Surgical Treatment of the Neglected Achilles Tendon Rupture with Hyalonect

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Background: The purpose of this study was to report the management and outcomes of ten patients with chronic Achilles tendon rupture treated with a turndown gastrocnemius-soleus fascial flap wrapped with a surgical mesh (Hyalonect).

Methods: Ten men with neglected Achilles tendon rupture were treated with a centrally based turndown gastrocnemius fascial flap wrapped with Hyalonect. Hyalonect is a knitted mesh composed of HYAFF, a benzyl ester of hyaluronic acid. The Achilles tendon ruptures were diagnosed more than 1 month after injury. The mean patient age was 41 years. All of the patients had weakness of active plantarflexion. The mean preoperative American Orthopaedic Foot and Ankle Society score was 64.8.

Results: The functional outcome was excellent. The mean American Orthopaedic Foot and Ankle Society score was 97.8 at the latest follow-up. There were significant differences between the preoperative and postoperative scores. Ankle range of motion was similar in both ankles. Neither rerupture nor major complication, particularly of wound healing, was observed.

Conclusions: For patients with chronic Achilles tendon rupture with a rupture gap of at least 5 cm, surgical repair using a single turndown fascial flap covered with Hyalonect achieved excellent outcomes. (J Am Podiatr Med Assoc 104(5): 434-443, 2014)

The Achilles tendon is the most frequently injured tendon in the body and may account for up to 40% of all tendon ruptures that undergo surgery.1-4 The increase in frequency is thought to be due to increased interest and participation in recreational sports by middle-aged and older patients.3 The diagnosis of the Achilles tendon rupture can initially be missed in up to 25% of patients because of the lack of pain and no obvious loss of plantarflexion.1-8

The management of chronic Achilles tendon ruptures is different from that of acute ruptures as the tendon ends are retracted and atrophied, with short fibrous distal stumps. The expected outcome after chronic Achilles tendon rupture treatment depends on the extent of the gap between the tendon ends and the potential for muscle recovery.3,5

The best functional outcomes are achieved through surgical reconstruction.8 Conservative treatment may be preferable for patients with poor skin condition, a history of smoking, soft-tissue complications from previous surgery, and poorly controlled long-standing diabetes mellitus.8

Many surgical techniques have been described for the management of neglected Achilles tendon ruptures. The goals of treatment are to restore
tendon length and tension, to optimize ultimate strength and function, to reduce time needed for rehabilitation, and to facilitate an early return to work and to the preinjury level of activity.\(^1,8\) End-to-end repair is ideal if the gap between tendon ends allows direct apposition after resection of the interposed scar tissue.\(^8\) However, primary repair is still an uncommon form of treatment for most chronic ruptures because of the shortening and contracture of the gastrocnemius-soleus muscle-tendon unit.\(^8,9\) Excision of scar tissue from neglected rupture often results in a sizable gap requiring other modalities to bridge the defect.\(^8\) The techniques described in the literature are proximal lengthening of the gastrocnemius-soleus complex to achieve mobilization of the proximal tendon end to facilitate primary repair,\(^10\), the gastrocnemius slide lengthening technique to achieve end-to-end anastomosis,\(^10,11\) gastrocnemius-soleus fascia turndown techniques (two flaps, one flap, etc),\(^6,9\) free fascia tendon graft,\(^4,5\) local tendon transfers,\(^4,12,13\) flexor hallucis longus tendon transfer,\(^14-19\) peroneus brevis tendon transfer,\(^20,21\) flexor digitorum longus tendon transfer,\(^22\) and combined techniques.\(^23\) Others examine the use of artificial tendons, such as carbon fiber,\(^24,25\) collagen tendon prostheses,\(^26\) and Dacron vascular grafts.\(^27\)

The purpose of this series was to report the management of ten patients with chronic Achilles tendon rupture treated with a single turndown flap of proximal Achilles tendon tissue wrapped with Hyalonect (Fidia Advanced Biopolymers, S.r.I., Italy). Hopefully, this treatment can improve the healing and strength of repair, protect soft-tissue adhesion, and help rehabilitation. As a result of these, ankle range of motion and the plantarflexion strength of the Achilles tendon were increased, and the American Orthopaedic Foot and Ankle Surgery (AOFAS) score was improved.

**Materials and Methods**

**Patients**

Approval was obtained from Okmeydani Research and Training Hospital, Ethics Committee for Clinical Trials. We reviewed a series of ten patients (all men) treated with a single turndown flap of proximal Achilles tendon tissue covered with Hyalonect by a single surgeon (C.Z.E.) from September 14, 2007 to June 6, 2010. All of the patients had a chronic Achilles tendon rupture where all Achilles tears were diagnosed or treated more than 1 month after the index lesion. The mean time to surgery was 1.9 months (range, 1–3 months). The mean age of patients at surgery was 41 years (range, 38–45 years). For rating, AOFAS scores, including four rating systems, were used (Table 1). The systems incorporate subjective and objective factors into numerical scales to describe function, alignment, and pain.\(^28\) The mean preoperative AOFAS score was 64.8 of a total score of 100 (range, 50–72).

All of the injuries occurred during a sports activity (seven patients were playing football and three were jogging). Five left and five right tendons were involved, and there was no bilateral involvement. All of the patients had dominant-side tendon ruptures. No patients had any symptoms in the Achilles tendon before injury. There was no systemic disease, infection, or neurovascular problems in these patients.

To test the strength of the plantarflexors, the patients were asked to point the feet toward the ground, and resistance in the direction of dorsiflexion was applied. The normal and operated sites were compared by the examiner. All of the patients experienced major weakness of active plantarflexion. On clinical examination, plantarflexion power was reduced in all of the patients compared with the contralateral limb. Before the operation, all of the patients were unable to perform plantarflexion when resistance was applied. Also, the gastrocnemius and soleus functional strength test described by Lunsford and Perry\(^29\) was applied. In this test, the patients were asked to stand on one leg with the knee extended. They used only one or two fingers on a table for balance. They were asked to raise the heel from the floor through full range of plantarflexion. Patients were asked to go up onto their toes and then down 25 times. Grading was as follows: 25 standing heel-raise repetitions was accepted as “normal,” 10 to 24 as “good,” 1 to 9 as “fair,” and 1 as “poor.” Patients were unable to stand on tiptoe (the heel-raise test was poor in all of the patients) and limped.

Magnetic resonance imaging was performed on all of the patients before surgery and again at last follow-up. Magnetic resonance imaging of the patients’ ankles showed the defect in the Achilles tendon preoperatively. There was retraction of tendon ends. The mean defect size was 4.1 cm (range, 3–5 cm). The site of rupture was 30 to 50 mm proximal to the Achilles tendon insertion. There was an area of low-intensity signal on T1-weighted images and alteration in T2-weighted signal.
Surgical Procedure

All of the patients underwent the same surgical procedure by a single surgeon (C.Z.E.). Surgery was performed with the patient under general or epidural anesthesia and in the prone position. A tourniquet was applied to the thigh. After antiseptic preparation, the limb was draped in a sterile field. A posteromedial skin incision was made, curving to the middle line in the more proximal part of the calf. After sural nerve location, the paratenon was exposed from the calcaneal insertion to the musculotendinous junction. Tenolysis was performed, and the Achilles tendon was inspected and palpated for any abnormality. The tendon stumps were trimmed, and the fibrous tissue was resected. The distal and proximal ends of the tendon were examined (Fig. 1).

Then, the tendon ends were repaired using the modified Kessler 2-strand core suture technique with a No. 2-0 Ethibond thread (Ethicon Inc, Somerville, New Jersey), which provides suitable tension with the ankle at the maximum plantarflexed position. It was not necessary to join the surfaces of the tendon stumps (Fig. 2). After this, the defect between the tendon ends was evaluated again. The average Achilles tendon defect after this primary suture was 3 cm (range, 2–4 cm). A 10-mm-wide central gastrocnemius aponeurosis flap was cut and freed (Fig. 3 A and B). This flap was twisted backward through 180° so that the smooth surface lay against the skin (Fig. 3C). The origin of the flap was 3 to 4 cm above the tendon suture, and the tissue that had been rotated and drawn downward

Figure 1. The ruptured ends of the tendon are identified. After the degenerated tendon is removed, the defect between the tendon ends is seen. The size of the defect is approximately 6 cm.
adequately covered the suture line in the tendon and was fixed in the distal stump with a few interrupted sutures (Fig. 3C). Absorbable sutures (Vicryl; Fidia Farmaceutici SpA, Abano Terme, Italy) were applied on both sides of the Hyalonect to obtain easier application. Hyalonect was applied in this order around the tendon flap. If we used more than one Hyalonect, we tried not to overlap them. After repair of the gap, the tendon flap was surrounded with a Hyalonect (Fig. 3D), and the incision in the fascia of the gastrocnemius was closed. Finally, the crural fascia, the external peritenon, the subcutaneous tissue, and the skin were sutured.

After the operation, patients were placed in a nonweightbearing below-the-knee cast in plantarflexion for 3 weeks and in a neutral position for 3 weeks. Six weeks postoperatively, a rehabilitation program for weightbearing, strengthening, and range of motion was begun. Athletic activities were restricted for 6 months after surgery.

Outcome Assessment at the Latest Follow-up

Postoperative complications were recorded. At the last follow-up visit, all of the patients were examined to assess gait, the surgical wound, pain, ankle range of motion, tiptoe stance, calf atrophy, and ankle plantarflexion strength (Fig. 4 A-C). Active and passive ranges of motion were assessed at the ankle joints. Each motion was evaluated with the patient supine on the examination table. The patient was asked to first move the ankle to the desired position, and the joint motions were measured with a goniometer. The mean dorsiflexion of the ankle was 13° and the mean active plantarflexion was 15° preoperatively. Tiptoe stance was evaluated with the test described by Lunsford and Perry. For calf atrophy, girth measurement of the calf was performed with the patients in the prone position, with their knees extended, and the lower-extremity musculature relaxed. Before formally measuring calf girth, it was necessary to determine the region of the calf that was greatest in circumference on the noninvolved extremity because this point would serve as the landmark for each of the calf measurements. After identification of the largest calf region in girth on the noninvolved extremity, a mark was drawn at this point on the skin of the lateral aspect of the calf. The distance between this point and the fibular head was measured. Then, the same distance from the fibular head was measured and marked on the involved extremity. All of the measurements were taken with a nonelastic tape measure. A single investigator (A.C.T.) took all of the measurements. The AOFAS score before the operation and follow-up scores were compared by means of the Student t test. Differences between the two groups were considered statistically significant at \( P < 0.05 \).

Results

Mean follow-up was 43.2 months (range, 24–60 months). There were no major complications and no wound-healing problems in any patients. The mean time to work was 4 months (range, 2–5 months, depending on the type of work). All of the patients returned to their sports activities at the preinjury level. No rerupture was seen in any patient during follow-up.

The mean ± SD AOFAS scale score was 64.8 ± 8.1 (range, 50–72) before the operation and 97.8 ± 4.1 (range, 90–100) at the most recent follow-up visit (\( P < 0.0001 \)). There was no pain in any of the patients. Ankle range of motion was similar to that in the noninvolved ankle. The mean dorsiflexion of the ankles was 13° (range, 12°–18°) on both sites (\( P > 0.05 \)). The mean plantarflexion of the ankles was 44.7° (range, 40°–50°) at the injured ankles and 45° (range, 41°–50°) at the noninjured ankles (\( P > 0.05 \)). The gastrocnemius and soleus functional strength test was also applied. All of the patients in this study completed heel raises more than 25 times, and the results were noted to be normal for all of the patients. There was no limping during gait.

The mean calf girth measurement was 38.5 cm on the involved side and 38.8 cm on the normal side (\( P > 0.05 \)). There was no significant calf atrophy in any
patients. Tiptoe stance was possible for all of the patients without limitation. Magnetic resonance imaging findings at the final follow-up visit showed an increase in the diameter of the heel cord at the disturbed site (Fig. 4D).

Discussion

Neglected or chronic rupture, late or old repair, and delayed reconstruction were used to describe this condition and treatment.\textsuperscript{10,31,32} Although there is no consensus regarding the specific time in which an acute rupture becomes a neglected rupture, 4 weeks may be the most widely accepted interval.\textsuperscript{14,32} Contraction of the triceps surae complex has been observed 3 or 4 days after injury.\textsuperscript{9} Regardless of the lack of a chronological definition, neglected ruptures are characterized by the difficulty of achieving an end-to-end apposition with plantarflexion of the foot during surgical reconstruction.\textsuperscript{8}

Functional ankle plantarflexion is critical for efficient gait. In patients with neglected Achilles tendon rupture, the triceps surae was shortened, and the distance between the proximal and distal stumps had lengthened with fibrous tissue. Therefore, the muscle strength of the plantarflexion of the ankle was weakened. In this study, Achilles tendons were contracted preoperatively, and, therefore, abundant scar tissue formed between the tendon ends in all of the patients. None of the patients could stand on tiptoe because of reduced plantarflexion. For this reason, reconstruction of the
Achilles tendon to a functional length is important in the treatment of neglected Achilles tendon ruptures. Many surgical techniques have been reported for repair of the neglected Achilles tendon rupture.\textsuperscript{4-6,8,10-16,20-27} Depending on the procedure, choices are available for augmentation of tendons or ligaments.\textsuperscript{19} Autograft has the major advantage of being fresh and histologically compatible.\textsuperscript{19} Synthetic materials, which have been widely available since the late 1980s, are typically made of polymers.\textsuperscript{19} These materials have shown complications ranging from a severe foreign-body reaction to complete implant failure.\textsuperscript{19}


Using gastrocnemius fascial flaps according to the method described by Lindholm,\textsuperscript{33} two gastrocnemius fascial flaps are used to repair neglected Achilles tendon ruptures. This has the advantage of providing a firm connection between the distal and proximal stumps without damaging healthy tissues.\textsuperscript{34} The problem is the bulky distal part, which makes skin closure difficult. A centrally based turndown flap can be developed from the proximal segment, which is then turned $180^\circ$ on itself and approximated to the distal stump. In this technique, the proximal flap is passed deep to the proximal portion to decrease the bulk. Although this method
is useful in bridging the gap in continuity, strength deficits of up to 23% have been reported.34 We used a single flap to decrease the bulk. However, we did not pass the proximal flap deep to the tendon. In this study, the repaired site was not bulky, and wound closure was not a problem in any of the patients. To reinforce the repair and to promote the biological regeneration of tendon tissue, Hyalonect was wrapped around the flap.

Extracellular matrix biomaterials have been used in tendon repair for more than a decade with clinical success.15,35 These materials are used to augment primary repair of tendons, to reinforce weakness, and to promote healing in a tissue that represents a significant clinical challenge.15 Tendons have a limited vascular supply, and large tears, similar to those common in the rotator cuff, do not heal spontaneously, necessitating surgical intervention with high recurrence rates.15 These materials are also commonly used as a wrap during Achilles tendon repair, tendon-lengthening procedures, and other foot and ankle tendon reattachment procedures.15–17 SurgiMend (TEI Biosciences, Waltham, MA) was used in the repair of an injured posterior tibiotalar ligament.18 This material has been used to promote biological regeneration of tendon tissue around a supporting suture in what would otherwise be a large tissue gap.18

Additional bioscaffolds are augmentation indications that are poorly described in the literature. The lack of definitive indications is mainly because of novelty of technology and paucity of clinical research.19 When there is inadequate tendon and ligament length, strength, or girth, tissue augmentation with bioscaffold is an option that can be considered. A thorough preoperative examination, which may include magnetic resonance imaging or tenograms, can provide a greater degree of detail for planning purposes. However, inadequate tendon or ligament length or girth may become evident only intraoperatively. In some cases, the native tissue itself appears weak and atrophied, with poor ability to retain sutures. This is common in patients with a traumatic or chronic disease state.19

A variety of bioscaffold options are available, with several products taking advantage of the similarities between wound and tendon healing. Bioscaffolds serve two primary functions in tendon and ligament augmentation.19 The first is their enhancement of healing in the pathologic setting. This occurs by stimulating angiogenesis and promoting host cellular migration and proliferation.19

The ideal scaffold for ligament and tendon tissue should be biodegradable, biocompatible, and porous; have sufficient mechanical strength; and promote the formation of new tissue.36 Hyalonect (Fidia Farmaceutici SpA) is a knitted mesh composed of HYAFF (Anika Therapeutics S.R.L; former Fidea Farmaceutici SpA), a benzyl ester of hyaluronic acid, a naturally occurring constituent of the extracellular matrix. Hyalonect is a resorbable, suturable, and biocompatible mesh.37 It may be fixed to the surgical site.37

Bioactivity is the main strategy in the modern development of biomaterials, which addresses the appropriate response to external stimuli.36 The degradation products of Hyalonect are oligosaccharides, which are implicated in several biological processes, including angiogenesis, cell differentiation and morphogenesis, cell migration and aggregation, and the maturation of mesenchymal progenitor cells.38–41 HYAFF 11, which is modified hyaluronan, has been widely used in clinical products and experimental studies in a variety of forms, and its biodegradation and efficiency have been studied in vitro and in vivo when used as scaffolds.42–56

Hyaluronan (hyaluronic acid) is a high-molecular-weight glycosaminoglycan that has a ubiquitous distribution in the extracellular matrix, with high concentrations in soft connective tissue.57 Hyaluronan has several physiologic and biologic functions and a variety of embryologic and wound-healing properties, such as space filling, lubrication, and the facilitation of cell migration and differentiation during tissue formation and repair.58–63 It is synthesized in the cellular plasma.57,64 Although free hyaluronic acid concentrations are relatively low, hyaluronic acid levels are dramatically elevated after tissue injury.65 It delays or reduces the development of granulation tissue.66 Hyaluronan has a pivotal role in the regulation of angiogenesis.48,67–69 Neoangiogenesis is the critical point in providing adequate nutrient transportation and toxic metabolite removal.36,69 In addition, hyaluronan is likely to increase cell migration, proliferation, and differentiation at the surgical site and to enhance the organization of the extracellular matrix.37,70 When in close contact with bone tissue, it has been shown that it participates in bone morphogenesis68 and the early events of osteogenesis,71 modulating the effects of a variety of cytokines and growth factors,72,73

At the same time, the bacteriostatic activity of hyaluronan has been reported. Therefore, the presence of hyaluronan in the recovered tissues is important in the prevention of bacterial contamination of the wound.49 In this study, we did not
observe infection in any patients. Wound healing was good, without any wound breakdown.

Patients were allowed to return to their normal activities approximately 4 months after surgery. There was no incidence of rerupture, wound infection, or skin adhesion. All of the patients had normal gait and normal ankle range of motion. They returned to their preinjury level of activity. Foreign-body reaction was not seen in any of the patients. All of the patients were satisfied with their surgical outcome.

In conclusion, good restoration of function can be obtained by surgical treatment of chronic ruptures of the Achilles tendon with a single central gastrocnemius aponeurosis flap wrapped with a surgical mesh (Hyalonect). With this approach, patients can expect excellent or good return of function after surgery.

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References

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