

■ FOOT AND ANKLE

Reconstruction of defects involving the Achilles tendon and local soft tissues

A QUICK SOLUTION FOR A LINGERING PROBLEM

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A total of seven patients (six men and one woman) with a defect in the Achilles tendon and overlying soft tissue underwent reconstruction using either a composite radial forearm flap (n = 3) or an anterolateral thigh flap (n = 4). The Achilles tendons were reconstructed using chimeric palmaris longus (n = 2) or tensor fascia lata (n = 2) flaps or transfer of the flexor hallucis longus tendon (n = 3). Surgical parameters such as the rate of complications and the time between the initial repair and flap surgery were analysed. Function was measured objectively by recording the circumference of the calf, the isometric strength of the plantar flexors and the range of movement of the ankle. The Achilles tendon Total Rupture Score (ATRS) questionnaire was used as a patient-reported outcome measure. Most patients had undergone several previous operations to the Achilles tendon prior to flap surgery. The mean time to flap surgery was 14.3 months (2.1 to 40.7).

At a mean follow-up of 32.3 months (12.1 to 59.6) the circumference of the calf on the operated lower limb was reduced by a mean of 1.9 cm (SD 0.74) compared with the contralateral limb (p = 0.042). The mean strength of the plantar flexors on the operated lower limb was reduced to 88.9% of that of the contralateral limb (p = 0.043). There was no significant difference in the range of movement between the two sides (p = 0.317). The mean ATRS score was 72 points (SD 20.0). One patient who had an initial successful reconstruction developed a skin defect of the composite flap 12 months after free flap surgery and this resulted in recurrent infections, culminating in transtibial amputation 44 months after reconstruction.

These otherwise indicate that reconstruction of the Achilles tendon combined with flap cover results in a successful and functional reconstruction.

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Acute rupture of the Achilles tendon is a common injury. It can be treated conservatively or surgically using various techniques, including open or minimally invasive repair.^{1–4} Complications of surgical treatment include severe wound infections in up to 2.2% of cases,¹ requiring further surgical treatment or salvage.

Infection may cause major soft-tissue defects that can be debilitating, resulting in lingering problems for the patient. Typical strategies of treatment include vacuum-assisted closure (VAC), debridement and subsequent skin grafts. Necrosis of the Achilles tendon can add significantly to the problem, requiring debridement of the tendon itself. The result is a complex defect involving the overlying soft-tissue and the substance of the Achilles tendon which needs surgical repair in young and active people. In order to address this problem, composite flaps including a vascularised tendon graft in chimeric flaps, or with transfer of the flexor hallucis longus, can be used.

A chimeric flap consists of several otherwise independent flaps, each with an independent vascular supply but with all pedicles linked to a larger common source vessel.⁵ This type of flap can be designed and used for extensive, complex and three-dimensional defects, where many types of tissue are missing, in a one-stage reconstruction.⁶ An example of this includes reconstruction of a tendinous defect with tensor fascia lata and skin, using an island of skin made from an anterolateral thigh flap, all receiving their vascular supply from a single artery, the descending branch of the lateral femoral circumflex artery.

The purpose of this study was to assess the long-term functional results after reconstruction of both tendon and soft-tissue defects by free flap surgery in patients with wound breakdown after primary repair of the Achilles tendon.

Patients and Methods

Between April 2008 and April 2010, seven patients, (six men and one woman) with a

Table I. The demographics of the seven patients

	n
Gender (m:f)	6:1
Age (yrs), mean (SD)	43.0 (14.3)
Body mass index, mean (SD)	27.8 (5.2)
Tobacco	3/7
Hypertension	1/7
Diabetes mellitus	0/7
Time to flap surgery (mths):median (IQR)	4.6 (2.4 – 30.9)
Follow-up (mths): median (IQR)	36.9 (15.6 – 43.9)

combined defect of the Achilles tendon and overlying soft tissue underwent surgery using a free flap, in three institutions in The Netherlands. The mean age of the patients was 43 years (24 to 68) and their mean BMI was 27.8 kg/m² (SD 5.2). None of the patients was diabetic, but three were smokers and one was hypertensive. All had undergone surgical treatment for a rupture of the Achilles tendon, which had failed, prior to referral (Table I). The mean interval between the primary surgery and the reconstruction was 14.3 months (2.1 to 40.7).

All patients were treated with a one-stage operation which included radical debridement (Fig. 1a,b) followed by reconstruction of the Achilles tendon and soft-tissue using either a radial forearm free flap (FRFF) or an anterolateral thigh (ALT) free flap (Fig. 1c). The Achilles tendon was reconstructed using either tendon graft within the flap (palmaris longus in FRFF or tensor fascia lata in ALT) or by transfer of the flexor hallucis longus tendon to the Achilles tendon.^{7,8} Post-operatively, the ankle was immobilised with a lower limb splint or an external fixator for six weeks (Fig. 1d). The details of the treatment are shown in Table II.

We analysed the total time between the initial repair of the Achilles tendon and the reconstructive surgery, the nature of the surgery, the size of the defect after debridement prior to flap surgery, and the complications after flap surgery.

In addition to assessing the surgical outcome, functional studies were conducted after a minimum follow-up of one year. All measurements were performed bilaterally by one assessor (JS), to enable comparison between the reconstructed side and the uninjured limb.

As an assessment of the development of the gastrocnemius, the maximum circumference of the calf was measured, with the patient positioned prone and with no contraction of the plantar flexors of the foot as the measurements were made.

The isometric strength of the plantar flexors was assessed with a handheld dynamometer (MicroFET2, Hoggan Health Industries, West Jordan, Utah) using the make-test as described by Wang et al.⁹ This was performed supine with the lower limb stabilised proximal to the ankle on both sides to enable a comparison to be made. Three measurements of four seconds' effort were performed with the ankle in the neutral position while a maximum contraction was made to plantar flex against the dynamometer, which was positioned at the midpoint of the first metatarsal. The

result was presented as a mean strength of the operated lower limb/mean strength of the non-operated lower limb × 100%. The mean of three contractions was used for analysis, as mean values have been shown to be more reliable than maximum values.¹⁰ In addition, patients were asked to stand on tiptoe.

The sliding condition and shortening of the Achilles tendon was evaluated by measuring the range of movement using the neutral zero method.¹¹ This measures the angle between the longitudinal axis of the fibula and the fifth metatarsal during active dorsi- and plantar flexion of the ankle. The zero degree starting position for measuring joint movement of the ankle is a neutral position, which is the anatomical position (90° between the longitudinal axis of the fibula and the fifth metatarsal).

Patients were asked about persistent symptoms and satisfaction with the cosmetic appearance. They also completed the Achilles tendon Total Rupture Score (ATRS) questionnaire.¹² This is a validated, injury-specific and self-reported instrument for measuring outcome after the treatment of a complete rupture of the Achilles tendon.^{13,14} It consists of ten items that evaluate symptoms and function. The maximum score is 100 points, representing full function. A lower score indicates more symptoms and greater limitation of activity.

Statistical analysis. All data were analysed using SPSS version 20.0 (IBM, Armonk, New York). Descriptive data are reported as mean and range or standard deviation (SD), or mean and interquartile range (IQR), as appropriate. Mean and standard error (SE) of the mean are shown in bar charts. The Wilcoxon signed ranks test was performed to evaluate differences between the operated and the contralateral side. The level of significance was set at $p < 0.05$.

Results

The mean follow-up was 32.3 months (12.1 to 59.6). A total of six patients had several operations on the ruptured tendon prior to flap surgery, mostly debridement, split skin grafting or transposition flaps performed by the referring departments. Patient 6 was directly referred with necrosis of the tendon after surgical repair. A detailed overview of the outcomes is shown in Table II.

In all, five patients had minor complications requiring four additional procedures. Two had further treatment for a haematoma and in one patient a residual defect was



Fig. 1a

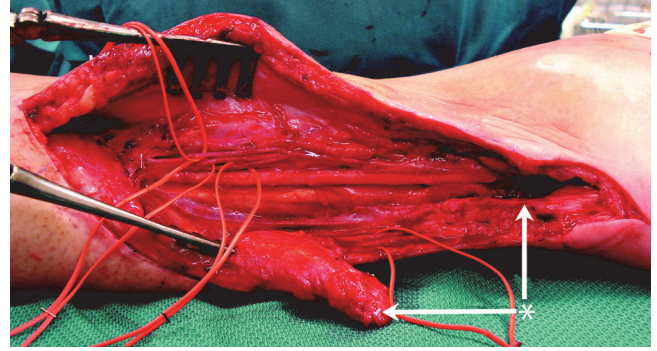


Fig. 1b

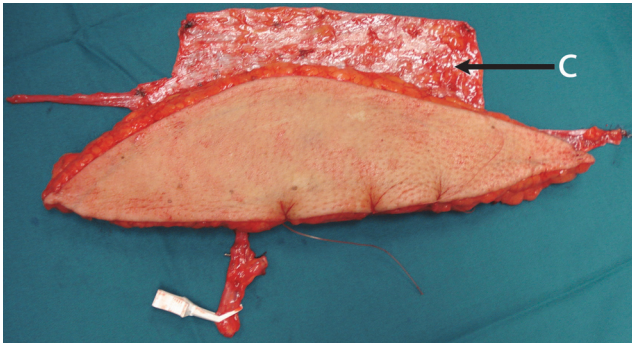


Fig. 1c

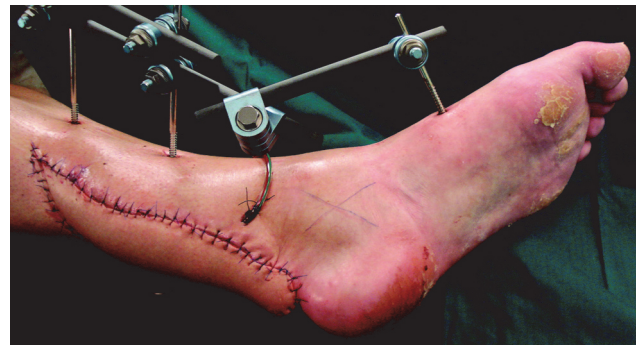


Fig. 1d



Fig. 1e

Photographs of a one-stage operation (patient 4) showing a) combined Achilles tendon and overlying soft-tissue defect of left lower leg, b) after radical debridement of necrotic and infected tissues (* proximal and distal ends of the Achilles tendon), c) free anterolateral thigh flap with vascularised tensor fascia lata graft, d) post-operative result with the external fixator in place and e) aesthetic result 5 years after reconstruction showing tiptoe position.

covered by split skin grafting. One patient needed correction of the flap one year after surgery because of problems with footwear due to the thickness of the flap. Another developed complex regional pain syndrome (CRPS) type I of the foot. This was successfully treated with vitamin C and dimethylsulfoxide cream. One patient developed a skin defect 12 months after free flap surgery, which led to recurrent infection and eventually a transtibial amputation was undertaken 44 months after flap surgery.

Two patients, one with a transtibial amputation and one with successful surgical treatment of a rupture of the contralateral Achilles tendon, were excluded from the meas-

urements of the circumference of the calf and testing strength of the plantar flexors.

In the remaining five patients, the mean side-to-side difference in circumference of the calf showed a mean reduction of 1.9 cm (SD 0.74) in the operated limb ($p = 0.042$, Wilcoxon signed ranks test). This limb could achieve a mean of 88.9% (83.0% to 93.3%) of the power attained by the contralateral limb ($p = 0.043$, Wilcoxon signed ranks test). All patients were able to stand on tiptoe.

Another patient had sustained a previous inversion injury of the contralateral ankle. This patient and the patient with transtibial amputation were excluded from

Table II. Detailed overview of clinical data of the patients

Patient	Gender	Age (yrs)	Defect (cm x cm)	Prior surgery	Time to flap surgery (mths)	Follow-up (mths)	Type of flap	Tendon graft	Additional surgery	Institution
1	M	48	10 x 12	Open surgical repair/debridement (2 x)	2.6	37.0	Radial forearm	PL + TFL	N/a	MST
2	M	44	4.5 x 15	Open surgical repair/debridements (multiple)/transposition flap/ split skin graft (2 x)	16.9	20.9	Radial forearm	PL	N/a	MST
3	M	24	10 x 15	Open surgical repair (2 x)/transposition flap/ split skin graft (2 x)/ debridement	31.0	15.6	Anterolateral thigh	TFL	Split skin graft (2 x)	MST
4	F	41	4.5 x 14	(Open) surgical repair/transposition flap/ necrosectomy	2.4	59.6	Anterolateral thigh	TFL	Debulking correction	UMCG
5	M	47	5 x 10	(Open) surgical repair/debridement	2.1	36.9	Anterolateral thigh	FHL	N/A	Erasmus MC
6	M	68	6 x 18	Open surgical repair	4.6	12.1	Anterolateral thigh	FHL	N/A	Erasmus MC
7	M	29	11 x 11	Open surgical repair/debridement/transposition flap	40.7	43.9	Radial forearm	FHL	Transtibial amputation	Erasmus MC

N/A, not applicable; Erasmus MC, Erasmus Medical Center, Rotterdam; MST, Medical Spectrum Twente, Enschede; UMCG, University Medical Center Groningen; FHL, flexor hallucis longus; PL, Palmaris longus; TFL, tensor fascia lata

measurements of the range of movement, limiting this assessment to five patients. The mean difference in the range of plantar to dorsiflexion between the two limbs was 2° less on the operated side, which was not significant ($p = 0.317$) (Fig. 2, Wilcoxon signed ranks test). In addition, we compared the effect of chimeric flap reconstruction ($n = 3$) versus flexor hallucis longus reconstruction ($n = 2$). This showed a mean 3° (-5 to 5) disadvantage for chimeric graft reconstruction.

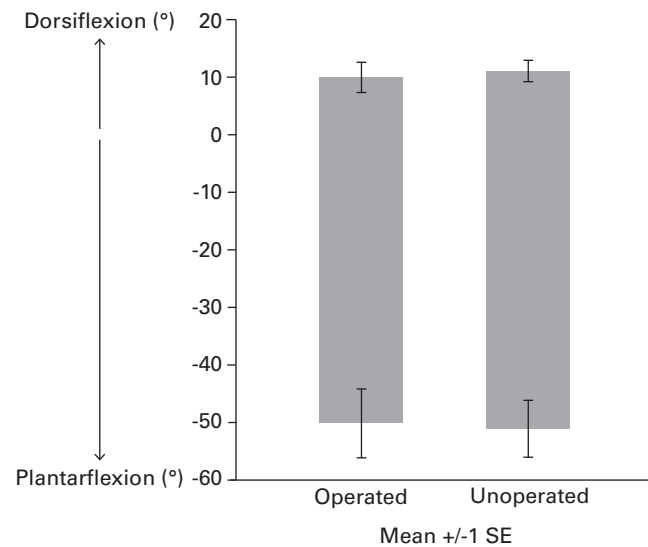
All six patients mentioned fear of re-rupture of the Achilles tendon. One mentioned disability attributed to pain in the operated lower limb, when walking long distances or walking stairs. The remaining five patients had no impairment during walking. No patient reported stiffness in the operated lower limb. All were satisfied with the cosmetic results. The mean ATRS score was 72 points (SD 20).

Discussion

Initially, all patients had successful reconstruction of the Achilles tendon and stable cover by a composite flap and vascularised graft or tendon transfer. One patient had an unfortunate late complication eventually undergoing transtibial amputation. This patient did not smoke and had no comorbidities, but was morbidly obese with a BMI of 36.6 kg/m².

Long-term objective functional outcomes after surgical repair of acute and chronic Achilles tendon ruptures have been reported,¹⁵⁻²⁰ but there have been no reports of the functional outcome after reconstruction of the tendon and soft-tissue defects using composite flaps.

The circumference of the calf on the operated side in comparison with the non-operated side is an objective measure of atrophy of the calf muscles.¹⁵ In our study, there was a mean difference of -1.9 cm (SD 0.74) at a mean of 32.3 months after flap surgery. Willits et al¹⁶ reported a

**Fig. 2**

Bar chart showing the mean range of movement of the ankle comparing the operated and unoperated limb ($n = 5$). (Error bars show 1SD.)

mean reduction of 1.3 cm (SD 1.4) in the circumference of the calf on the operated side one year, and 1.7 cm (SD 2.0) two years after surgical treatment of an acute rupture of the Achilles tendon ($n = 72$). Horstmann et al¹⁵ reported a mean reduction in the circumference of the calf on the operated side of 1.1 cm at a mean of 10.8 years (SD 3.4) after repair of an acute rupture of the Achilles tendon ($n = 63$). Although the difference between these results and ours is small, it could be explained by longer periods of immobility due to the many surgical procedures and prolonged wound problems prior to flap surgery in our patients.

The mean strength of the plantar flexors of the operated lower limb was 88.9% of that of the non-operated lower

limb in our patients. This is slightly superior to the results in studies by Maffulli et al¹⁸⁻²⁰ on the treatment of chronic ruptures of the Achilles tendon with avascular tendon grafts using gracilis tendon (n = 15) or semitendinosus tendon grafts (n = 28),^{18,20} or with transfer of peroneus brevis (n = 32).¹⁹ Guillo et al¹⁷ reported a mean isometric strength of 96% in the gastrosoleus complex of the operated limb compared with the contralateral side after percutaneous repair of acute ruptures at a mean follow-up of 25.7 months. As the technique for measuring isometric strength in these studies was different from ours, a true comparison cannot be made. Although the reduction in the isometric strength of plantar flexion in our patients was relatively small, no patient reported a subjective loss of strength and all were able to stand on tiptoe.

There was a mean decrease of 2° in range of movement of the ankle in the operated side. This is in line with Willits et al,¹⁶ who found a greater range of movement on the unaffected side at each follow-up visit up to 24 months after surgery, although they did not report the exact differences. Horstmann et al¹⁵ showed a greater reduction of 1.9° in mean maximum dorsiflexion and 3.5° in mean maximum plantar flexion compared with the contralateral limb at a mean of 10.8 years (SD 3.4) after surgical repair (n = 63). The dorsi- and plantar flexions were analysed separately instead of as a combined range of movement. In a study by Guillo et al¹⁷ involving 23 patients, the mean dorsiflexion was 17.4° on the operated side and 19.1° on the contralateral side at a mean of 25.7 months after percutaneous repair of acute ruptures; this difference was not significant (p = 0.07). There was also no significant difference in the range of movement between the two sides (p = 0.317) in our patients.

We used a validated patient-reported outcome measure (PROM) to collect subjective data on function, and our six patients achieved a mean ATRS score of 72 points. In comparison, using a percutaneous repair following acute rupture of the Achilles tendon, Guillo et al¹⁷ reported a mean ATRS score of 84.3 points at a mean of 25.7 months post-operatively. Maffulli et al²⁰ recorded a mean ATRS score of 90.1 in 15 patients after treatment for a chronic rupture of the Achilles tendon at a mean follow-up of 10.9 years. These patients had been misdiagnosed with ankle sprain and had been treated with a free autologous tendon graft approximately five months later. Another study by Maffulli et al¹⁸ reported a mean ATRS score of 86 points in 28 patients with a chronic rupture of the Achilles tendon who were treated with an ipsilateral free semitendinosus tendon graft with screw fixation at a mean follow-up of 31.4 months. Furthermore, Maffulli et al¹⁹ reported a mean ATRS score of 92.5 points in 32 patients receiving a peroneus brevis tendon transfer for a chronic rupture at final review 48.4 months from the operation. The measurements in these studies were performed in patients who had not undergone previous surgical procedures and were not compromised by soft-tissue defects, making comparison with

our patients difficult. However, we have concluded that a score of 72 represents a patient who can actively participate in daily activities and sports, and which may be considered an acceptable result considering the severity of the injury.

Limitations of our study are the heterogeneity of the patients, the small size of the cohort, and the fact that three centres were involved. Although this is the first study to record the objective functional outcome after reconstruction of defects in the Achilles tendon and soft-tissues using composite flaps, it is underpowered to provide definitive conclusions. Also, the follow-up for functional testing ranged from 12.1 to 59.6 months after flap surgery. Although this could alter some results, it has been reported that only minor improvements occur after the first post-operative year.²¹

We wish to highlight the delay between the initial rupture of the Achilles tendon and treatment using a combined free flap and vascularised reconstruction. Before they were referred for reconstruction, six of the seven patients had undergone several unsuccessful procedures. In these patients, free flap surgery instead of extensive regional surgery gave a faster and more satisfying result. Even well-trained plastic surgeons may not have expertise in these complex flaps, and therefore treatment should be undertaken in centres with special expertise in microsurgery and trauma.

In conclusion, patients with severe local complications after repair of the Achilles tendon can be treated effectively using chimeric flaps with tendon grafts or flaps combined with a tendon transfer. We recommend early referral to specialists with interest and experience in the treatment of these complex defects.

Author contributions

J. Soons: Study design, Data collection, Data analysis.
H. A. Rakhorst: Study design.
M. Ruettermann: Provided surgical data for patient 4.
A. J. M. Luijsterburg: Provided surgical data for patients 5 to 7.
P. K. Bos: Provided surgical data for patients 5 to 7.
O.T. Zöphel: Study design, Provided surgical data for patients 1 to 3.

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