed distinct edges and a more uniform echostructure. However, persistent irregularities were still observed. A significant reduction in thickness, width, and cross-sectional area was documented, with return to nearly normal sizes and no statistically significant difference as compared with preoperative measurements.

At 18 months, the regenerated tissue appeared very similar to normal semitendinosus tendon, with a return to

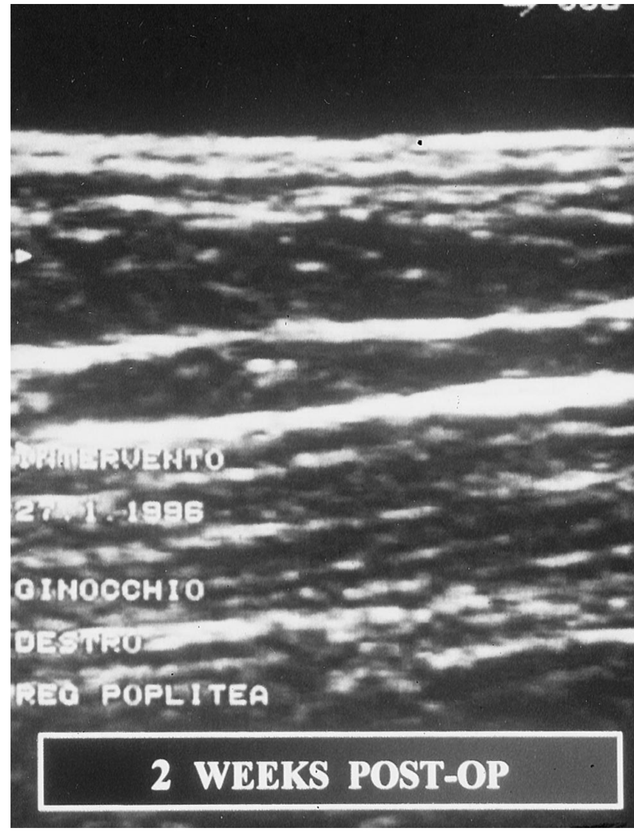

Figure 4. Two weeks after surgery the semitendinosus tendon was absent (longitudinal sonogram).

a regular echostructure and distinct edges (Fig. 7). All measurements revealed no further changes in width, thickness, and cross-sectional area as compared with the 1-year evaluation. However, in all cases, the distal insertion of the regenerated semitendinosus tendon was not clearly identified at the anatomic site in the pes anserinus, rather the distal fibers of the regenerated tendon seemed to be attached to the medial popliteal fascia, about 4 cm proximal to the pes anserinus at the level of the medial joint line. No further changes were observed at the 2-year follow-up.

DISCUSSION

There is ample evidence in the available literature that tendons heal intrinsically; the tenosynovial environment provides both the reparative cells and nutrition required for tendon healing.[13,16,17] A phenomenon similar to that reported here was noted independently by Sammarco and DiRaimondo[26] and Snook et al.,[28] who had cause to reexplore several peroneus brevis donor tendons, half of which had been used in ankle ligament tenodesis reconstructions. In both studies, the donor tendon was reported to undergo hypertrophy.

The potential for healing of the patellar tendon donor site for ACL reconstruction has been documented.[3,19,22] Although the patellar tendon does not have a true tendon

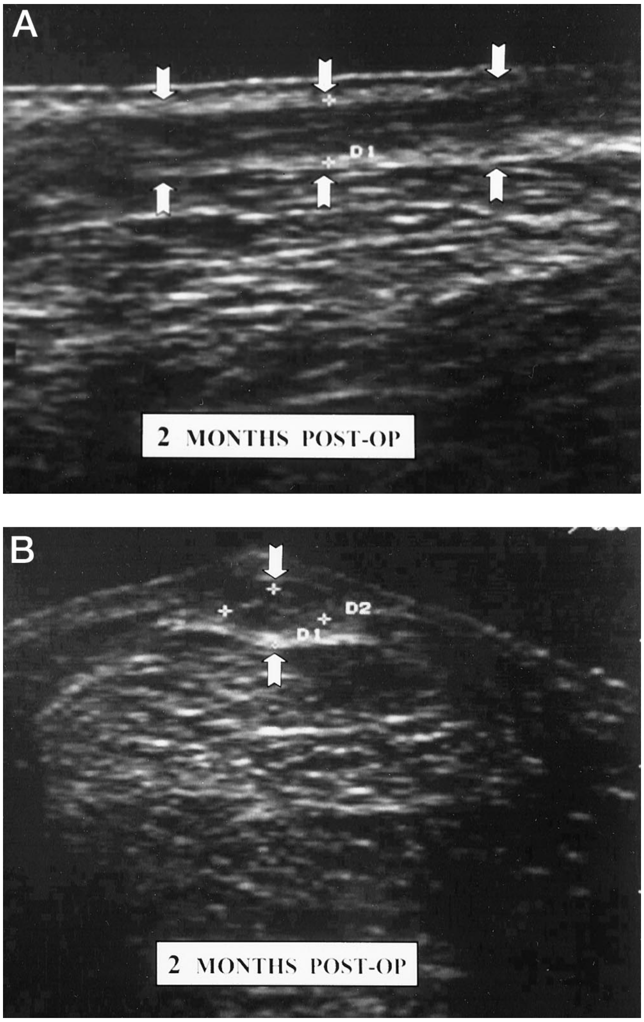

Figure 5. Longitudinal (A) and transverse (B) sonograms at 2 months after surgery. The area of the semitendinosus tendon is outlined by the arrows.

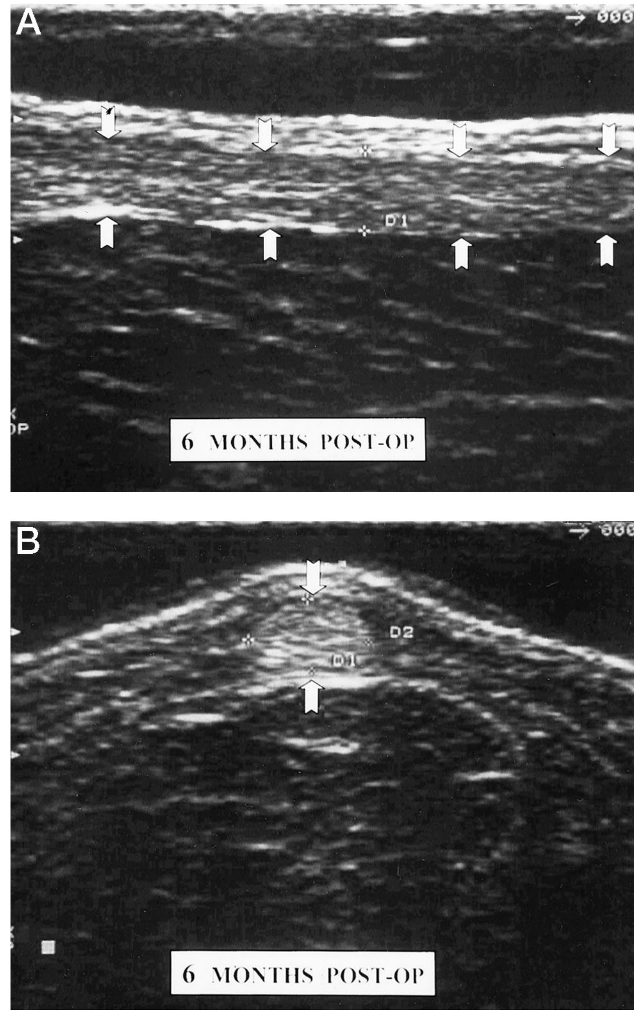

Figure 6. Longitudinal (A) and transverse (B) sonograms at 6 months after surgery. The area of the semitendinosus tendon is outlined by the arrows.

sheath, it is enclosed by paratenon. One report showed histologic evidence of healing of the donor defect with hypertrophic tendinous tissue at 8 months after surgery.[2] The histologic specimens depicted a linear array of collagen, which strongly suggests that the regenerated tissue had been subjected to tensile stresses.

An MRI study evaluating patellar tendon harvest sites during the postoperative period demonstrated signal intensity consistent with normal tendon at 18 months after surgery.[4] Another evaluation of the patellar tendon donor site using MRI and histologic studies confirms that 2 years after harvest of the graft, the central one-third of the patellar tendon appears to reconstitute into tissue indistinguishable from normal tendon.[21]

The results of ultrasound evaluation after the central one-third of the patellar tendon had been used as a graft for ACL reconstruction were presented by Benedetto et al. (personal communication, 1989), who studied the patients at various times after operation for up to 3 years. The width of the remaining tendon was slightly wider and markedly thicker than that of the uninvolved side at 1 year. The width slowly returned to normal, but the thickness remained increased 3 years after surgery.

However, all the studies mentioned here were investigations of the tendon healing from tendon to tendon or the tendon healing to itself, as in a case of half of a tendon regenerating. This process could be different from the process of regeneration investigated by ultrasonography in the present study, which is a regeneration from muscle to something we do not really know. However, as suggested by the sonography findings, a fibrillary tendon-like tissue seems to fill the site originally occupied by the semitendinosus tendon. Moreover, sonography confirms the trend of the healing of the donor defect, with hypertrophic tendinous tissue seen up to 6 months after surgery, while the ultrasound structure and measurements are consistent with normal tendon 12 to 18 months after surgery.

Only a few previous studies in the literature report the regrowth of the semitendinosus and gracilis tendons after their use in ACL reconstruction. Cross et al.[5] demon-

TABLE 1
Ultrasound Measurements of the Semitendinosus Tendon 4 cm Above the Medial Joint Line at Six Different Time Periods (Mean ± SD)

Measurement	Preoperative	Postoperative (months)				
		1	2	6	12	18
Thickness (mm)	3.5 (±0.89)	4.3 (±0.91)[a]	5.9 (±2.93)[a]	3.4 (±1.00)	3.1 (±0.80)	3.2 (±1.07)
Width (mm)	5.2 (±0.73)	5.7 (±1.38)	7.6 (±2.29)[a]	5.8 (±0.90)[a]	5.4 (±1.00)	5.3 (±1.12)
Cross-sectional area (mm^2)	13.1 (±2.95)	18.0 (±7.20)[a]	30.7 (±14.94)[a]	16.2 (±4.00)[a]	12.8 (±5.00)	12.8 (±5.30)

[a] Significantly different from the preoperative value ($P < 0.05$).

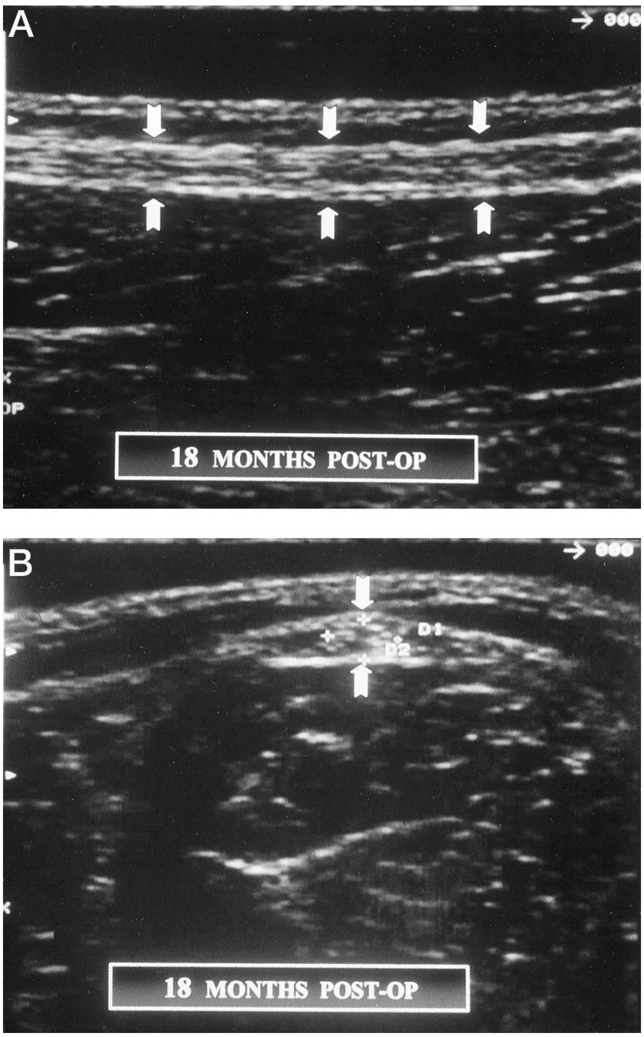

Figure 7. Longitudinal (A) and transverse (B) sonograms at 18 months after surgery. The area of the semitendinosus tendon is outlined by the arrows.

strated that MRI, in which a composite of the slices was used, provided clear details of the anatomy of these regrown tendons from the muscle bellies to the medial aspect of the gastrocnemius muscle. The authors postulated that the mechanism for this regeneration was that the regrowth occurs from the distal cut end of the muscle belly, following the fascial planes to the popliteal fossa. Simonian et al.[27] used MRI to evaluate the cross-sectional areas of the biceps femoris, semimembranosus, and sartorius muscles of both thighs of patients who had undergone semitendinosus and gracilis tendon harvest in one leg at the same level above the knee joint; they were unable to document any significant difference. Using MRI, moreover, they retrospectively identified a more proximal insertion of the harvested gracilis and semitendinosus tendons than on the nonoperated side in six of nine patients. These authors concluded that the tendon harvest of the semitendinosus and gracilis muscles does not significantly compromise function and strength, despite a more proximal insertion of the tendon remnant. They suggested that repeat harvest of these tendons may be a possibility for revision ACL surgery in the majority of cases. Our results differ slightly from their findings. In our prospective study, ultrasonography revealed a regenerated and more proximally inserted semitendinosus tendon in all cases. These findings are in agreement with what we have seen in our clinical practice, in which the evidence of a regenerated semitendinosus, as revealed by a “string” in the posteromedial aspect of the knee, is a rule.

Several investigators have attempted to functionally evaluate hamstring muscle strength after semitendinosus and gracilis tendons were harvested for ACL reconstruction. Despite some authors demonstrating a loss of hamstring strength,[14,18] the majority of these investigators found no significant difference between the operated and nonoperated side in the postoperative period.[15,25,27,29,30] In a recent study performed in our department (M. Fontana et al., unpublished data, 1995), 20 ACL-deficient knees operated with the same technique described in the present study were functionally evaluated. A complete recovery of hamstring muscle strength, as measured with an isokinetic dynamometer, was documented at the 6-month follow-up.

There are two possible explanations for the return of hamstring muscle strength after harvest of the semitendinosus and gracilis tendons: Either the tendons regenerate or there is compensatory hypertrophy of the undisturbed knee flexors. A compensatory hypertrophy was not demonstrated by Simonian et al.[27] The results of our investigation, which are in agreement with the clinical evidence provided by the studies of Cross et al.[5] and Simonian et al., seem to support the hypothesis that a regeneration of the semitendinosus tendon occurs, which in turn could contribute to a functional recovery of hamstring muscle strength. In the early postoperative period, the regenerated tendon was found to be significantly increased in cross-sectional area as compared with the nonoperated knee. As time progressed in the postoperative period, we noted a gradual reduction in the thickness, accompanied by a gradual return to the normal appearance on ultrasonography of the operated semitendinosus tendon. By 18 months, the tendon appeared very similar to the normal tendon with respect to thickness, cross-sectional area, and echogenicity.

CONCLUSIONS

The results of this study suggest that the semitendinosus tendon has the potential to regrow in a near-anatomic position. In the early postoperative period the regenerated tissue was significantly increased in cross-sectional area as compared with the control knee. As time progressed, we noted a gradual reduction in cross-sectional area accompanied by a gradual return to normal sonographic anatomy. By 18 months postoperatively, the tendon appeared very similar to the normal tendon. However, the regenerated tendon can be clearly identified about 4 cm proximal to the pes anserinus, revealing a more proximal insertion of the regrown semitendinosus tendon. Further histologic studies are needed to document the true progression of the healing process in the harvest site and the actual functional efficacy of the new structure.

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