Achilles Tendon Elongation After Rupture Repair

A Randomized Comparison of 2 Postoperative Regimens

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Background: A few prospective controlled trials comparing early functional rehabilitation after Achilles tendon repair and nonoperative immobilization have been reported.

Hypotheses: There is no difference in Achilles tendon elongation between early motion and immobilization after Achilles tendon repair. Tendon elongation does not correlate with the clinical outcome.

Study Design: Randomized clinical trial; Level of evidence, 2.

Methods: Fifty patients with acute Achilles tendon rupture were randomized postoperatively to receive either early movement of the ankle between neutral and plantar flexion in a brace for 6 weeks or immobilization in tension using a below-knee cast with the ankle in a neutral position for 6 weeks. Full weightbearing was allowed after 3 weeks in both groups. Standardized radiographs to measure previously placed radiographic markers were taken on the first day postoperatively and at 1, 3, 6, 12, 24 weeks postoperatively, with the final radiograph a mean of 60 (SD, 6.4) weeks postoperatively. The outcome was assessed at the 3-month and final checkups by the clinical scoring method described by Leppilahti et al and included subjective factors and objective factors.

Results: Tendon elongation occurred in both groups but was somewhat less in the early motion group (median 2 mm in the early motion group vs median 5 mm in the cast group a mean of 60 weeks postoperatively, $P = .054$). The elongation curves first rose and then slowly fell in both groups. The patients who had less elongation achieved a better clinical outcome ($\rho = -.42$, $P = .017$). Tendon elongation did not correlate significantly with age, body mass index, or isokinetic peak torques.

Conclusion: Achilles tendon elongation was somewhat less in the early motion group and correlated with the clinical outcome scores. We recommend early functional postoperative treatment after Achilles rupture repair.

Keywords: Achilles tendon rupture; postoperative regimen; early motion; cast immobilization

There is no consensus on the best treatment for acute Achilles tendon (AT) ruptures.[5] Although nonoperative treatment has its own supporters, surgical treatment seems to be the method of choice in the case of athletes and young people and for delayed ruptures.[6] There is no single, uniformly accepted surgical technique, and the surgical options include open repair with or without augmentation and percutaneous techniques.

There has been a trend toward functional treatment postoperatively, but only a few prospective controlled trials comparing an early functional rehabilitation regimen with the nonoperative immobilized regimen have been reported. Cetti et al[1] showed that patients treated postoperatively for 6 weeks with a mobile cast were able to resume sports activities sooner than those treated for the same length of time with a below-knee cast with the ankle in a 20° equine position. Mortensen et al[11] reported that 8 weeks of early restricted motion shortened the time needed for rehabilitation compared with 8 weeks of cast immobilization with the ankle in the equinus position for 6 weeks. Our previous study based on the same material (Kangas et al[4]) showed that patients receiving early restricted functional treatment for 6 weeks postoperatively have somewhat better isokinetic calf muscle strength results than those treated with the

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No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 35, No. 1
DOI: 10.1177/0363546506293255

TABLE 1
Demographic Data on the Achilles Rupture Patients in the 2 Randomized Groups

Variable	Group 1 (early motion) n = 25	Group 2 (cast) n = 25	Statistical Significance
Men/Women	22/3	24/1	0.609
Age (mean)	35 (21-55)	37 (23-53)	0.318
Body mass index	26 (20-31)	26 (20-38)	0.872
Activity level, competitive athlete/ recreational athlete/ nonathlete	4/17/4	3/18/4	0.714
Previous Achilles tendon symptoms	2	2	>.99

ankle in a neutral position in a cast for 6 weeks with early AT immobilization in tension.

Separation of the AT ends after rupture repair has been investigated by some authors. Nyström and Holmlund[15] reported that elongation followed a biphasic course, and Mortensen et al[10] showed that no difference with respect to AT elongation was found between the 2 suture techniques (Mason vs CSSS), despite immobilization.

The purpose of our prospective, randomized clinical trial was to determine AT elongation after rupture repair in 2 postoperative regimens and to study whether there is any correlation between AT elongation and the clinical outcome.

MATERIAL AND METHODS

The study was approved by the local research ethics committee. All patients received oral and written information, and a written statement of freely given informed consent was obtained. This work is a part of a larger research project concerning postoperative treatment after Achilles rupture repair.

One hundred six patients were treated for an acute complete closed AT rupture at the Oulu University Hospital between July 1995 and July 1998. Fifty-six patients were excluded from the study on the grounds of age greater than 60 years (12 patients), a delay of 1 week or more in treatment after the rupture (4 patients), systemic corticosteroid treatment (2 patients), local corticosteroid injection(s) around the AT during the 6 months before the rupture (2 patients), previous AT rupture on the opposite side (1 patient), diabetes mellitus (1 patient), living outside the county (12 patients), or noncompliance with the protocol (23 patients). Thus, the series consisted of 50 patients (47 men and 3 women; age range, 21-55 years), 47 of whom (95%) had sustained the rupture during a sports-related activity, most frequently badminton (21 patients; 42%), volleyball (9 patients; 18%), soccer (5 patients; 10%), tennis (4 patients; 8%), or indoor hockey (3 patients; 6%).

Operative Technique

All the patients were managed with the same operative technique. One author repaired 42 of the ruptures, and 6 other surgeons operated on the remaining 8. The operations were performed with the patient under spinal anesthesia and in a prone position using a tourniquet. A posteromedial skin incision was made, and the fascia and paratenon were divided in the same line. The tendon was repaired by the 2 modified Kessler suture technique with 2-0 gauge absorbable polydioxanone (PDS) 2-0 sutures (Ethicon, Somerville, NJ) and smaller apposition sutures made with Vicryl (polylactin, Ethicon). A central gastrocnemius aponeurosis flap, as proposed by Silfverskiöld,[16] was turned down over the suture line and stitched to the AT with Vicryl. After suturing, the titanium markers were placed on both sides of ruptured tendon ends. The ankle was then gently placed in a neutral position, the fascia was carefully resutured with Vicryl, and the skin was closed with Ethilon (nylon) sutures (Ethicon). At the end of the operation, a below-knee rigid plaster splint was applied with the ankle in a neutral position in all the patients. The postoperative randomization group was not known at the time of the operation. The final cast or brace was placed at the first postoperative day after the randomization.

Postoperative Care

The 50 patients were randomized postoperatively between regimens of either early mobilization (25 patients, group 1) or immobilization in tension (25 patients, group 2) by drawing randomly mixed numbered, sealed, opaque envelopes. The groups did not differ significantly with respect to gender, age, body mass index, activity level, or previous AT symptoms (Table 1). The patients randomized into the early motion group received in the first postoperative day a below-knee dorsal rigid plaster splint (3M, St Paul, Minn) for 6 weeks that allowed active free plantar flexion of the ankle with dorsiflexion restricted to neutral, whereas those randomized into the immobilization group were given in the first postoperative day a below-knee plaster splint (3M Scotch Cast) with the ankle in a neutral position for 6 weeks. Full weightbearing was allowed after 3 weeks in both groups.

The patients in both groups were advised to perform postoperative exercises according to a standard rehabilitation program (Table 2). None of the patients received professional physical therapy. Jogging was begun at 12 weeks. Swimming and cycling exercises were recommended. Running at full

TABLE 2
Postoperative Exercise Program

Group 1 (early mobilization)	Group 2 (early immobilization in tension)
At 0-3 wk	At 0-3 wk
1. Flexion and extension of the toes in a supine position; 25 × 3 series, 3 times daily	1. Flexion and extension of the toes in a supine position. 25 × 3 series, 3 times daily
2. Plantar flexion of the ankle and dorsiflexion to neutral in a supine position; 30 × 3 series, 3 times daily	2. Concentric contractions of the plantar flexors and extensors of the ankle (hold 5 s). 30 × 3 series, 3 times daily
3. Extension of the knee in a sitting position (hold 2 s); 10 × 3 series, 3 times daily	3. Extension of the knee in a sitting position (hold 2 s). 10 × 3 series, 3 times daily
4. Flexion of the knee in a prone position; 10 × 3 series, 3 times daily	4. Flexion of the knee in a prone position. 10 × 3 series, 3 times daily
5. Extension of the hip in a prone position (hold 2 s); 10 × 3 series, 3 times daily	5. Extension of the hip in a prone position (hold 2 s). 10 × 3 series, 3 times daily
At 3-6 wk	At 3-6 wk
As above	As above
At 6-9 wk	At 6-9 wk
1. Ankle flexion and extension exercises with manual help; 30 × 3 series, 3 times daily	As in group 1
2. Rotation of the ankles in both directions; 30 × 3 series, 3 times daily	
3. Standing on the toes and heels alternately; 30 × 3 series, 3 times daily	
4. Ankle extension exercises against a rubber strip; 20 × 3 series, 3 times daily	
5. Ankle stretching exercises to flexion with the help of a rubber strip; 30 s × 5 series, 3 times daily	
6. Stretching of the calf muscle by standing with the leg to be stretched straight behind and the other leg bent in front and leaning the body forward, with support from a wall or chair; 30 s × 5 series, 3 times daily	
7. Stretching exercises for the toes and ankle against the hand in a sitting position; 30 s × 5 series, 3 times daily	
At 9 wk	At 9 wk
1. Raising and lowering of the heel, first with both feet at the same time and later with 1 foot; 20 × 5 series, 3 times daily	As in group 1
Exercises against a rubber strip for	
Ankle extension 20 × 5 series, 3 times daily	
Ankle flexion 20 × 5 series, 3 times daily	
Ankle abduction 20 × 5 series, 3 times daily	
Ankle adduction 20 × 5 series, 3 times daily	
Stretching of the calf muscle against the wall; 30 s × 5 series, 3 times daily	
Standing with the knee somewhat flexed; 30 s × 5 series, 3 times daily	

speed, ball games, and all other types of sports were allowed at 6 months.

Follow-up

One patient in the cast group moved abroad and was withdrawn after randomization. Standardized radiographs to measure previously placed radiographic markers were taken on the first day postoperatively and at 1, 3, 6, 12, and 24 weeks postoperatively, with a final radiograph a mean of 60 (SD, 6.4) weeks postoperatively. During the radiographs, the ankle was fixed in the brace in the plantigrade position. The distance between the radiograph source and the film plate was fixed at 100 cm, and the radiograph was focused at the midpoint of the AT. Magnification ×1.1 was taken into account. The AT elongation curves for both groups were analyzed and correlated with the previously published clinical data of outcome score (Table 3) and isokinetic calf muscle strength scores (Table 4, Kangas et al[4]). The patients were examined clinically at 1, 3, 6, 12, 24, and finally at a mean of 60 weeks (SD, 6.4 weeks) postoperatively. The outcome was assessed at the 3-month and final checkups by the clinical scoring method described by Leppilahti et al[7] (Table 3). The scoring included subjective factors such as pain, stiffness, muscle weakness, footwear restrictions, and subjective outcome and objective factors such as the range of active ankle motion and isokinetic calf muscle strength. The isokinetic muscle function parameters were assessed for the 2 groups at

TABLE 3
Achilles Rupture Performance Score

	No. of Points[a]
Pain (15 points)	
None	15
Mild, no limitations on recreational activities	10
Moderate, limitations on recreational but not daily activities	5
Severe, limitations on recreational and daily activities	0
Stiffness (15 points)	
None	15
Mild, occasional, no limitations on recreational activities	10
Moderate, limitations on recreational but not daily activities	5
Severe, limitations on recreational and daily activities	0
Subjective calf muscle weakness (15 points)	
None	15
Mild, no limitations on recreational activities	10
Moderate, limitations on recreational but not daily activities	5
Severe, limitations on recreational and daily activities	0
Footwear restrictions (10 points)	
None	10
Mild, most shoes tolerated	5
Moderate, unable to tolerate fashionable shoes, modified shoes tolerated	0
Active range of motion difference between ankles (15 points)	
Normal (≤5°)	15
Mild (6°-10°)	10
Moderate (11°-15°)	5
Severe (≥16°)	0
Subjective result (15 points)	
Very satisfied	15
Satisfied with minor reservations	10
Satisfied with major reservations	5
Dissatisfied	0
Isokinetic muscle strength score (15 points)	
Excellent	15
Good	10
Fair	5
Poor	0
Maximum possible total	100

[a]At least 90 points = excellent, 75 to 89 points = good, 60 to 74 points = fair, and less than 60 points = poor.

TABLE 4
Isokinetic Ankle Strength Scale for Scoring Plantarflexion and Dorsiflexion Peak Torques of the Ankle at 3 Test Speeds (60 deg/s, 120 deg/s, 180 deg/s)

	No. of Points[a]
Plantarflexion peak torque 60 deg/s percentage difference (uninjured-injured) (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Dorsiflexion peak torque 60 deg/s percentage difference (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Plantarflexion peak torque 120 deg/s percentage difference (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Dorsiflexion peak torque 120 deg/s percentage difference (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Plantarflexion peak torque 180 deg/s percentage difference (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Dorsiflexion peak torque 180 deg/s percentage difference (17 points)	
≤2%	17
>2% ≤ 5%	15
>5% ≤ 10%	13
>10% ≤ 25%	9
>25% ≤ 50%	5
>50%	0
Maximum possible total	102

[a]At least 87 points = excellent, 72 to 86 points = good, 57 to 71 points = fair, and less than 56 points = poor.

the 3-month and final checkups using the computer-based Lido Multi-Joint II isokinetic dynamometer (Loredan Biomedical Inc, West Sacramento, Calif). The isokinetic dorsiflexion and plantarflexion peak torque strengths were measured, first at a speed of 60 deg/s, then at 120 deg/s, and finally at 180 deg/s. The isometric strength was measured with the ankle at the neutral position. The patients were also asked to complete a written questionnaire independently. The clinical observers were not blinded to the treatment groups.

Statistical Analysis

The statistical analysis was performed with the Statistical Package for Social Sciences (SPSS, version 10.0, SPSS

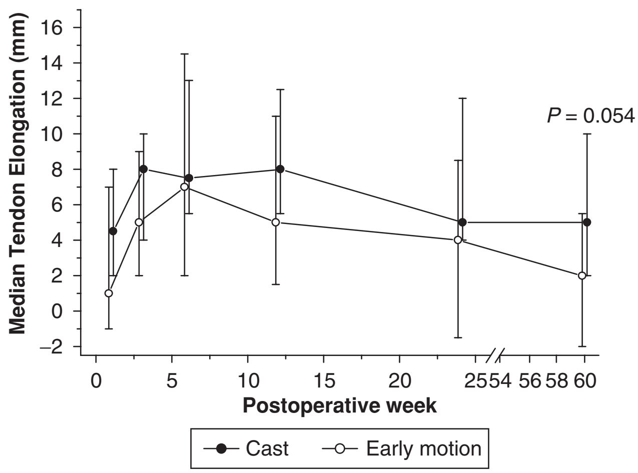

Figure 1. Achilles tendon elongation at each time point.

Science Inc, Chicago, Ill). Summary statistics for continuous variables are expressed as median with 25th and 75th percentiles. Spearman correlation coefficients (ρ) were used to determine the correlations between AT elongation and clinical outcome and the *t* test to calculate the differences in AT elongation. Categorical data were analyzed by Fisher's exact test. Two-tailed *P* values are reported.

RESULTS

Elongation of the AT occurred to a lesser extent in the early motion group than in the cast group ($P = .054$ at mean 60 weeks; Figure 1). The curves increased significantly up to 6 weeks in both groups, however, and were not biphasic in either. The median AT elongation was 1.0 mm (25th and 75th percentiles, –1.0 to 7.0) in group 1 and 4.5 mm (2.0-8.0) in group 2 at 1 week, 5.0 mm (2.0-9.0) in group 1 and 8.0 mm (4.0-10.0) in group 2 at 3 weeks, and 7.0 mm (2.0-14.5) in group 1 and 7.5 mm (5.5-13.0) in group 2 at 6 weeks.

After 6 weeks, the AT shortened somewhat in both groups, the median difference with respect to the starting point being 4.0 mm (–1.5 to 8.5) in group 1 and 5.0 mm (4.0-12.0) in group 2 at 24 weeks and 2.0 mm (–2.0 to 5.5) in group 1 and 5.0 mm (2.0-10.0) in group 2 at a mean of 60 weeks.

Achilles tendon elongation correlated significantly with the clinical outcome ($\rho = -.42$, $P = .017$), the patients with less AT elongation achieving a better clinical outcome, but not with age, body mass index, or isokinetic peak torque values (Table 5). The performance scores and isokinetic measurements have been reported in our earlier publication.[4] The ankle performance scores were excellent or good in 88%, fair in 4%, and poor in 8% of the patients in group 1 at the last control visit, whereas the scores in group 2 were excellent or good in 92% and fair in 8% of the patients ($P = .85$). The isokinetic calf muscle scores were excellent in 56%, good in 32%, fair in 8%, and poor in 4% of the patients in group 1 at the last control checkup, whereas the scores in the cast group were excellent in 29%, good in 50%, and fair in 21% of the patients ($P = .17$). One patient in group 2 who had moved abroad was excluded.

TABLE 5
Correlation of Achilles Tendon Elongation With Clinical Outcome, Age, Body Mass Index (BMI), and Isokinetic Peak Torques

	Correlation Coefficient	*P*
Clinical outcome	–.42	0.017
Age	0.02	>.9
BMI	–.07	0.65
Peak torque		
Plantar flexion		
60 deg/s	0.07	0.717
120 deg/s	0.137	0.478
180 deg/s	0.132	0.497
Mean work		
Plantar flexion		
60 deg/s	0.07	0.717
120 deg/s	0.134	0.488
180 deg/s	0.06	0.756
Isometric strength		
Plantar flexion	0.066	0.735

DISCUSSION

The major finding was that significant AT elongation occurred in both groups but was somewhat less marked in the early motion group. Achilles tendon elongation correlated significantly with the clinical outcome; the less elongation occurred, the better the outcome scores. The AT elongation did not correlate with isokinetic calf muscle strength values, age, and body mass index.

Although Nyström and Holmlund[15] reported that separation of the AT ends followed a biphasic course, with an initial separation in the interval 0 to 7 days, no separation in 8 to 12 days, and late separation in 22 to 35 days, the present elongation curves first rose and then slowly fell in both groups. Elongation increased up to 6 weeks in both groups, but the rise was somewhat steeper in the cast group. After 6 weeks, the AT preserved its length or even shortened a little in the early motion group. This shortening of the tendon between 24 and 60 weeks in the early motion group has not been mentioned in any earlier report. There are some conceivable reasons why this should happen, however. The primary mechanical strength of the tendon depends on the extracellular formation of triple helix collagen fibrils with stabilizing molecular cross-links[3] that takes place in this postoperative period. As the AT descends, its fibers rotate by up to 90°, with the posterior gastrocnemius tendon fibers rotating anterolaterally and the anterior soleus fibers running posteromedially.[2] It is also possible that both may rerotate at that time and make the tendon shorter.

The causes of AT elongation may be numerous. Technical causes can include failure of the suture material or slipping of the knot or necrosis around the sutures that allows one of them to cut through the tendon. There is no universal consensus that a definite suture type and a definite suture thickness is the method of choice in AT rupture repair. We want to use absorbable suture material with minimal tissue response but with enough tensile strength for tendon healing. The authors found no clear suture insufficiency. Suture techniques show differences from continent to continent. In Europe, many authorities use strong monofilament or braided absorbable sutures,[11] whereas in North America the tendency is to use mechanically strong stitches extending well above and below the site of rupture (the Krackow technique) with braided nonabsorbable material.[8]

The effects of various suture materials and suture techniques on the separation of sutured AT ends have also been studied. Laboratory tests on cadaverous ATs showed the 6-strand suture technique (CSSS) to have a better gapping resistance than the Mason or Bunnell technique,[9] but no difference was found between the 2 techniques in a clinical study.[10] Meanwhile, in an experimental study of the effects of various suture materials, suture techniques, and lengths of postoperative immobilization on the separation of sutured AT ends in rabbits, Nyström et al[12-14] found that for the classic Bunnell suture, steel wire was much more suitable than plastic polypropylene or smooth polyester materials because its use gave rise to a very small initial separation. A short single loop resulted in at least initial separation with all materials tested, whereas suturing techniques involving long suture loops led to an excessively large initial separation. Dexon ligatures around the tendon ends did not result in lower tendon end separation. Their findings also indicated that a considerable reduction in immobilization time is possible without causing higher values for early separation. If the tendon is not sutured at all, however, or not immobilized during the first postoperative week, a much greater initial separation of the tendon ends occurs. They emphasized the importance of maintaining muscle tone during cast treatment, as the groups with a high initial separation showed very marked signs of degenerative muscle changes, a decrease in percentage of type I fibers, and a decrease in the diameter of both type I and type II fibers.[17] Mortensen et al[11] reported in a controlled study that 8 weeks of early restricted postoperative treatment led to a mean tendon elongation of 9 mm at 6 weeks and 11.5 mm at 12 weeks, whereas 8 weeks of postoperative cast treatment with the ankle in the equine position for 6 weeks and in the neutral position for 2 weeks led to a mean elongation of 5 mm at 6 weeks and 9 mm at 12 weeks. We found here that early separation was greater in the cast group, where the ankle was immobilized in tension in a neutral position for 6 weeks, whereas in the early motion group the tension was perhaps more appropriate and thus only minor tendon elongation occurred.

There were no selection, performance, and detection biases in the present series. The clinical outcome measures included a standardized scoring system.[7] The patients were asked to complete a written questionnaire independently.

One limitation was the small number of patients in the series, which reduced the statistical power of the study. Thus, although the AT elongation curve was somewhat lower in the early motion group than in the immobilization group, this and other important clinical differences may be obscured by the lack of statistical significance. The use of intratendinous metallic markers may result in a source of error, although no loosening of the markers was found at follow-up. Another possible source of error may be variations in the ankle position in the radiographs. To eliminate this, a standardized brace was used and the ankle was fixed in the plantigrade position in all cases.

Although AT elongation occurred significantly in both groups, it was somewhat less marked in the early motion group. It also correlated significantly with the clinical outcome scores. We recommend early functional postoperative treatment after Achilles rupture repair.

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