Direct Repair of Chronic Achilles Tendon Ruptures Using Scar Tissue Located Between the Tendon Stumps

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Background: Several surgical procedures for chronically ruptured Achilles tendons have been reported. Resection of the interposed scar tissue located between the tendon stumps and reconstruction using normal autologous tissue have been well described. We developed a direct repair procedure that uses scar tissue, which obviates the need to use normal autologous tissue.

Methods: Thirty consecutive patients with Achilles tendon ruptures with a delay in diagnosis of >4 weeks underwent removal of a section of scar and healing tissue with direct primary suture of the ends of the tendon without the use of allograft or autograft. Patients were followed for a mean time of 33 months. Preoperative and postoperative clinical outcomes were measured with the Achilles Tendon Total Rupture Score (ATRS) and the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot score. In addition, the patients underwent preoperative and postoperative functional measurements and magnetic resonance imaging. Lastly, we evaluated the histology of the interposed healing tissue.

Results: The mean AOFAS scores were 82.8 points preoperatively and 98.1 points postoperatively. The mean postoperative ATRS was 92.0 points. At the time of the latest follow-up, none of the patients had experienced tendon reruptures or difficulties in walking or climbing stairs, and all except 2 patients could perform a single-limb heel rise. All athletes had returned to their pre-injury level of sports participation. Preoperative T2-weighted magnetic resonance imaging showed that 22 Achilles tendons were thickened with diffuse intratendinous high-signal alterations, and 8 Achilles tendons were thinned. Postoperative T2-weighted magnetic resonance imaging findings included fusiform-shaped tendon thickening and homogeneous low-signal alterations of the tendons in all patients. Histologically, the interposed scar tissue consisted of dense collagen fibers.

Conclusions: Shortening of the tissue between the 2 tendon ends that included healing scar and direct repair of healing tendon without allograft or autograft can be effective for treatment-delayed or neglected Achilles tendon rupture.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Numerous surgical procedures have been reported for the reconstruction of a chronic Achilles tendon rupture[1-23]; these involve resection of the interposed scar tissue and reconstruction using normal autologous tissue. Although these reconstructive surgical procedures have been shown to have good clinical results, they are time-consuming and difficult to perform compared with primary repair. In addition, procedures involving the use of a normal autologous tendon are associated with donor-site morbidity[24].

The gap between the tendon stumps in chronic Achilles tendon rupture is reported to be filled with interposed scar tissue[4,5,7,8,21,25,26]. The histology of healing tendon shows thick collagen fibers with highly cellular fibrovascular tissue[25]. If interposed scar tissue has a similar histology, the sacrifice of normal tissues could be obviated. An experimental study in a rabbit model demonstrated that the scar tissue between the tendon stumps evolves to tendon tissue over time[27]. Moreover, in a clinical study, histologic examination showed that the

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surgical biopsy specimen obtained from the scar tissue contained a prominent granulation tissue response[26]. These results suggest that scar tissue can be used in the repair of a chronically ruptured Achilles tendon. Accordingly, in 2001, we developed a direct repair procedure for chronic Achilles tendon rupture that involves the use of interposed scar tissue. We reported the clinical results of reconstruction for 6 chronic Achilles tendon ruptures[28]; the interposed scar tissue could be utilized for chronic Achilles tendon rupture repair if preoperative magnetic resonance imaging (MRI) showed that the Achilles tendon was fusiform-shaped. Although this series yielded good clinical results, postoperative MRI findings were not evaluated. Thus, we used interposed scar tissue to perform reconstruction of consecutive chronic Achilles tendon ruptures associated with tendon thickening or thinning on preoperative MRI. Furthermore, we evaluated tendon healing using postoperative MRI.

We aimed to describe our surgical procedure and prospectively review its outcomes. Additionally, preoperative and postoperative MRI findings and histologic features of the scar tissue located between the tendon stumps are described. Our hypothesis was that our direct repair procedure using the interposed scar tissue could be effectively used for reconstructing chronic Achilles tendon rupture.

Materials and Methods

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. All patients provided informed consent and this study was approved by our institutional review board. From February 2001 through December 2012, 31 consecutive patients with a chronic Achilles tendon rupture underwent direct tendon repair using interposed scar tissue located between the stumps. All patients underwent a surgical procedure performed by one of the authors. The indications for a surgical procedure were a symptomatic chronic Achilles tendon rupture with disability involving activities of daily living (i.e., walking and climbing stairs) and a limp. A limp was defined as an asymmetric gait with poor push-off or failure of push-off (plantar flexion weakness) on the involved side. All patients could not perform a single-limb heel rise and 22 patients had pain. All patients reported muscle weakness during the push-off phase of walking and desired surgical treatment. Conservative treatment, including an ankle-foot orthosis or arch supports, had failed in these patients.

All patients with chronic Achilles tendon rupture for >4 weeks after injury were included[4,10,26]. Chronic Achilles tendon rupture was diagnosed preoperatively on the basis of a positive Thompson test, the inability to perform a single-limb heel rise, limping, and preoperative MRI findings. Exclusion criteria were Achilles tendon rerupture, a previous surgical procedure on the affected Achilles tendon, and corticosteroid therapy for other illnesses. One patient (1 foot) was lost to follow-up because she had moved and could not be contacted. The remaining 30 patients (30 feet) were 16 men and 14 women with a mean age of 52.7 years; they were available for follow-up for at least 2 years (Table I). The mean body mass index was 23.8 kg/m^2. With regard to comorbidities, 6 patients had hypertension, 5 had hyperlipidemia, and 3 had diabetes. There were 2 smokers. With regard to occupation, 9 patients were office workers, 8 were workers who performed their work while standing up, 6 were homemakers, and 3 were students. The patient group included 3 competitive athletes (1 college basketball player, 1 high school basketball player, and 1 semiprofessional baseball player) who participated in sports every day and 11 recreational athletes who participated in sports once or twice a week. Of the 30 patients, 13 had a neglected Achilles tendon rupture and 17 had a misdiagnosed Achilles tendon rupture. Some misdiagnosed patients were treated with a posterior splint or an ankle brace for 1 to 2 weeks. We defined patients with a neglected Achilles tendon rupture as those who did not see a doctor within 4 weeks after injury. In 27 patients, the duration from injury to the time of the surgical procedure was >12 weeks, and the mean duration was 22 weeks (range, 5 to 70 weeks). The mean postoperative follow-up period was 33 months (range, 24 to 43 months).

TABLE I Characteristics of Patients

Characteristics	Patients (N = 30)
Sex*	
Male	16 (53.3%)
Female	14 (46.7%)
Age† *(yr)*	52.7 (17 to 78)
Side*	
Right	17 (56.7%)
Left	13 (43.3%)
Body mass index† *(kg/m²)*	23.8 (17.4 to 30.0)
Smokers*	2 (6.7%)
Athletes*	
Competitive	3 (10.0%)
Recreational	11 (36.7%)
Reasons for chronic rupture*	
Neglect	13 (43.3%)
Misdiagnosis	17 (56.7%)
Time from injury to the surgical procedure† *(wk)*	22 (5 to 70)
Length of gap† *(mm)*	43.3 (25 to 80)
Length of excised scar tissue† *(mm)*	26.1 (15 to 50)
Follow-up period† *(mo)*	33 (24 to 43)

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean, with the range in parentheses.

Clinical Evaluation

All patients were clinically evaluated preoperatively and every 6 months thereafter until the most recent follow-up examination. We evaluated subjective outcomes, including pain, functional deficit (i.e., walking and climbing stairs), and return to sports activities according to a questionnaire. Objective outcomes, including active range of motion of the ankle, the ability to perform a single-limb heel rise, and maximum calf circumference, were investigated. Range of motion was measured by placing one goniometer arm parallel to the fibula and the other goniometer arm parallel to the long axis of the fifth metatarsal. The fulcrum of the goniometer was located below the lateral malleolus. Active dorsiflexion and plantar flexion were measured. All measurements were performed at least twice until 2 reproducible measurements within 1° of each other were achieved. To assess the function of the reconstructed gastrocnemius-soleus-Achilles tendon complex, patients were asked to perform 10 single-limb heel rises on the affected side and were assessed as being either able or unable to do so[11-13]. Patients were allowed to place 2 fingertips per hand, at shoulder height, on the wall for balance. Calf atrophy was assessed by measuring the maximum calf muscle circumference in both legs. We confirmed the distance from the patellar apex to the point of measurement in both legs for standardization. The measurements were repeated consecutively 3 times for each patient, and the data were registered. The mean of the 3 values was recorded as the calf circumference for standardization. Also, we evaluated the clinical results using the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot scale[29] and the Achilles Tendon Total Rupture Score (ATRS)[30,31] at the time of the latest

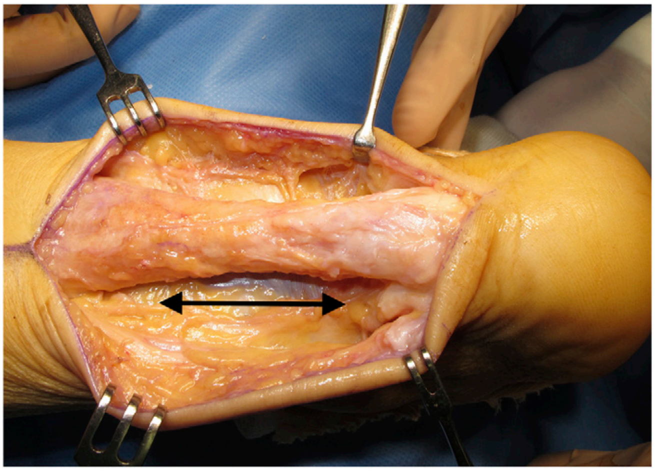

Fig. 1

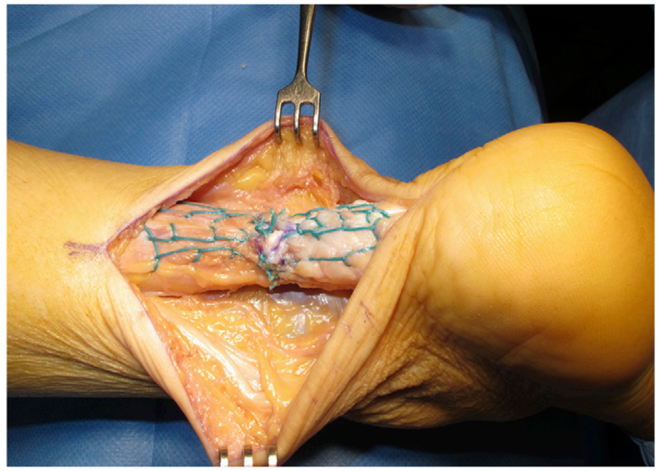

Fig. 2

Fig. 1 Operative photograph showing the gap between the tendon stumps filled with scar tissue (double-headed arrow). **Fig. 2** Operative photograph showing direct repair incorporating the scar tissue interposed between the tendon stumps. The repair was performed by placing Krackow sutures of no.-2 nonabsorbable polyfilament in each tendon stump and in the scar tissue.

follow-up. We used the Japanese version of the ATRS questionnaire. ATRS questionnaires were answered by 24 of the 30 patients at the most recent follow-up.

Preoperative and Postoperative MRI

All patients underwent MRI for an evaluation of the contour and signal intensity of the Achilles tendon preoperatively and at 6 and 12 months postoperatively. The duration from preoperative MRI to the time of the surgical procedure was <4 weeks. A 1.5-T scanner (GE Signa HDxt 1.5T [GE Medical Systems], Siemens 1.5T Symphony [Siemens]) was used. T1 and T2-weighted images in the axial and sagittal planes were examined.

We calculated the interobserver reliability to evaluate the contour and signal changes with MRI using 10 preoperative images and 10 postoperative images

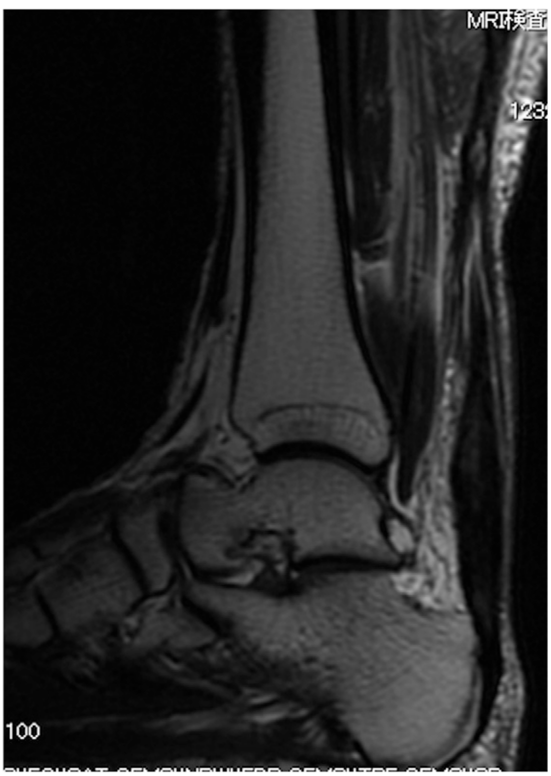

Fig. 3-A

Fig. 3-B

Figs. 3-A and 3-B T2-weighted MR images of the tendons of a 34-year-old woman showing fusiform-shaped tendon thickening. **Fig. 3-A** Preoperative image also showing diffuse intratendinous high-signal alterations at 4 months after injury. **Fig. 3-B** Postoperative image also showing homogeneous low-signal alterations at 6 months postoperatively.

of patients in the present study. The identification labels of all of the MR images were removed. Two foot and ankle surgeons independently assessed the contour and signal changes on MRI. Tendon thickening was defined as the narrowest part of the tendon in the sagittal plane being ≥1 cm, and tendon thinning was defined as the narrowest part of the tendon in the sagittal plane being <1 cm.

Histologic Examination

A specimen of interposed scar tissue located between the tendon stumps was obtained for histologic examination from each patient. The scar tissue specimen was fixed in 20% buffered neutral formalin, was dehydrated, and was embedded in paraffin. Longitudinal sections of the scar tissue were stained with hematoxylin and eosin and examined histologically.

Surgical Technique

The surgical procedure was performed with the patient in the prone position. A longitudinal incision was made along the posteromedial aspect of the Achilles tendon. Both the paratenon and the interposed scar were incised longitudinally about 2 to 3 mm deep, and we inspected the tendon substance from the inside. The gap between the native tendon stumps, 25 to 80 mm in length, was filled with scar tissue (Fig. 1). The mean length of the gap was 43.3 mm (Table I). Proximally, the triceps surae was released by blunt dissection of the adhesion. The middle part of the scar tissue located between the tendon stumps was resected. After the resection, we confirmed that the approximation of the proximal and distal ends of the tendon was possible with the ankle in 20° to 30° of plantar flexion. If needed, the additional scar tissue was resected. The excised tissue was 15 to 50 mm in length. The mean length of the excised scar was 26.1 mm (Table I). The repair was performed using Krackow sutures of no.-2 nonabsorbable polyfilament[32] in each tendon stump. The tendon stumps, with the interposed scar tissue, were then sutured (Fig. 2), with the ankle in 20° to 30° of plantar flexion to match the uninvolved ankle. After completing the repair, the paratenon was sutured, and the subcutaneous tissue and skin were closed.

Postoperative Treatment

Postoperatively, patients wore a below-the-knee cast that held the ankle in 20° of plantar flexion, and non-weight-bearing walking was continued for 2 weeks. At 3 weeks postoperatively, the cast was removed and an ankle-foot orthosis with 3 heel wedges that held the ankle in 20° of plantar flexion was applied. Partial weight-bearing walking and range-of-motion exercises were initiated. One heel wedge was removed each week. Patients were encouraged to bear weight on the involved limb as soon as they felt comfortable and to gradually progress to full weight-bearing. At 6 weeks postoperatively, the orthosis was removed. Double-heel-rise exercises were allowed at 7 weeks. Sports activities were encouraged at 4 to 5 months postoperatively.

Statistical Analysis

Differences between preoperative and final postoperative measurements were analyzed using the Wilcoxon signed rank test. The Wilcoxon-Mann-Whitney test was used to compare the maximum calf circumference between the ruptured and nonruptured sides at the time of the latest follow-up. Significance was defined as $p < 0.05$. Kappa statistics were used to analyze the interobserver reliability using SPSS, version 22.0 (IBM).

Results

Clinical Results

At the time of the latest follow-up, none of the patients exhibited any difficulty in walking or climbing stairs.

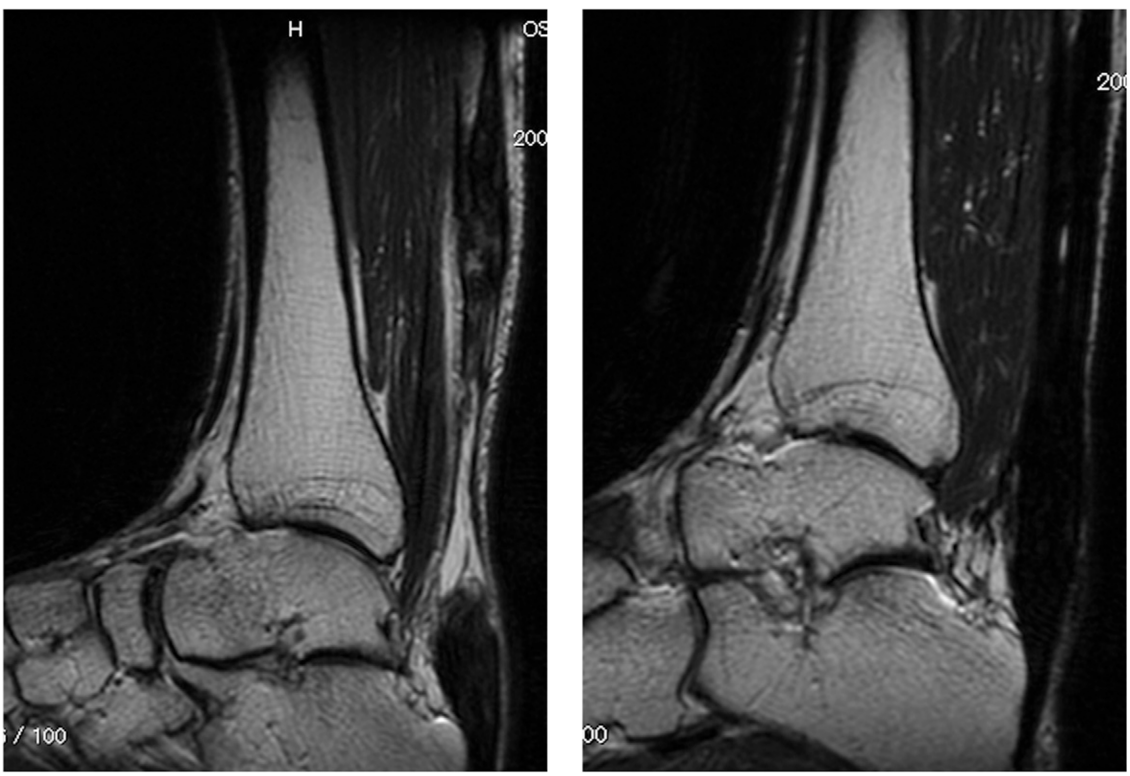

Fig. 4-A Fig. 4-B

Figs. 4-A and 4-B T2-weighted MR images of the tendons of a 63-year-old man. **Fig. 4-A** Preoperative image showing tendon thinning and diffuse intratendinous high-signal alterations at 3 months after injury. **Fig. 4-B** Postoperative image showing fusiform-shaped tendon thickening and homogeneous low-signal alterations at 6 months postoperatively.

Twenty-eight patients were pain-free and 2 patients reported occasional mild calf pain. All 14 athletes had returned to their pre-injury level of sports participation. The 3 competitive athletes had full return to sports (i.e., played in a game at their pre-injury level) at 5 to 6 months postoperatively, and the 11 recreational athletes fully returned to sports by 12 months postoperatively. The mean plantar flexion angle of the involved ankle significantly increased postoperatively ($p = 0.0049$). The mean dorsiflexion angle of the involved ankle significantly decreased postoperatively ($p = 0.009$). The mean calf circumference of the involved leg significantly increased postoperatively ($p = 0.0087$). The mean difference in circumference between the involved and uninvolved calves was significantly higher preoperatively than that at the time of the latest follow-up ($p = 0.0135$). At the most recent follow-up examination, all except 2 patients could perform a single-limb heel rise. The mean AOFAS score was 82.8 points preoperatively and 98.1 points at the time of the most recent follow-up examination (Table II). The mean ATRS at the time of the latest follow-up was 92.0 points (range, 80 to 100 points).

The only postoperative complication was delayed wound-healing in 1 case, which healed within 4 weeks postoperatively without antibiotic treatment. There were no cases of infection, deep-vein thrombosis, skin necrosis, or rerupture.

Preoperative and Postoperative MRI

The kappa value for the interobserver reliability of MRI was 0.83 for tendon contour and 0.90 for a signal change. According to the system of Landis and Koch[33], these values corresponded to an almost perfect level of agreement. On preoperative T2-weighted images, fusiform-shaped tendon thickening and diffuse intratendinous high-signal alterations in the tendons were seen in 22 patients (Fig. 3-A), but these patients had homogeneous low-signal alterations in the tendons on MRI at 6 months postoperatively (Fig. 3-B). Tendon thinning was seen in the remaining 8 patients. Diffuse intratendinous high-signal alterations were seen preoperatively in 6 of these 8 patients (Fig. 4-A), but fusiform-shaped tendon thickening and homogeneous low-signal alterations were seen in the tendons on MRI at 6 months postoperatively (Fig. 4-B). Homogeneous low-signal alterations in the tendons were seen in 2 patients (Fig. 5-A) preoperatively, but both fusiform-shaped tendon thickening and homogeneous low-signal alterations were seen in the tendons on MRI at 6 months postoperatively (Fig. 5-B).

Histologic Findings

In all specimens, scar tissue located between the tendon stumps consisted of dense and thick collagen fibers with vessels. Obvious degenerative changes, such as tendolipomatosis, mucoid

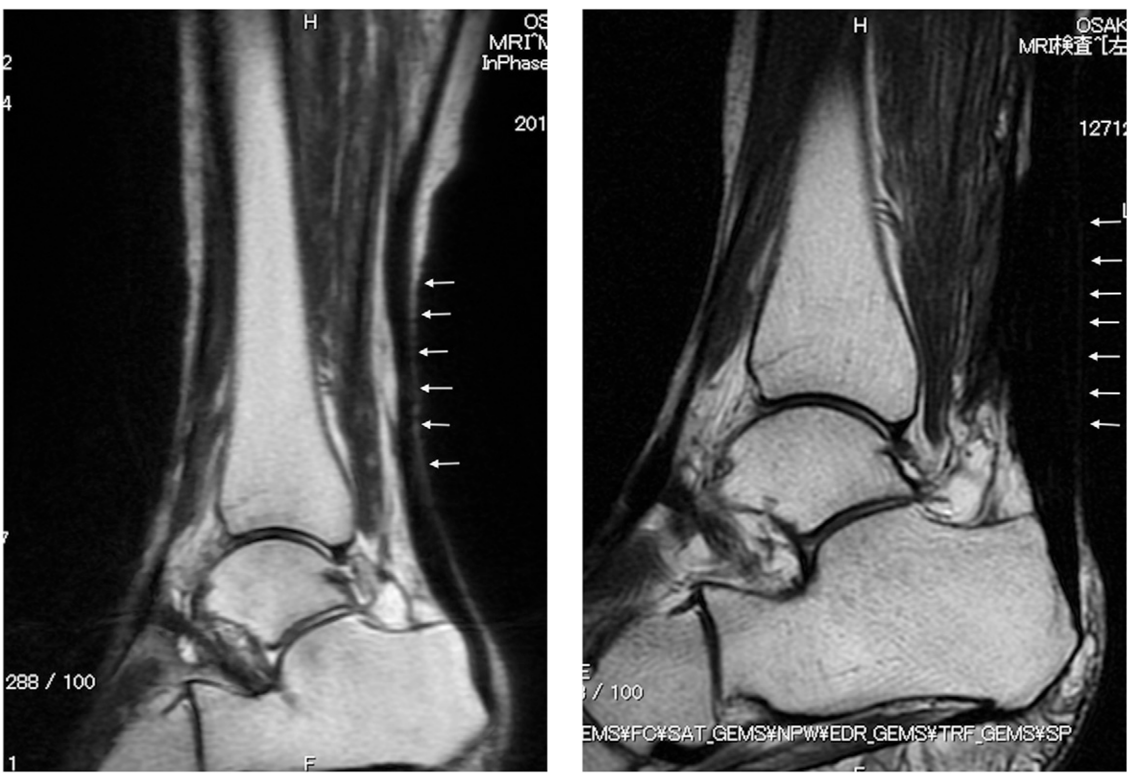

Fig. 5-A   Fig. 5-B

Figs. 5-A and 5-B T2-weighted MR images of a 43-year-old woman with chronic Achilles tendon rupture. **Fig. 5-A** Preoperative image showing tendon thinning and homogeneous low-signal alterations in the tendons (arrows). **Fig. 5-B** Postoperative image showing fusiform-shaped tendon thickening and homogeneous low-signal alterations (arrows) at 6 months postoperatively. Note that the tendon thinning observed preoperatively was changed to tendon thickening postoperatively.

TABLE II AOFAS Score, Ankle Motion, and Calf Circumference

	Before the Surgical Procedure*	At the Time of the Latest Follow-up*	P Value
AOFAS score *(points)*	82.8 ± 8.3 (51 to 97)	98.1 ± 3.9 (90 to 100)	NA†
Ankle motion			
Plantar flexion *(deg)*	52.7 ± 5.5 (40 to 60)	55.2 ± 5.0 (45 to 60)	0.0049
Dorsiflexion *(deg)*	24.3 ± 7.4 (15 to 35)	20.8 ± 2.7 (15 to 30)	0.009
Calf circumference			
Size of involved calf *(cm)*	33.9 ± 3.5 (27 to 40.5)	34.4 ± 3.4 (27 to 39.5)	0.0087
Calf wasting *(cm)*	1.6 ± 1.0 (0.5 to 4)	1.2 ± 0.6 (0 to 2.5)	0.0135

*The values are given as the mean and standard deviation, with the range in parentheses. †NA = not applicable.

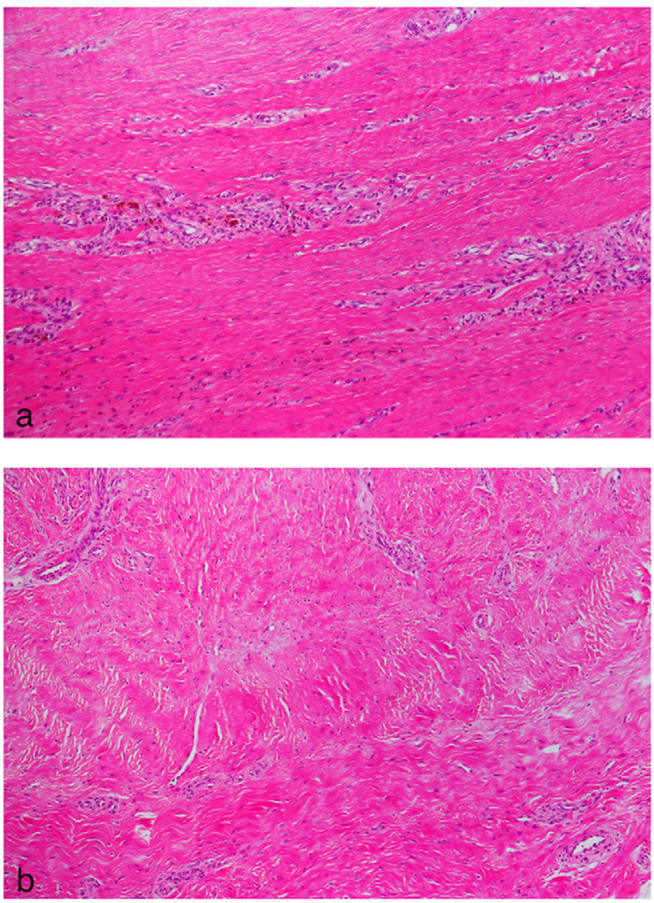

Fig. 6

Figs. 6-A and 6-B Histology of the scar tissue between the tendon stumps (hematoxylin and eosin, ×100). **Fig. 6-A** The 34-year-old woman whose images are presented in Figure 3. The scar tissue contains dense collagen fibers running parallel along the tendon axis. The collagen network is longitudinally oriented with rows of fibroblasts lying between the bundles of collagen. **Fig. 6-B** The 63-year-old man whose images are presented in Figure 4. Histologic examination of the specimen showed interposed scar tissue composed of irregularly arranged collagen fibers with highly cellular fibrovascular tissue.

degeneration, or vascular changes[34], were not observed in any specimen. In 9 patients, scar tissue between the tendon stumps contained dense collagen fibers running parallel along the tendon axis with rows of fibroblasts lying between the bundles of collagen. However, the bundles of collagen fibers were thinner, and more fibroblasts were seen, compared with the intact tendon (Fig. 6-A). In the remaining 21 specimens, the scar tissue contained dense collagen fibers with highly cellular fibrovascular material, but the fiber bundles were not oriented along the axis of the tendon (Fig. 6-B). In the 3 patients whose duration from injury to the time of the surgical procedure was <12 weeks, less dense and thinner collagen fibers not oriented along the axis of the tendon with highly cellular fibrovascular material were seen.

Discussion

Wounds can heal by primary union (first intention) or secondary union (second intention); second intention healing involves more extensive scarring and wound contraction[35]. Repair by connective tissue deposition involves angiogenesis, migration and proliferation of fibroblasts, collagen synthesis, and connective tissue remodeling[35]. After Achilles tendon rupture, Achilles tendon healing that occurs following immobilization with nonsurgical treatment corresponds to second intention healing. However, delayed or neglected Achilles tendon ruptures do not progress to natural second intention healing. During wound-healing, a granulating wound that is assisted in its healing by an operative procedure, is changed from healing by second intention to healing by third intention[36]. Similarly, in the present study, we performed delayed primary suturing for these delayed or neglected Achilles tendon ruptures, creating healing by third intention.

We treated 30 consecutive patients with chronic Achilles tendon rupture using a direct repair procedure. The postoperative scores were 98.1 points for the AOFAS score and 92.0 points for the ATRS, both of which were greater than previously reported scores for chronic Achilles tendon rupture, which ranged from 85 to 96.5 points for the AOFAS and 83 to 91 points for the ATRS[6,12,13,17-19,25]. There were no cases of re-rupture, and all 14 athletes had returned to their pre-injury

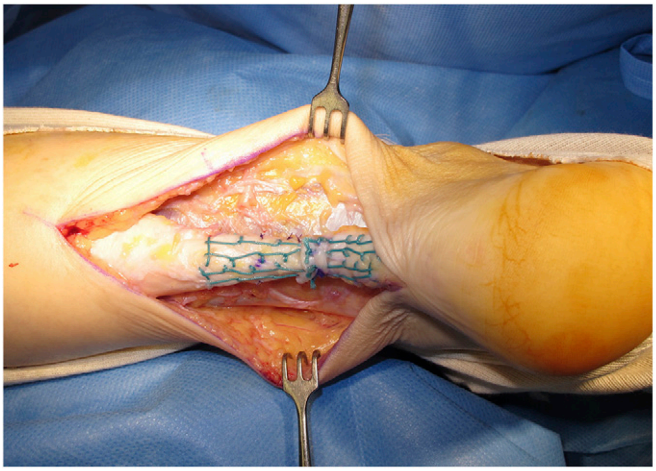

Fig. 7
Operative photograph showing direct repair in a patient with thin scar tissue interposed between the tendon stumps.

level of sports participation. Thus, the clinical outcomes of our operative method were at least comparable with previously reported outcomes for chronic Achilles tendon rupture. Moreover, our technique was associated with a lower rate (3%) of postoperative complications than those previously reported, which ranged from 4 to 45%[6,7,11,12,14,17,18,20]. All except 2 patients could perform a single-limb heel rise postoperatively. We think that shortening of the elongated scar tissue restored the length of the Achilles tendon.

A few reports have been published on the histologic findings of scar tissue between tendon stumps in chronic Achilles tendon ruptures[25,26,28]. Lee et al.[25] showed that the interposed scar tissue was composed of thick collagen fibers that ran in parallel along the tendon axis. In our study, interposed scar tissue contained dense collagen fibers with arteries, veins, and capillaries. In 9 patients, interposed tissue contained dense collagen fibers running parallel along the tendon axis. In the remaining 21 specimens, the scar tissue contained dense collagen fibers with highly cellular fibrovascular tissue not oriented along the axis of the tendon. Histologic findings have clearly indicated that the scar tissue has the capacity to form tendon-like tissue. In the present study, 27 patients were >12 weeks post-injury, so the interposed tissue in these patients showed the healing of the fairly mature tendon; however, the bundles of collagen fibers were thinner than the intact tendon. The histology results suggest that it is possible to use interposed healing tissue to repair chronic Achilles tendon rupture.

Postoperative MRI findings indicated good tendon healing of the reconstructed Achilles tendon in all patients. Preoperatively, thin elongated scar tissue was observed in 8 patients (Figs. 4-A and 5-A). Even in these cases, we performed direct repair using interposed scar tissue (Fig. 7), and postoperative MRI findings showed fusiform-shaped tendon thickening and homogeneous low-signal alterations in the tendons (Figs. 4-B and 5-B). We think that resection of the middle part of the scar tissue led to the migration of the fibroblasts from the stumps. The proliferation of fibroblasts and neovascularization followed by fibrogenesis in the repaired tendon may have increased the tendon thickness and resulted in the fusiform shape observed postoperatively. Furthermore, tension on the suture site due to early functional rehabilitation may have aligned the bundles of collagen fibers parallel to one another along the axis of the tendon, thus increasing its mechanical strength[27,37]. We believe that our operative method restored the length of the elongated scar and improved the tendon strength based on the postoperative tendon thickening and good arrangement of the bundles of collagen fibers.

This study had some limitations. First, to our knowledge, the psychometric properties of the AOFAS scoring system, including its validity and reliability, have never been examined. However, there is still value in comparing our results with those of other published studies. Second, we used the Japanese version of the ATRS questionnaire. The validity and reliability of the English and Turkish versions of the ATRS questionnaire have been demonstrated[30,31]; however, the Japanese version has not been validated.

In conclusion, shortening of the tissue between the 2 tendon ends that included healing scar and direct repair of healing tendon without allograft or autograft can be effective for the treatment of delayed or neglected Achilles tendon rupture. ■

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References

1. Barnes MJ, Hardy AE. Delayed reconstruction of the calcaneal tendon. J Bone Joint Surg Br. 1986 Jan;68(1):121-4.
2. Bosworth DM. Repair of defects in the tendo Achillis. J Bone Joint Surg Am. 1956 Jan;38(1):111-4.
3. Bugg EI Jr, Boyd BM. Repair of neglected rupture or laceration of the Achilles tendon. Clin Orthop Relat Res. 1968 Jan-Feb;56:73-5.
4. Gabel S, Manoli A 2nd. Neglected rupture of the Achilles tendon. Foot Ankle Int. 1994 Sep;15(9):512-7.
5. Kissel CG, Blacklidge DK, Crowley DL. Repair of neglected Achilles tendon ruptures—procedure and functional results. J Foot Ankle Surg. 1994 Jan-Feb;33(1):46-52.
6. Lee DK. Achilles tendon repair with acellular tissue graft augmentation in neglected ruptures. J Foot Ankle Surg. 2007 Nov-Dec;46(6):451-5.
7. Lee YS, Lin CC, Chen CN, Chen SH, Liao WY, Huang CR. Reconstruction for neglected Achilles tendon rupture: the modified Bosworth technique. Orthopedics. 2005 Jul;28(7):647-50.

8. Leslie HD, Edwards WH. Neglected ruptures of the Achilles tendon. Foot Ankle Clin. 2005 Jun;10(2):357-70.

9. Maffulli N. Rupture of the Achilles tendon. J Bone Joint Surg Am. 1999 Jul;81(7):1019-36.

10. Maffulli N, Ajis A. Management of chronic ruptures of the Achilles tendon. J Bone Joint Surg Am. 2008 Jun;90(6):1348-60.

11. Maffulli N, Spiezia F, Testa V, Capasso G, Longo UG, Denaro V. Free gracilis tendon graft for reconstruction of chronic tears of the Achilles tendon. J Bone Joint Surg Am. 2012 May 16;94(10):906-10.

12. Maffulli N, Loppini M, Longo UG, Maffulli GD, Denaro V. Minimally invasive reconstruction of chronic Achilles tendon ruptures using the ipsilateral free semitendinosus tendon graft and interference screw fixation. Am J Sports Med. 2013 May;41(5):1100-7. Epub 2013 Mar 6.

13. Maffulli N, Oliva F, Costa V, Del Buono A. The management of chronic rupture of the Achilles tendon: minimally invasive peroneus brevis tendon transfer. Bone Joint J. 2015 Mar;97(3):353-7.

14. Mann RA, Holmes GB Jr, Seale KS, Collins DN. Chronic rupture of the Achilles tendon: a new technique of repair. J Bone Joint Surg Am. 1991 Feb;73(2):214-9.

15. Miskulin M, Miškulin A, Klobučar H, Kuvalja S. Neglected rupture of the Achilles tendon treated with peroneus brevis transfer: a functional assessment of 5 cases. J Foot Ankle Surg. 2005 Jan-Feb;44(1):49-56.

16. Dumbre Patil SS, Dumbre Patil VS, Basa VR, Dombale AB. Semitendinosus tendon autograft for reconstruction of large defects in chronic Achilles tendon ruptures. Foot Ankle Int. 2014 Jul;35(7):699-705. Epub 2014 Apr 10.

17. Rahm S, Spross C, Gerber F, Farshad M, Buck FM, Espinosa N. Operative treatment of chronic irreparable Achilles tendon ruptures with large flexor hallucis longus tendon transfers. Foot Ankle Int. 2013 Aug;34(8):1100-10. Epub 2013 Apr 26.

18. Sarzaeem MM, Lemraski MMB, Safdari F. Chronic Achilles tendon rupture reconstruction using a free semitendinosus tendon graft transfer. Knee Surg Sports Traumatol Arthrosc. 2012 Jul;20(7):1386-91. Epub 2011 Oct 29.

19. El Shazly O, Abou El Soud MM, El Mikkawy DME, El Ganzoury I, Ibrahim AM. Endoscopic-assisted Achilles tendon reconstruction with free hamstring tendon autograft for chronic rupture of Achilles tendon: clinical and isokinetic evaluation. Arthroscopy. 2014 May;30(5):622-8.

20. El Shewy MT, El Barbary HM, Abdel-Ghani H. Repair of chronic rupture of the Achilles tendon using 2 intratendinous flaps from the proximal gastrocnemius-soleus complex. Am J Sports Med. 2009 Aug;37(8):1570-7. Epub 2009 Jun 11.

21. Us AK, Bilgin SS, Aydin T, Mergen E. Repair of neglected Achilles tendon ruptures: procedures and functional results. Arch Orthop Trauma Surg. 1997;116(6-7):408-11.

22. Wapner KL, Pavlock GS, Hecht PJ, Naselli F, Walther R. Repair of chronic Achilles tendon rupture with flexor hallucis longus tendon transfer. Foot Ankle. 1993 Oct;14(8):443-9.

23. Wegrzyn J, Luciani JF, Philippot R, Brunet-Guedj E, Moyen B, Besse JL. Chronic Achilles tendon rupture reconstruction using a modified flexor hallucis longus transfer. Int Orthop. 2010 Dec;34(8):1187-92. Epub 2009 Aug 21.

24. Myerson MS. Achilles tendon ruptures. Instr Course Lect. 1999;48:219-30.

25. Lee KB, Park YH, Yoon TR, Chung JY. Reconstruction of neglected Achilles tendon rupture using the flexor hallucis tendon. Knee Surg Sports Traumatol Arthrosc. 2009 Mar;17(3):316-20. Epub 2008 Dec 16.

26. Porter DA, Mannarino FP, Snead D, Gabel SJ, Ostrowski M. Primary repair without augmentation for early neglected Achilles tendon ruptures in the recreational athlete. Foot Ankle Int. 1997 Sep;18(9):557-64.

27. Yasuda T, Kinoshita M, Abe M, Shibayama Y. Unfavorable effect of knee immobilization on Achilles tendon healing in rabbits. Acta Orthop Scand. 2000 Feb;71(1):69-73.

28. Yasuda T, Kinoshita M, Okuda R. Reconstruction of chronic Achilles tendon rupture with the use of interposed tissue between the stumps. Am J Sports Med. 2007 Apr;35(4):582-8. Epub 2007 Feb 9.

29. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994 Jul;15(7):349-53.

30. Nilsson-Helander K, Thomeé R, Silbernagel KG, Thomeé P, Faxén E, Eriksson BI, Karlsson J. The Achilles tendon Total Rupture Score (ATRS): development and validation. Am J Sports Med. 2007 Mar;35(3):421-6. Epub 2006 Dec 7.

31. Kaya Mutlu E, Celik D, Kiliçoglu Ö, Ozdincler AR, Nilsson-Helander K. The Turkish version of the Achilles tendon Total Rupture Score: cross-cultural adaptation, reliability and validity. Knee Surg Sports Traumatol Arthrosc. 2015 Aug;23(8):2427-32. Epub 2014 May 10.

32. Mandelbaum BR, Myerson MS, Forster R. Achilles tendon ruptures. A new method of repair, early range of motion, and functional rehabilitation. Am J Sports Med. 1995 Jul-Aug;23(4):392-5.

33. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977 Mar;33(1):159-74.

34. Kannus P, Józsa L. Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. J Bone Joint Surg Am. 1991 Dec;73(10):1507-25.

35. Mitchell RN. Inflammation and repair. In: Kumar V, Abbas AK, Aster JC, editors. Robbins basic pathology. 9th ed. Philadelphia: Elsevier Saunders; 2013. p 29-73.

36. Bate JT. Second and third intention healing of finger amputations. A salvage procedure. Clin Orthop Relat Res. 1966 Jul-Aug;47:151-5.

37. Becker H, Diegelmann RF. The influence of tension on intrinsic tendon fibroplasias. Orthop Rev. 1984;13(3):65-71.