0363-5465/98/2626-0794$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 26, No. 6

Early Active Motion and Weightbearing After Cross-Stitch Achilles Tendon Repair*

Mitsuhiro Aoki,† MD, PhD, Naoshi Ogiwara, MD, PhD, Takayuki Ohta, MD, PhD, and Yuki Nabeta, MD

From the Department of Orthopaedic Surgery, Sapporo Medical University, Sapporo, Japan

ABSTRACT

Twenty-two closed Achilles tendon ruptures caused by sports injuries in 22 patients (average age, 37.6 years) were repaired with Kirschmayer core suture and cross-stitch epitenon suture, and early active ankle motion with weightbearing was implemented after surgery. This study was undertaken to evaluate the effectiveness of the repair technique and rehabilitation protocol by assessing clinical results and magnetic resonance imaging findings. The follow-up period averaged 24.6 months. Twenty of the tendons (91%) healed without rerupture, and two tendons (9%) suffered a partial rerupture at 23 and 56 days, respectively. Active ankle extension reached from the minus range to 0° in an average of 9.7 days, and ankle motion recovered to normal in an average of 6.0 weeks. Full weightbearing without heel raising became possible in an average of 16.4 days, and heel raising with both legs became possible in an average of 7.3 weeks. The patients returned to full sports activity in 13.1 weeks. The interval until the area of high-intensity signal at the tendon repair site on T2-weighted magnetic resonance imaging scans became intermediate-intensity signal averaged 6.9 weeks, and the tendon repair site became low-intensity signal in an average of 12.6 weeks, demonstrating excellent tendon healing. Treatment employing Kirschmayer core suture and cross-stitch epitenon suture may help athletes return to sports activity in a shorter period than that allowed by previous methods of repair for Achilles tendon ruptures.

Achilles tendon rupture, which represents indirect injury of the tendon midsubstance, typically occurs in middle-aged people who engage in strenuous activity.[8,9,20] As a result of an increased interest in athletic activity and high-speed motion, Achilles tendons are likely to suffer repetitive overload, which occasionally results in spontaneous rupture.[10] Because of recent advances in sports medicine and the wider availability of information, competitive athletes trying to maintain high levels of activity hope to recover from their injuries in a reasonably short time.[6,18] This has made treatment of Achilles tendon rupture increasingly important in the clinical practice of sports medicine.

It is well known that long-term immobilization of joints while repaired tendons are healing impairs the recovery of the injured tendon and delays remodeling of newly formed collagen fibrils.[7] It becomes extremely important to use an early-mobilization rehabilitation protocol during treatment of injured athletes to allow recovery of muscle, tendon, and joint function and to enable athletes to return to their chosen levels of activity in a short period. Although many different methods of suture repair of Achilles tendon are available, until recently none has resulted in repairs that have been strong enough to allow early active range of motion exercise of the foot and ankle and early weightbearing.[6,9,16,17,21] In 1995, we began to use a strong cross-stitch suture technique to treat ruptured Achilles tendons. This technique was introduced for flexor tendon repair by Silfverskiöld and May[24] in 1994. Because of the strong mechanical properties of cross-stitch tendon repair,[12,15,24] we instituted early postoperative active motion and a weightbearing rehabilitation protocol to enhance tendon healing and strength. This study was designed to prospectively evaluate the clinical results of cross-stitch tendon repair and the early rehabilitation protocol. The postoperative appearance of the ruptured Achilles tendon was monitored by MRI.

MATERIALS AND METHODS

Between April 1995 and October 1996, 22 consecutive patients with Achilles tendon rupture whom we treated surgically using a combination of Kirschmayer core su-

* Presented at the 65th annual meeting of the AAOS, New Orleans, Louisiana, March 1998.

† Address correspondence and reprint requests to Mitsuhiro Aoki, MD, PhD, Department of Orthopedic Surgery, Sapporo Medical University, South-1, West-16, Chuo-ku, Sapporo 060-8543 Japan.

No author or related institution has received any financial benefit from research in this study.

tures and cross-stitch epitenon suture were managed after surgery according to the early active motion and weightbearing rehabilitation protocol.

Patient Population

Eleven of the patients were men, and 11 were women. The right side was involved in 11 patients and the left side was involved in 11 patients. The average age of the patients was 37.6 years (range, 21 to 55). Each patient had sustained an Achilles tendon rupture during sports activity as shown in Table 1; note that none of the patients was participating in highly competitive sports activities. The clinical diagnosis was based on a positive Thompson squeeze test, a palpable tendon defect, and local tenderness. No patients complained of previous Achilles tendon symptoms on the affected side. One patient had a history Achilles tendon rupture on the contralateral side.

Tendon Repair

Surgery was performed on an inpatient basis with the patient under local or spinal anesthesia and in the prone position. All patients were treated within 5 days after their injuries. A 10-cm longitudinal skin incision was performed over the tendon rupture site. The sheath of the Achilles tendon was opened, and the ruptured tendon ends with paratenon were exposed. The repair was performed by a combination of Kirschmayer core suture and cross-stitch epitenon suture using the technique developed by Silfverskiöld and May[24] in 1994, maintaining both apposition of the tendon ends and an adequate length of the repaired tendon. The suture material used in this study was No. 2 Tevdek (nonabsorbable braided polyester suture; Deknatel, Inc., Fall River, Massachusetts) for the core suture and 2–0 Maxon (absorbable monofilament suture; American Cyanamid Co., Wayne, New Jersey) for the epitenon suture. The mesh structure of the cross-stitch epitenon suture applied around the repaired tendon was able to cover and stabilize disheveled tendon ends. Multiple passes of suture material in an obliquely bridging weave pattern distributed the load evenly and thus multiplied the effective force of the relatively weak suture material (Fig. 1).[12] The ankle was passively moved through its range of motion to check the length of the repaired tendon and the stability of the apposed tendon ends. The sheath of the Achilles tendon was repaired with absorbable interrupted sutures to achieve tight closure over the tendon. After closing the skin, the lower leg was protected for 2 to 5 days with a below-the-knee posterior splint with the ankle in 10° to 20° of plantar flexion.

Postoperative Procedures

Between 1 and 2 days after surgery, early active range of motion exercise of the ankle was instituted with the ankle in 10° to 20° of flexion. Partial weightbearing (one-fourth of body weight) with a soft ankle orthosis was allowed when the patients were able to extend their affected ankles to greater than the neutral position. Under the careful supervision of a physical therapist, full weightbearing

TABLE 1
Clinical Data on 22 Patients with Closed Achilles Tendon Ruptures

Patient	Sex	Age (years)	Side	Occupation	Cause of injury	Period until surgery (days)	Follow-up (months)
1	M	21	R	Office work	Badminton	2	38
2	M	35	L	Office work	Volleyball	1	35
3	F	34	R	Housewife	Tennis	1	34
4	M	48	R	Carpenter	Vaulting horse	3	34
5	F	37	L	Housewife	Volleyball	4	32
6	F	39	L	Receptionist	Jump rope	1	32
7	F	27	R	Housewife	Mini volley	0	32
8	F	30	L	Receptionist	Badminton	1	31
9	F	30	L	Canvassing	Mini volley	2	30
10	M	36	L	Canvassing	Badminton	3	26
11[a]	M	34	R	Cleaning	Volleyball	[3]	[24]
12	F	33	R	Housewife	Volleyball	3	21
13	F	42	R	Housewife	Mini volley	2	18
14	F	50	L	Housewife	Tennis	3	16
15	M	32	R	Driver	Jump rope	1	18
16	M	41	L	Office work	Skiing	4	17
17	M	40	L	Canvassing	Badminton	5	16
18[a]	M	40	L	Canvassing	Volleyball	[2]	[15]
19	M	55	R	Express agent	Football	2	16
20	F	34	R	Nurse	Volleyball	4	15
21	M	45	R	Office work	Short distance race	2	15
22	F	45	L	Office work	Volleyball	4	15
Mean		37.6				2.4	24.6
SD		7.9				1.4	8.5
Minimum		21				0	15
Maximum		55				5	38

[a] Not included in the clinical data because of partial rerupture.

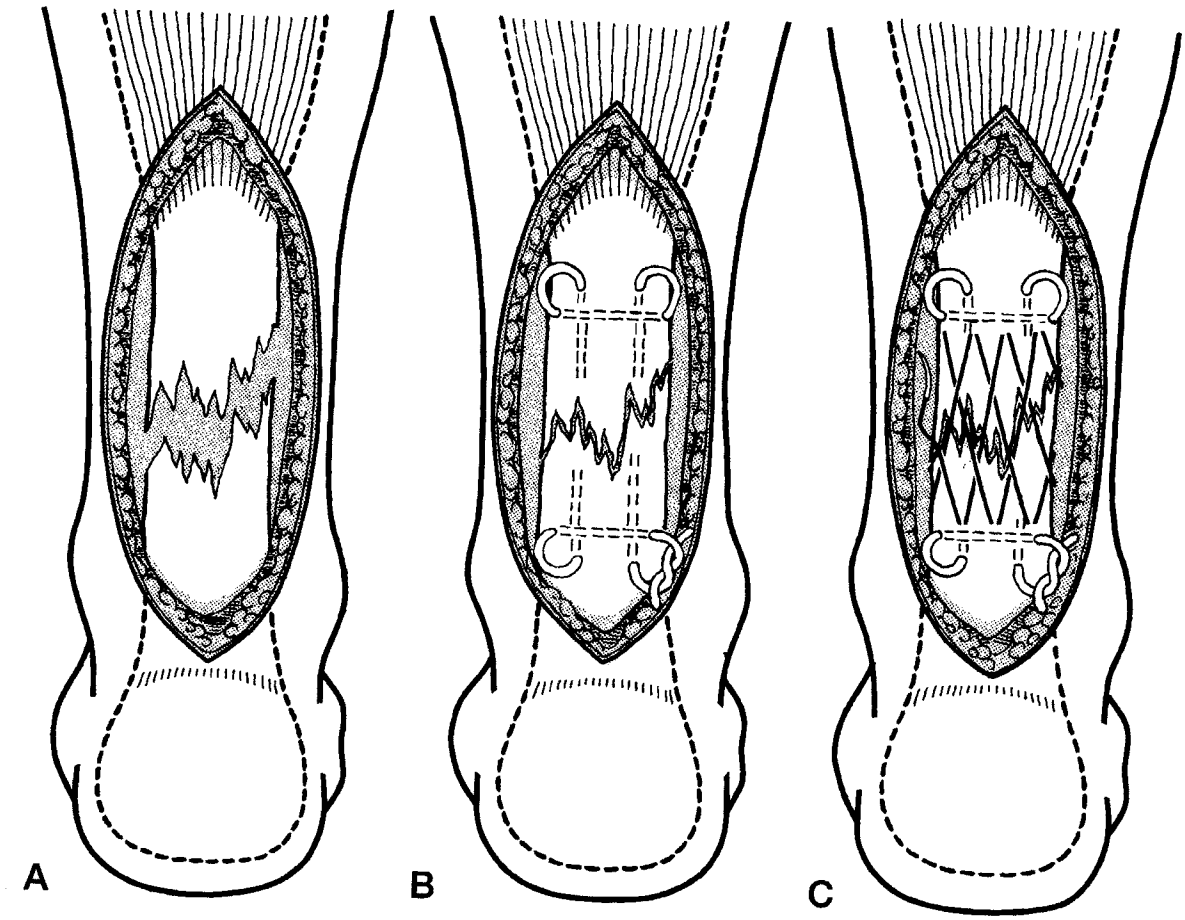

Figure 1. The Kirschmayer core suture and cross-stitch epitenon suture repair technique is demonstrated. A, a 10-cm skin and fascial incision was performed over the Achilles tendon. B, paratenon over the Achilles tendon was spared on both tendon ends. The Kirschmayer core suture with No. 2 Tevdek was applied to connect proximal and distal tendon ends in an appropriate length. C, the cross-stitch epitenon suture with 2–0 Maxon was placed inside the tendon grasps of the Kirschmayer core suture.

without heel raising was instituted by 2 weeks after surgery, when the patients were able to tolerate an uneasy feeling of overload at the tendon repair site. The patients were encouraged to achieve full ankle range of motion as well as heel raising with both legs by 8 weeks after surgery. Strenuous activity and return to sports was allowed when patients were able to raise the heel on the affected side freely without causing pain at the tendon repair site. The postoperative physical therapy protocol is outlined in Table 2.

Clinical Follow-up

We recorded the number of days after surgery until each patient began partial weightbearing, full weightbearing without heel raising, heel raising with both legs, free heel raising without pain at the tendon repair site, and recovery to original full sports activity. Range of ankle motion was evaluated every week until 8 weeks after surgery and then every month until 6 months after surgery. The duration of follow-up averaged 24.6 months (range, 15 to 38).

Magnetic Resonance Imaging

All MRI scans were obtained with a Gyroscan T5 II scanner (Philips Medical Systems, Best, the Netherlands) at approximately 4, 6, 8, 12, 16, and 20 weeks after surgery. The MRI findings through 12 weeks after surgery were available in 14 of the 22 cases (MRI was performed on patients who could afford the cost not covered by the national health insurance system). A body coil was used for the transmitter and a surface coil was used for the receiver with the patient in the supine position. A 205 × 256 pixel matrix and 280 × 280 mm field of view were used for all images, yielding a 0.4-mm plane resolution in the sagittal images and a 0.6 to 0.9 mm plane resolution in the axial images. In the sagittal plane, T2-weighted (repetition time [TR] of 3000 ms and echo time [TE] of 120 ms) images with 4-mm slice thickness were acquired. In the axial plane, T2-weighted (TR of 3000 ms and TE of 120 ms) images with 6 to 9 mm slice thickness were obtained.[11]

The intensity of the signal in the intratendinous region

TABLE 2
Early Active Ankle Motion and Weightbearing Rehabilitation Protocol After Achilles Tendon Repair

	Postoperative period					
	0–1 day	1–3 days	1–2 weeks	2–3 weeks	6–8 weeks	10–14 weeks
Protection	——Posterior splint——		——Soft ankle orthosis——			
Ankle motion		Active ankle extension (minus range to 0°)	Active ankle extension (more than 0°)		Full active ankle range of motion	
Weightbearing			Partial weightbearing (start with 1/4 body weight)	Full weightbearing (avoid heel raising)	Heel raising with both legs	Full heel raising with one leg and return to sports

on T2-weighted sagittal and axial views was visually evaluated and categorized as high, intermediate, or low. The cross-sectional area of the tendon at the repair site was measured on the T2-weighted axial images with a digitizer (Hitachi Table Digitizer, HDG-1212D; Hitachi Seiko, Ltd., Tokyo, Japan). However, this was not compared with the cross-sectional area of the uninjured Achilles tendon in each patient because only unilateral MRI information was obtained.

RESULTS

Range of Ankle Motion and Weightbearing

Twenty (91%) of the tendons healed without rerupture, and two (9%) of the tendons suffered a partial rerupture at 23 and 56 days, respectively. One of the two patients with rerupture was treated with a plaster cast for 2 weeks (No. 18) and the other was treated with protected weightbearing for 2 weeks (No. 11). Although healing and good functional recovery occurred in both patients, they were excluded from the subsequent clinical and MRI evaluations. There was no skin necrosis, infection, or paresis in any of the patients.

The average period until institution of active ankle motion was 3.0 days (SD, 2.2; range, 1 to 7) after surgery. The average period until active extension of the ankle reached 0° was 9.7 days (SD, 7.6; range, 2 to 29), and the interval until ankle motion reached a normal range was 6.0 weeks (SD, 2.7; range, 2 to 12). It took an average of 11.9 days (SD, 6.2; range, 7 to 28) until partial weightbearing became possible, 16.4 days (SD, 7.5; range, 7 to 38) until full weightbearing without heel raising became possible, 7.3 weeks (SD, 1.3; range, 5 to 10) until heel raising with both legs became possible, and finally 12.5 weeks (SD, 2.2; range, 8 to 17) until free heel raising on the affected side became possible without causing pain or an uneasy feeling at tendon repair site. The patients were able to return to full sports activity at 13.1 weeks (SD, 2.0; range, 11 to 18) with no limitation of performance.

MRI Findings

Fourteen of the 22 patients were available for MRI evaluations. The same type MRI machine under the same operating system was used for every patient. The T2-weighted sagittal and axial MRI views in the early postoperative period (around 1 to 4 weeks) showed an intratendinous area of high-intensity signal at the tendon repair site. The interval until the intratendinous high-intensity signal at the tendon repair site became intermediate-intensity signal on the T2-weighted sagittal MRI views averaged 6.9 weeks (SD, 3.4; range, 3 to 16), and the interval until the greater part of the tendon repair site became low-intensity signal averaged 12.6 weeks (SD, 3.8; range, 6 to 20). On the T2-weighted axial views, however, a small area of high-intensity signal in the intratendinous repair site was visible in 5 of the 14 patients at 12 to 20 weeks. However, this area of high-intensity signal was surrounded by a thick low-intensity signal tendon area (Fig. 2). The cross-sectional area of the injured tendon at 12 to 20 weeks after surgery averaged 296.8 mm^2 (SD, 55.2; range, 212 to 389). Because of the limited number of patients who would undergo MRI of their contralateral uninjured legs, the average cross-sectional area of the uninjured Achilles tendons was not determined.

Case Presentation

Patient No. 6, a 39-year-old female receptionist, suffered right Achilles tendon rupture while jumping rope. Tendon repair was performed on the same day and followed by early active ankle motion the next day. Active extension of the ankle joint recovered to neutral 2 days after surgery, and this was followed by partial weightbearing at 9 days. The patient was able to raise the heels of both legs simultaneously at 7 weeks and returned to full sports activity at 14 weeks. In the MRI findings, a high-intensity signal area was present in the tendon repair site in sagittal views at 5 weeks after surgery but changed to low- or intermediate-intensity signal at 12 weeks (Fig. 2). At 18 weeks, the entire tendon had become low-intensity signal in sagittal views. In the axial views, a small intratendinous area of high-intensity signal persisted at 8 weeks and was surrounded by a thick low-intensity signal tendon at 12 weeks (Fig. 2).

DISCUSSION

The treatment options for Achilles tendon rupture, that is, nonoperative closed methods, percutaneous sutures, or

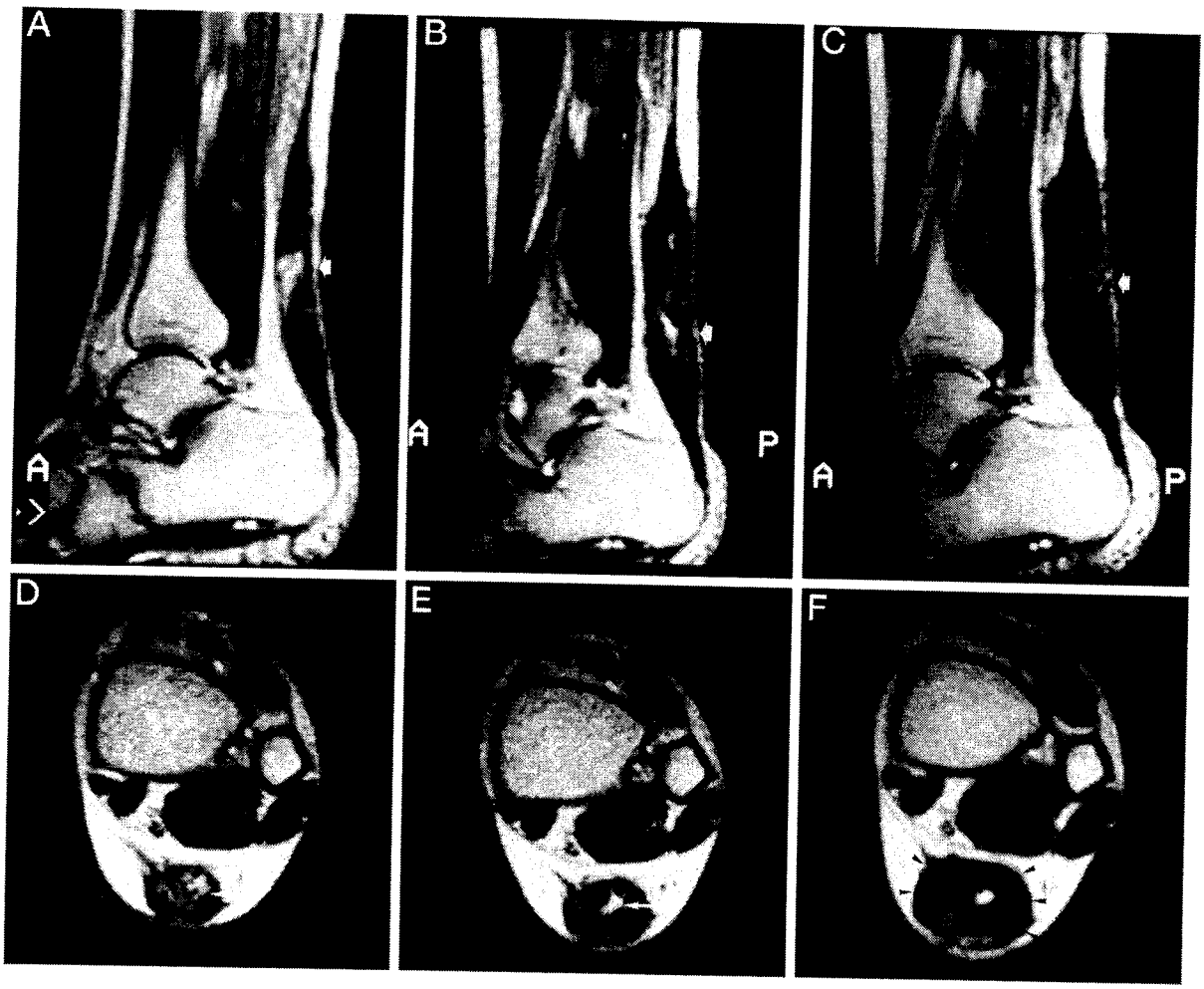

Figure 2. Sagittal T2-weighted MRI scans of the repaired Achilles tendon of patient No. 6 at 5 (A), 8 (B), and 12 (C) weeks after surgery. Axial T2-weighted MRI scans of the repaired tendon in the same patient at 5 (D), 8 (E), and 12 (F) weeks. The high-intensity signal area on sagittal views in the tendon repair site existed at 5 weeks (A, big arrow), changed to intermediate- or high-intensity signal at 8 weeks (B, big arrow), and to low- or intermediate-intensity signal at 12 weeks (C, big arrow). At 18 weeks, the entire tendon became low-intensity signal. On axial views, the high-intensity signal area in the tendon repair site existed at 5 weeks (D, arrow). A small intratendinous high-intensity area persisted at 8 weeks (E, arrow) and was surrounded by a thick low-intensity signal tendon at 12 weeks (F, arrowheads).

open surgical repair, have long been a matter of controversy among orthopaedic surgeons. Previous studies have suggested a rerupture rate of 10% to 30% after nonoperative treatment, and less strength and endurance compared with open surgical repair.[8,9,16,17,20,21,23] Complications of open surgical repair have become less frequent as advances have been made in surgical repair technique and knowledge of neurovascular anatomy.[5] However, regardless of the conservative or surgical technique used, postoperative immobilization in a cast has been mandatory.[18]

As a result of the development of repair techniques for flexor tendons in the hand, the postoperative rehabilitation protocol after flexor tendon repair has changed from immobilization to passive finger motion.[4,7,13] Current advances in techniques for strong repair have made active finger motion an important option in the postoperative rehabilitation protocol.[2,12,15,24] Since recent experimental studies of the flexor tendons have supported the concept that motion and tension applied at tendon repair sites enhance the tendon healing process and avoid surrounding adhesions,[1,7,14,19,25] both the suture technique and the postoperative rehabilitation protocol are becoming extremely important in tendon surgery.[19,24]

In a paper published in 1987, Beskin et al.[3] advocate functional range of motion exercises before casting with the three-bundle repair technique. They claim that there is no need of further bracing or heel lifts, and they show an early return to normal range of ankle motion and activities. Subsequently, a 1995 article by Mandelbaum et al.[18] demonstrates an early range of motion program after Krackow's 4-strand repair technique, and a 1997 article by Fernández-Fairén and Gimeno[6] reports active-assisted

mobilization with an early partial weightbearing protocol after Leeds-Keio ligament augmentation. Both studies emphasize the effectiveness of an early motion and weightbearing rehabilitation protocol.

In the present study we adopted a simple technique for strong tendon repair, the Kirschmayer core suture and cross-stitch epitenon suture, first described by Silfverskiöld and May in 1994.[24] Rehabilitation involving early active motion of the ankle and weightbearing was applied according to the distinct rehabilitation protocol (Table 2). Our clinical results demonstrated remarkable functional recovery without serious complications compared with other surgical studies.[8,9,17,20,21] While partial reruptures occurred as a result of accidents in two patients, the tendons healed after 2 weeks of additional protection. We believe that these excellent results are partly attributable to the characteristic behavior of cross-stitch repair, which stabilizes disheveled tendon ends, and partly to the fact that this weave thread pattern distributes the load evenly and thus multiplies the effective force around the tendon.[12,24]

It is important to consider the transition that MRI signals undergo in the intratendinous area of the tendon repair site on T2-weighted views. In our current study, an intratendinous high-intensity signal area was present until 4 weeks after surgery, and faded into intermediate-intensity signal by 8 weeks. The greater part of repaired tendon became low-intensity signal with marked hypertrophy by at least 12 to 20 weeks after surgery. According to a meticulous study of MRI T2-weighted images by Karjalainen et al.,[11] 12 weeks after open surgical repair (including 3 weeks of immobilization) Achilles tendons showed an intratendinous area of high-intensity signal in 19 of 21 cases. In that study, three patients with large areas of high-intensity signal had clinically poor outcomes. The authors surgically examined the tendon repair site in those three patients, and they found that the corresponding area of high-intensity on the MRI scans had unorganized active scar formation. Therefore, our results, showing a smaller area of high-intensity signal in addition to a greater area of low-intensity signal in patients at 12 weeks after surgery, may suggest progressing tendon healing with less immature scar formation.[11] The increase in cross-sectional area at the tendon repair site may also contribute to the strength of the repaired tendon, even though the repaired tendon has relatively weak material properties in the healing period. An early motion and weightbearing rehabilitation protocol may allow newly formed collagen fiber to grow and be remodeled rapidly, eventually enhancing tendon strength.[14]

Maxon absorbable sutures were used for cross-stitch repair in our study. An experimental study of rabbit Achilles tendons repaired with absorbable sutures showed tensile strength in the postoperative period comparable with that of tendons repaired with nonabsorbable sutures.[22] Therefore, we believe that absorbable sutures maintain the strong mechanical characteristics of cross-stitch repair during the healing process for ruptured Achilles tendons. Moreover, the use of absorbable suture material for cross-stitch repair may also reduce the risk of implantation of foreign material in the tendon.[26]

Achilles tendon ruptures in the athletic population are becoming increasingly common. This injury occurs in a variety of people, from the recreational or weekend sports participant to the professional athlete. Although this clinical study includes only recreational and midgrade competitive athletes, each has an activity level according to his or her physical potential, lifestyle, or surrounding environment, and each hopes to return to a particular level of activity. The goal of sports medicine physicians treating this injury is to minimize morbidity and optimize rapid return to full functional performance at each person's chosen level.[18] We believe that strong and stable tendon repair as well as an early rehabilitation protocol may restore good muscle and joint function. The rehabilitation protocol described above may help athletes with Achilles tendon rupture recover function in a shorter period than when other protocols are used.

ACKNOWLEDGMENTS

We cordially thank Sei-ichi Ishii, MD, Professor and Chairman of Sapporo Medical University, for useful suggestions and comments. We thank Megumu Yamamura, MD, of Sapporo and Maruyama Seikeigeka, Yoshihiko Tsuchida, MD, Toshiaki Takiuchi, MD, and Hideji Kura, MD, of Sapporo Medical University, for collection of clinical and MRI data on the patients. Illustrations were drawn by Chieko Kamijo, ORT.

REFERENCES

1. Aoki M, Kubota H, Pruitt DL, et al: Biomechanical and histologic characteristics of canine flexor tendon repair using early postoperative mobilization. *J Hand Surg 22A:* 107–114, 1997
2. Aoki M, Pruitt DL, Kubota H, et al: Effect of suture knots on tensile strength of repaired canine flexor tendons. *J Hand Surg 20B:* 72–75, 1995
3. Beskin JL, Sanders RA, Hunter SC, et al: Surgical repair of Achilles tendon ruptures. *Am J Sports Med 15:* 1–8, 1987
4. Bunnell S: Primary repair of severed tendons. The use of stainless steel wire. *Am J Surg 47:* 502–516, 1940
5. Carr AJ, Norris SH: The blood supply of the calcaneal tendon. *J Bone Joint Surg 71B:* 100–101, 1989
6. Fernández-Fairén M, Gimeno C: Augmented repair of Achilles tendon ruptures. *Am J Sports Med 25:* 177–181, 1997
7. Gelberman RH, Woo SL-Y, Lothringer K, et al: Effects of early intermittent passive mobilization on healing canine flexor tendons. *J Hand Surg 7:* 170–175, 1982
8. Hattrup SJ, Johnson KA: A review of ruptures of the Achilles tendon. *Foot Ankle 6:* 34–38, 1985
9. Inglis AE, Scott WN, Sculco TP, et al: Ruptures of the tendo Achillis. An objective assessment of surgical and non-surgical treatment. *J Bone Joint Surg 58A:* 990–993, 1976
10. Kannus P, Józsa L: Histological changes preceding spontaneous rupture of a tendon: A controlled study of 891 patients. *J Bone Joint Surg 73A:* 1507–1525, 1991
11. Karjalainen PT, Aronen HJ, Pihlajamäki HK, et al: Magnetic resonance imaging during healing of surgically repaired Achilles tendon ruptures. *Am J Sports Med 25:* 164–171, 1997
12. Kim PT, Aoki M, Tokita F, et al: Tensile strength of cross-stitch epitenon suture. *J Hand Surg 21B:* 821–823, 1996
13. Kleinert HE, Kutz JE, Ashbell TS, et al: Primary repair of lacerated flexor tendons in "no man's land" [abstract]. *J Bone Joint Surg 49A:* 577, 1967
14. Kubota H, Aoki M, Pruitt DL, et al: Effect of motion and tension on injured flexor tendons in chickens. *J Hand Surg 21A:* 456–463, 1996

15. Kubota H, Manske PR, Aoki M, et al: Mechanical properties of various circumferential tendon suture techniques. *J Hand Surg 21B:* 474–480, 1996
16. Lea RB, Smith L: Rupture of the Achilles tendon. Nonsurgical treatment. *Clin Orthop 60:* 115–118, 1968
17. Ma GWC, Griffith TG: Percutaneous repair of acute closed ruptured Achilles tendon. A new technique. *Clin Orthop 128:* 247–255, 1977
18. 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 23:* 392–395, 1995
19. Manske PR: Flexor tendon healing. *J Hand Surg 13B:* 237–245, 1988
20. Motta P, Errichiello C, Pontini I: Achilles tendon rupture: A new technique for easy surgical repair and immediate movement of the ankle and foot. *Am J Sports Med 25:* 172–176, 1997
21. Nistor L: Surgical and non-surgical treatment of Achilles tendon rupture. A prospective randomized study. *J Bone Joint Surg 63A:* 394–399, 1981
22. O'Broin ES, Earley MJ, Smyth H, et al: Absorbable sutures in tendon repair. A comparison of PDS with Prolene in rabbit tendon repair. *J Hand Surg 20B:* 505–508, 1995
23. Shields CL Jr, Kerlan RK, Jobe FW, et al: The Cybex II evaluation of surgically repaired Achilles tendon ruptures. *Am J Sports Med 6:* 369–372, 1978
24. Silfverskiöld KL, May EJ: Flexor tendon repair in zone II with a new suture technique and an early mobilization program combining passive and active flexion. *J Hand Surg 19A:* 53–60, 1994
25. Tanaka H, Manske PR, Pruitt DL, et al: Effect of cyclic tension on lacerated flexor tendons in vitro. *J Hand Surg 20A:* 467–473, 1995
26. Tang JB, Usui M, Aoki M, et al: An experimental study of tendon suture using a new absorbable material Maxon: A preliminary report. *Hokkaido J Orthop Traumatol 36:* 133–138, 1992