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Management of acute Achilles tendon rupture with tendon-bundle technique

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Abstract

Objective: To explore tendon-bundle technique for treating Achilles tendon rupture with no defects.

Methods: Patients with full unilateral Achilles tendon rupture with no defects were included. The Achilles tendon medial edge surgical repair approach was used, revealing horsetail-like rupture bundles. Tendon bundles were anatomically realigned and repaired end-to-end using 5-0 sutures. Patients were followed-up for 1 year, and assessed for differences between the repaired versus healthy limb.

Results: Out of 24 patients (18 male, 6 female; aged 19–56 years) at 1 year following surgery, mean American Orthopaedic Foot and Ankle Society score was 92.4 ± 5.9; mean differences between the surgically repaired versus contralateral side in dorsiflexion and plantarflexion angle were $3.5 \pm 2.3^{\circ}$ and $5.6 \pm 3.2^{\circ}$, respectively; mean difference in calf circumference between the two sides was 0.9 ± 0.5 cm; and mean increase in Achilles tendon width versus the healthy side was 0.8 ± 0.2 cm. By 1 year post-surgery, there were no significant between-side differences in dorsiflexion and plantarflexion angle, or calf circumference.

Conclusions: Tendon-bundle surgery resulted in good ankle function restoration and low complication rates. Tendon-bundle surgery may reduce blood supply destruction and maximally preserve Achilles tendon length, and may be effective for treating Achilles tendon rupture with no defects.

Keywords

Achilles tendon, rupture, tendon-bundle

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Introduction

The Achilles tendon is the strongest tendon in the human body.[1] Achilles tendon rupture is a common injury seen in orthopaedic departments, and with an increase in

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sporting activities, incidence of Achilles tendon rupture is increasing, particularly in young people.[2] There is no consensus regarding optimal treatment, however,[3,4] with published studies covering conservative treatment,[5] percutaneous or open repair,[6–8] or minimally invasive repair techniques.[9,10] Although repair procedures vary considerably, end-to-end suturing techniques to repair Achilles tendon without defects have achieved good success rates.[11] Surgical treatment significantly reduces the risk of re-rupture, but increases the risk of complications associated with surgery,[12] such as wound infection and necrosis caused by excessive dissection, and Achilles tendon contracture. End-to-end suture techniques lead to reduced complication rates and more successful outcomes[13] compared with tendon augmentation methods.[13,14] In a study that compared the Krakow locking loop technique with triple bundle technique in terms of Achilles tendon tensile strength following repair,[15] the triple bundle technique represented statistically significant superiority. In another study, Achilles tendon repair using the triple-bundle technique was shown to result in good functional restoration with a low complication rate.[16]

The triple-bundle technique changes the physiological structure of the Achilles tendon trauma site resulting in destruction of the Achilles tendon blood supply, and/or keloid formation, and may result in incision necrosis and muscle adhesion.[16] The aim of the present study was to present the range of motion, American Orthopaedic Foot and Ankle Society (AOFAS) score, calf circumference, and Achilles tendon suture keloid width (evaluated using magnetic resonance imaging [MRI]), at 12 months following surgery, in patients with Achilles tendon rupture treated using the tendon-bundle surgical technique with end-to-end suture.

Patients and methods

Study population

This single-centre, case series included consecutive patients with unilateral complete Achilles tendon rupture (open or closed injury) with no defects, who were treated at the Department of Orthopaedics, Tongji Hospital, Shanghai, China between June 2012 and May 2014. Patients were excluded if they had a previous injury to the same tendon; functional impairment on the contralateral side; and/or history of vasculopathy, diabetes, systemic diseases requiring immunosuppressive agents, hyperuricemia or corticosteroid injections. Patients who had severe tendinosis and degeneration that required adjunctive procedures, such as augmentation of the plantaris, flexor hallucis longus, or gastrocnemius muscle, were also excluded from the study.

Achilles tendon rupture was diagnosed by presenting symptoms, including a sudden increase in pain around the Achilles, weakness, poor balance, and limited walking distance. At initial clinical evaluation, a sense of emptiness at the rupture site and a positive Thompson test were also used to diagnose Achilles tendon rupture. MRI was performed in all closed injury cases to detect and confirm the diagnosis.

This work complied with the Helsinki Declaration related to research carried out on human subjects. Ethical approval was obtained from the Human Research Ethics Committee, Tongji Hospital, Tongji University School of Medicine, Shanghai, China. All patients provided verbal informed consent.

Surgical technique

Surgery was performed with the patient in prone position, and with a thigh pneumatic tourniquet for haemostasis. The contralateral extremity may also have been draped for resting length comparison. Spinal

anaesthesia (60–70 mg lidocaine) or continuous epidural anaesthesia (250–300 mg lidocaine) was provided. For patients with open injury, hydrogen peroxide and iodine water were used to clean the wound, followed by careful debridement until adequate exposure of the Achilles tendon rupture end, and slight trimming along the original wound or prolonged wound incision suture. For closed injury, an approximately 8 cm posteromedial longitudinal approach was used, with a full-thickness incision down to the paratenon. Using careful subcutaneous tissue dissection, the paratenon deep fascia was incised according to the skin incision. Then the torn fibres of the tendon were exposed and irrigated, and blood clots were removed, taking care to protect the anterior vascular supply of the tendon. All of the tendons were aligned at their anatomical location using the tendon-bundle technique, following accurate debridement. Transverse tendon ruptures were easily reduced at the anatomical location. Horse-tail ruptures underwent reduction with caution, so that the distal long fibre bundle was equal in length to the proximal brevis bundle. Tendons were examined during surgery to decide whether augmentation was necessary.

The Achilles tendon was typically divided into 20–30 bundles, then the tendon bundles were repaired end-to-end, from deep to lamina, using absorbable 5-0 sutures to connect the ends of each tendon-bundle and absorbable 3-0 sutures to reinforce the repair (Figure 1). Surgery aimed to restore

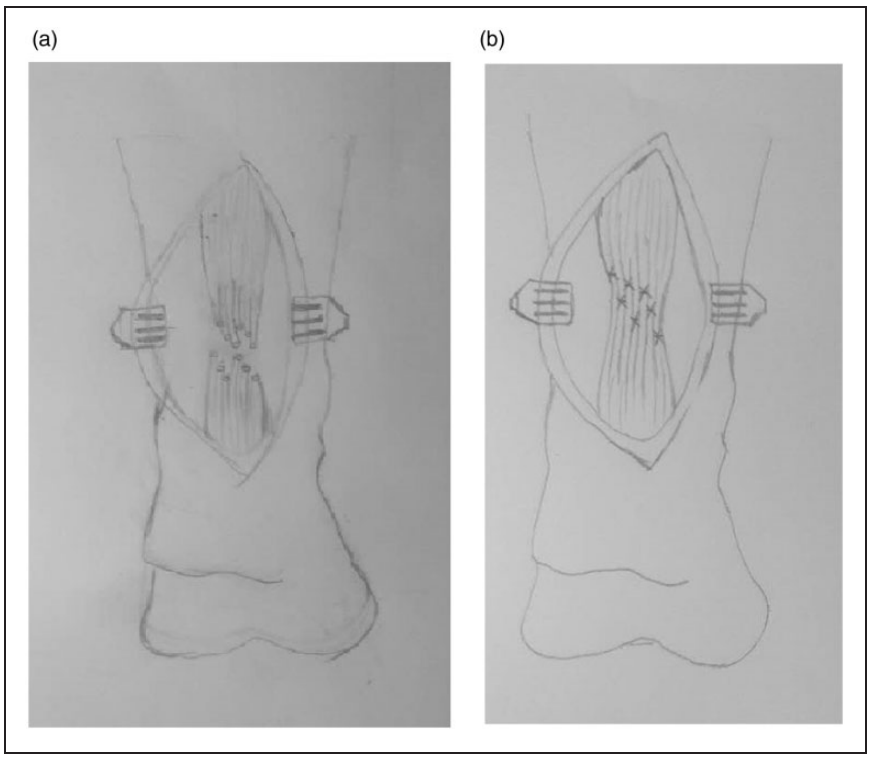

Figure 1. Representative intraoperative sketch of Achilles tendon-bundle surgery showing: (a) horse-tail rupture stumps observed during surgery; and (b) the Achilles tendon sutured using the tendon-bundle technique.

proper tension in all cases, with no more than 5° difference between dorsiflexion on the surgically repaired side versus the contralateral side. Prior to incision closure, the strength of the repaired tendon was tested. A silicone drainage tube was placed in the incision, and the outer membrane of the Achilles tendon, deep fascia, subcutaneous tissue and skin were sutured using nonabsorbable 3-0 sutures. The wound was covered with sterile dressing and an ankle plantar-flexion position cast was applied in a neutral position.

Postoperative management

All patients received postoperative treatment to improve microcirculation, comprising 10 μg alprostadil in 100 ml physiological saline (intravenous drip, daily for 7–14 days) and infrared heat treatment to the repaired limb. Patients with open injury were permitted to receive antibiotic treatment, according to the extent of wound contamination. The treated limb remained fixed by ankle plantar-flexion plaster at 20°, with limb elevation. Attention was paid to plaster tightness to avoid oedema affecting the blood supply. The drainage tube was removed 3 days post-surgery, and skin sutures were removed 2 weeks post-surgery. Following soft tissue healing, the cast was replaced by a range of motion AO-27 walker brace (Ober, Shenzhen City, China), and patients were permitted to walk with the help of crutches to avoid bearing weight on the repaired limb. Patients were kept non-weight bearing for weeks 3 and 4 post-surgery, and the walker brace was maintained for 6 weeks post-surgery. At the beginning of week 5 post-surgery, passive motion of the ankle was performed, then the walker brace was full locked in the neutral position, and partial weight bearing was allowed. The brace was unlocked and active motion of the ankle was performed at week 7. Partial weight bearing was increased daily until the walker brace was removed and full load was progressively applied at week 8 post-surgery.

Clinical evaluation and follow-up

Clinical evaluation was performed at 15, 30, 45, and 90 days, and at 6 months and 1 year post surgery. Dissatisfied patients were followed-up for 2 years. Complications including superficial infection, deep infection, persisting pain and re-rupture were recorded. Each patient in the cohort was evaluated by: (1) the AOFAS Ankle-Hindfoot scale[17] with a maximum score of 100 points (90–100 points = excellent, 75–89 points = good, 50–74 points = fair, and <50 points = poor); (2) ankle joint range of motion; (3) ipsilateral calf circumference compared with the contralateral limb; and (4) the Achilles tendon suture keloid width, measured using MRI (MAGNETOM Aera XQ 1.5T; Seimens, Erlangen, Germany).

In addition, pain was evaluated using a visual analogue scale, scored from 0 (no pain)–10 (severe pain). Scores <3 were regarded as indicative of good pain relief. Patients with AOFAS Ankle-Hindfoot scale scores ≥75, who returned to normal work, and who's daily activities were not disrupted, were classified as satisfied with treatment.

Statistical analyses

Data are presented as *n* (%) patient incidence, median (range) or mean ± SD and results were assessed using paired *t*-test and Student's *t*-test. All statistical analyses were performed using SPSS software, version 17.0 (SPSS Inc., Chicago, IL, USA). A P value < 0.05 was considered to be statistically significant.

Results

A total of 24 consecutive patients with unilateral complete Achilles tendon rupture

with no defects were included (18 male and 6 female patients; mean age, 35.4 years [range, 19–56]). There were four cases of open Achilles tendon rupture, in which the wound edge was regular and the tendon rupture end was clear with no contamination. All other cases were closed injuries. Transverse rupture was observed in four cases, and horse-tail rupture was observed in 20 cases. The Achilles tendon rupture involved the left limb of 10 patients and the right limb of 14 patients. The duration from initial injury to hospital admission was ≤ 48 h in closed rupture cases and ≤ 3 h in open rupture cases. Ten patients (41.7%) were smokers (>10 cigarettes/day). Causes of initial injury were varied: 17/24 (70.8%) occurred during sports activity (badminton, football, or basketball); 2/24 (8.3%) occurred while walking up and down the stairs; 3/24 (12.5%) were cases of incised injury; and 2/24 (8.3%) occurred falling from height.

The main presenting symptoms were sudden increase in pain around the Achilles tendon, weakness, poor balance, and limited walking distance. The rupture sites were localised at 3–8 cm from the calcaneal insertion (Figure 2). The median duration from injury to surgery was 38 h (range, 4–96 h).

At 1-year follow-up, good pain relief was achieved in all patients, and no patients were recorded as having superficial infection, deep infection, persisting pain or re-rupture of the Achilles tendon. All but two patients were satisfied with their final treatment outcome. Of the two dissatisfied patients, one, a 26-year-old dancer, had persistent postoperative pain and calf atrophy. In a subsequent 2-year follow-up assessment, the patient reported being unable to return to his previous dancing level. The other dissatisfied patient was an open injury case with a large scar in the healing wound, and adhesion of the skin and tendon, that prevented participation in sporting activities that were undertaken prior to injury.

Mean AOFAS score at 1 year follow-up was 92.4 ± 5.9 (range, 73–98), classified as excellent (16/24 [66.7%]), good (6/24 [25.0%]) and fair (2/24 [8.3%]). In terms of range of motion at 1 year post surgery, the mean difference in dorsiflexion between the repaired and contralateral side was $3.5 \pm 2.3^{\circ}$, and the mean difference in plantarflexion between the repaired and contralateral side was $5.6 \pm 3.2^{\circ}$. At 1 year

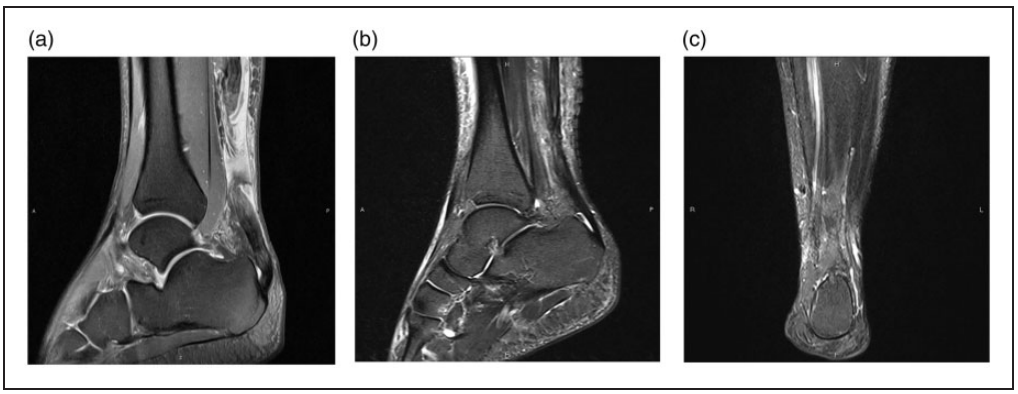

Figure 2. Representative magnetic resonance images from patients with unilateral complete Achilles tendon rupture with no defects showing: (a) Achilles tendon rupture prior to surgery; (b) Achilles tendon that had been sutured using a tendon-bundle technique; and (c) suture keloid width at 1 year post-surgery.

post surgery, the mean difference in calf circumference between the repaired side and contralateral side was 0.9 ± 0.5 cm, and the mean increase in Achilles tendon width compared with the contralateral side, measured using MRI, was 0.8 ± 0.2 cm.

The AOFAS score was significantly improved at 1 year post surgery compared with 6 months post-surgery ($P < 0.05$). The difference in plantarflexion angle between the healthy contralateral side and the repaired side was also significantly improved at 1 year post surgery versus 6 months post-surgery ($P < 0.05$). All other test items (dorsiflexion angle, Calf circumferences, suture keloid width) between the healthy contralateral side and the repaired side were not significantly changed at 1 year post surgery versus 6 months post-surgery (Table 1).

The dorsiflexion and plantarflexion angles were significantly different between the healthy contralateral side and the surgically repaired side at 6 months post-surgery ($P < 0.05$), but there was no statistically significant difference in calf circumference. By 1 year post-surgery, there were no statistically significant differences between the healthy contralateral side and the surgically repaired side in any of the function measures (Table 2).

Discussion

Rupture of the Achilles tendon is a relatively common and severe injury.[18] The management goals of Achilles tendon ruptures are to minimize the morbidity of the injury, optimize rapid return to full function, and prevent complications. Optimal treatment for acute Achilles tendon ruptures remains controversial, with multiple studies, reviews, and meta-analyses supporting both nonsurgical and surgical management.[18–23] Many different open techniques of repair have been described, from end-to-end suturing to complex repairs using augmentation with fascial reinforcement or tendon grafts. The preferred method for early diagnosed ruptures has been simple end-to-end suture with Bunnel or Kessler type sutures placed 2–4 cm from the frayed tendon ends at the rupture site. Because of the reported sural nerve injuries and wound complications, many surgeons prefer a medial incision. End-to-end suturing can be performed under local anaesthesia and the tendon can be sutured through a 6–8-cm long medial

Table 1. Functional results following tendon-bundle surgery in 24 consecutive patients with unilateral complete Achilles tendon rupture (open or closed injury) with no defects.

Measure	Preoperative	6 months Postoperative	1 year Postoperative	Statistical significance[a]
AOFAS score	62.5 ± 7.6	85.5 ± 3.8	92.4 ± 5.9	$P < 0.05$
Dorsiflexion ROM[b]		$3.9 \pm 2.4^\circ$	$3.5 \pm 2.3^\circ$	NS
Plantarflexion ROM[b]		$8.3 \pm 1.8^\circ$	$5.6 \pm 3.2^\circ$	$P < 0.05$
Calf circumference[b]		1.2 ± 0.7 cm	0.9 ± 0.5 cm	NS
Suture keloid width[b]		1.0 ± 0.3 cm	0.8 ± 0.2 cm	NS

Data presented as mean $\pm$ SD.

[a]6 months post-surgery versus 1 year post-surgery.

[b]Mean difference between the surgically repaired side and the healthy contralateral side.

AOFAS, American Orthopaedic Foot and Ankle Society Ankle-Hindfoot scale; ROM, range of motion.

NS, no statistically significant difference between 6 months and 1 year post surgery ($P > 0.05$; paired *t*-test).

Table 2. Functional results following tendon-bundle surgery in 24 consecutive patients with unilateral complete Achilles tendon rupture (open or closed injury) with no defects: differences between the surgically repaired side and contralateral side.

	6 months post-surgery			1 year post-surgery		
Measure	Healthy side	Repaired side	Statistical significance	Healthy side	Repaired side	Statistical significance
Dorsiflexion ROM	$12.7 \pm 0.6^\circ$	$8.8 \pm 1.8^\circ$	$P < 0.05$	$12.9 \pm 1.1^\circ$	$9.4 \pm 2.2^\circ$	NS
Plantarflexion ROM	$45.3 \pm 2.6^\circ$	$37.0 \pm 2.9^\circ$	$P < 0.05$	$45.8 \pm 3.3^\circ$	$40.2 \pm 3.2^\circ$	NS
Calf circumference	38.2 ± 1.1 cm	37.0 ± 2.3 cm	NS	38.0 ± 1.2cm	37.2 ± 0.8 cm	NS

Data presented as mean ± SD.
ROM, range of motion.
NS, no statistically significant difference between healthy side and surgically repaired side ($P > 0.05$; Student's *t*-test).

approach with low complication rates.[24] Augmentation is commonly reserved for late-presenting ruptures, neglected cases, or re-ruptures, and is usually the second surgical step, adding extra strength to an end-to-end suture. Distant tissue may be used to reinforce tendon repair, or local tissues, such as the plantaris tendon, the peroneus tendon, the flexor hallucis longus tendon, or the flexor digitorum longus tendon, for simple reinforcement or in a tendon transfer procedure.[11] Percutaneous repair was first described in 1977,[25] and since then many technique modifications have been described. The percutaneous procedure is easy to perform, and surgery time is short, reducing the chance of infection. Tendon blood supply can be fully retained by lesser tissue damage and a short physiological postoperative recovery period, however, percutaneous repair easily re-ruptures. Arthroscopy has been used as an adjunct to percutaneous techniques to allow direct visualization of the sural nerve and rupture site;[26,27] however, surgery times increase and there is no evidence of improved clinical results.

The most commonly used technique for open repair in the Department of Orthopaedics, Tongji Hospital has involved Krackow locking sutures to grasp each end of the torn Achilles tendon and bring them together for end-to-end repair with the foot in plantarflexion. The present study showed that tendon-bundle technique was a safe and reliable technique for open repair of Achilles tendon rupture with good results and minimal complications. This technique could align the amputation stump, distribute the amputation stump tension into the tendon-bundle and avoid the tension influence on the blood supply. Plantarflexion was significantly improved between 6 months and 1 year post surgery in the present study, and other functional measures achieved equivalent recovery levels at 6 months and 1 year post surgery. Retaining the horsetail stumps and maintaining the continuous appearance of the Achilles tendon, which maximally preserves the length of the Achilles tendon, provides a structural basis for normal post-surgery ankle activity. The postoperative length of the Achilles tendon is known to be associated with the activity of the ankle. Achilles tendon shortening may result in the foot being in a plantarflexion position, with restriction of dorsiflexion motion (authors' own experience). While the present technique showed good clinical results, it was

also associated with Achilles tendon crispation and foot plantarflexion deformity requiring reoperation, as shown in two dissatisfied patients.

At 1 year post surgery in the present study, the Achilles tendon width increased by 0.8 ± 0.2 cm compared to the contralateral side, using the tendon-bundle technique. The Achilles tendon receives its blood supply from three regions: the musculotendinous junction, along its length, and in the region of insertion.[28] Anteriorly, vessels can enter the tendon through a mesotenon. In the tendon itself, vessels in the endotenon run longitudinally between the collagen bundles. The density of vessels was reported to be lowest in the midportion of the tendon as assessed by angiographic injection techniques[29] and vessel density measurements on histologic material.[30] Poor vascularity in the main body of the Achilles tendon can result in wound ischemic necrosis, increasing the risk of infection.[31] If the amplitude of suture keloid width broadening decreases, the outer membrane and subcutaneous tissue layer incisions can be closed at a lower tension, and complications such as wound infection, ischaemia, and the risk of Achilles tendon re-rupture may be avoided.[11] Every Achilles tendon bundle in the present study was sutured in isolation so that the tendon stumps were firmly connected. Even if a tendon bundle was not physiologically healed, it would not affect the continuous integrity of the tendon. In the present cohort, no re-ruptures were observed. Excellent results have been reported, including no re-ruptures and early mobilisation, by bone-marrow aspirate-concentrate augmentation in primary Achilles tendon repair.[32] Bone-marrow aspirate-concentrate augmentation combined with tendon-bundle technique can be used to improve stump healing.[32]

Excessive debridement may cause overtightening and prompt the need for lengthening surgery. Traditional surgical methods often debride both stumps and realign the bundles, to effectively remove necrotic tissue on the tear stumps.[11] These techniques reduce the length of the Achilles tendon, however, which can lead to equinus deformity.[11] The triple-bundle technique, with reshaping of the Achilles tendon stump, has been reported to have low complication rates and good functional restoration, when assessed using isokinetic tests.[16] End-to-end tendon suture and tendon flap is indicated for the treatment of acute Achilles tendon rupture, and could be employed for the treatment of old ruptures that have a gap between the tendon ends of less than 5 cm in length.[33] Both of these techniques (triple-bundle, and end-to-end suture with tendon flap) change the physiological structure of the Achilles tendon without weakening the overall strength of the tendon, and protect the tendon suture in the short term.

Time from injury to surgery is important to the prognosis, and injury times of more than 1 week are not suitable for surgery. This is generally due to greater swelling of the soft tissue, which becomes more fragile, and the broken ends may have degenerated and need debridement, leading tendon shortening.[34] These factors are not conducive to Achilles tendon suture and oedema is not conducive to paratenon suture, thus, surgical treatment is avoided in this period. In the present cohort, the time from initial injury to surgery was no more than 96 h. No obvious degeneration or necrosis was detected during surgery in any of the patients, and the fibre bundle length was retained so that the tendon-bundle technique could be performed.

To the best of the authors' knowledge, the present study is the first to report using tendon-bundle technique to repair Achilles tendon rupture. The results may be limited by several factors, however. The present surgical technique was not compared with any other technique using biomechanical tests; the investigation lacked biomechanical

experimental support overall; the follow-up period was relatively short; and finally, the sample size was small, and so patients were not divided into Achilles tendon rupture subtypes. Further studies with larger sample groups, and longer follow-up periods are required to enable investigation of the subtypes of Achilles tendon rupture, and to validate the present therapeutic effects of the tendon-bundle technique.

In conclusion, the tendon-bundle technique showed good ankle function restoration and was associated with low complication rates. This technique may reduce destruction of the blood supply and maximally preserve the length of the Achilles tendon. Thus, the tendon-bundle technique may be considered an effective surgical option for the treatment of Achilles tendon rupture with no defects.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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