Endoscopy and Percutaneous Suturing in the Achilles Tendon Ruptures and Proprioceptive Physiotherapy

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Abstract

Achilles tendon ruptures commonly occur during sports activities and there is an increasing tendency in the incidence of these ruptures due to 'weekend warriors' who are over 30 years of age. Achilles tendon ruptures are the third most frequent major tendon ruptures after rotator cuff and quadriceps ruptures. Various modalities have been recommended as appropriate treatment options for Achilles tendon ruptures; however, there is no consensus on the treatment method, which is still determined by the surgeon and patient. Open surgical repair of the Achilles tendon carries specific risks, including adhesions between the tendon and the skin, infection and, in particular, wound breakdown. Thus, to avoid these complications the percutaneous repair technique has been described and has become popular. Endoscopy-assisted percutaneous suturing of the Achilles tendon under infiltration anesthesia offers a rational alternative for the treatment of both athletic and non-athletic individuals. This technique results in acceptable wound appearance that is able to endure early active mobilization and satisfactory clinical recovery without any severe complications. Furthermore, this procedure protects the paratenon, and thus blood supplies of the tendon, and enhances biologic recovery. Also, direct visualization and manipulation of the tendon ends provides a precise apposition of the ruptured tendon, thus diminishing the handicaps of the single percutaneous technique. In this chapter the authors describe their own Achilles tendon repair technique under local anesthesia without a tourniquet and with cooperation of the patient, and the results of their clinical experiences as well as those in the literature.

Historical Perspective

The Achilles, which takes its name from the ancient Greek hero of the Trojan War and Homer's Iliad (Maffulli 1999), is the strongest tendon. Achilles was the son of the nymph Thetis, who tried to make him immortal by dipping him in the river Styx. However, he was left vulnerable at the part of the body she held him by – his heel – and was killed by a poisoned arrow fired by the Trojan prince Paris that embedded in his heel. This has given rise to the description of a person's weakest point being called their 'Achilles heel'. Hippocrates said "this tendon, if bruised or cut, causes the most acute fevers, induces shocking, deranges the mind and at length brings death". Previously, it was known as the "tendo magnus of Hippocrates" (Kirkup 1988). Since Ambroise Paré initially described it in 1575 and it was reported in the literature in 1633, Achilles tendon breakage has received a lot of attention.

Background

Achilles tendon ruptures are the third most common major tendon ruptures after rotator cuff and quadriceps ruptures. Nevertheless, there is no consensus on the treatment method for them, which is still determined by the surgeon and patient. Cast immobilization, a conservative treatment, may lead to elongation of the tendon with reduced strength of the calf muscles and a high rate of re-ruptures, with an incidence of up to 37 % (Fierro and Sallis 1995; Winter et al. 1998). Similarly, open surgical repair of the Achilles tendon also includes potential problems such as joint stiffness, muscle atrophy, tendocutaneous adhesions, deep venous thrombosis due to prolonged immobilization after surgical repair, and infection, scarification, algodystrophy and, in particular, the breakdown of the wound (Mortensen et al. 1999; Bhandari et al. 2002). Ma and Griffith (1977) introduced the percutaneous repair technique to avoid all of these complications. However, it is difficult to achieve satisfactory contact of the tendon stumps and adequate initial fixation using this technique. Sural nerve entrapment also seems to be a potential complication of this technique. Nevertheless, percutaneous repair has become a popular technique among orthopedic surgeons (Lecestre et al. 1997; Chillemi et al. 2002; Henríquez et al. 2012), especially due to its lower complication rates (Khan and Carey Smith 2010).

The advantages of percutaneous techniques are faster wound healing, less scarring, minimal blood loss, less perioperative pain (so improved functional status of the patient), decreased perioperative morbidity, a shorter hospital stay and lower cost (Phisitkul 2012; Carmont et al. 2013). In addition, early weight-bearing (Doral 2013) and early return to work can be allowed in many patients. The minimally invasive percutaneous repair techniques combine the advantages of operative and conservative methods, but they do not provide direct observation. Thus, endoscopy is a useful device when combined with percutaneous repair, as it has benefits in the evaluation of the properties of tendon ends, vascularity and approximation of the repair site, and in the guided passage of sutures. Therefore, in this chapter we evaluate the results of percutaneous repair with endoscopic control, discuss the pathophysiologic effects of this type of treatment, and share our experience of this issue.

Anatomy

The Achilles tendon begins near the middle of the calf and is the conjoint tendon of the gastrocnemius and soleus muscles. The relative contribution of the two muscles to the tendon varies. Spiralization of the fibers of the tendon produces an area of concentrated stress and confers a mechanical advantage. The calcaneal insertion is specialized and designed to aid the dissipation of stress from the tendon to the calcaneum. The insertion is crescent shaped and has significant medial and lateral projections. The tendon is situated in a well-formed tunnel surrounded by a paratenon, and therefore endoscopic interventions can be performed successfully. The blood supply of the tendon is from the musculotendinous junction, vessels in the surrounding connective tissue and the osteotendinous junction (Doral et al. 2010). There are three simply classified vascular territories, with the midsection supplied by the peroneal artery, and the proximal and distal sections supplied by the posterior tibial artery. This leaves a relatively hypovascular area in the mid-portion of the tendon where most problems occur. The Achilles tendon derives its innervation from the sural nerve with a smaller supply from the tibial nerve. Tenocytes produce type I collagen and form 90 % of the normal tendon. Evidence suggests ruptured or pathological tendons produce more type III collagen, which may affect the tensile strength of the tendon. Direct measurements of forces reveal loading in the Achilles tendon as high as 9 KN during running, which is up to 12.5 times higher than body weight.

Indications

Patients were selected for percutaneous repair if the following criteria were fulfilled:

1. Closed traumatic Achilles tendon rupture;
2. No previous Achilles tendon or ankle joint surgery;
3. Complete rupture in the tendinous portion within the last 7–10 days.

Caution should be considered when treating patients with systemic disorders (such as diabetes mellitus, neuropathies, immune insufficiencies, peripheral vascular diseases), smoking habit, sedentary lifestyle, older age (>65 years) and high body mass index (>30). However, good results are obtained with the percutaneous technique in selected patient groups (Maffulli et al. 2010, 2011a).

In Achilles tendon ruptures, with a defective tendon or chronic course, tendon augmentations or graft loop augmentation techniques can be applied under endoscopic control (Lui 2007; El Shazly et al. 2011).

Contraindications

Patients were treated with modalities other than a percutaneous procedure if the following criteria were fulfilled:

1. Skin lesions present;
2. Previous Achilles tendon surgery;
3. Previous ankle joint surgery;
4. Distal tendon end smaller than 2 cm.

The optimal treatment period is 7–10 days after acute total rupture. According to the authors' experience, systemic diseases such as diabetes mellitus are not an absolute contraindication for percutaneous repair. This technique is also useful for bilateral injuries.

Diagnosis

The diagnosis of an Achilles tendon rupture was based on the following clinical criteria:

1. Palpable gap in the tendon;
2. Positive Thompson test;
3. Clinical signs of the rupture (patients unable to rise onto their toes or heels)
4. More dorsiflexion on the ruptured side than on the healthy side.

In any equivocal case, ultrasonography or magnetic resonance imaging has to be performed to confirm the diagnosis.

Endoscopy-Assisted Percutaneous Repair Technique

The operation is performed under infiltrative anesthesia with the patient in the prone position and with the injured foot in approximately 15° plantar flexion in order to achieve a comfortable portal for the scope. Full communication with the patient is ensured to instruct the active motion of the ankle. The procedure is performed without using a tourniquet in order to evaluate the vascular status of the tendon and its paratenon. No antibiotic or antithrombotic prophylaxis is given. Before starting the procedure, the rupture and location of the diastases (gap) are determined. Then, to minimize local bleeding, proximal (about 5 cm) and distal (about 4 cm) to the palpated gap, the cutis, subcutis and peritendon are infiltrated with saline solutions through eight puncture holes, four proximal and four distal from the line of the rupture from the proximal to the distal end with a 3–4 cm interval between the portals, which are later enlarged and used for needle entry (Fig. 1).

Fig. 1 Schematic drawing of entry points

Special attention is paid to the lateral side, particularly proximally, as the sural nerve lies in the vicinity and crosses the Achilles tendon. Under infiltrative anesthesia (Citanest® 5 cc + Marcain® 5 cc), the patient is prompted to report any changes or soreness felt in the sural nerve area during the puncture or infiltration. When pain is experienced, the puncture site is shifted approximately 0.5–1 cm toward the middle (internally). After the level of the rupture is determined by endoscope, the continuum of the surrounding synovial tissue, its thickness and vascularization are endoscopically evaluated. During this evaluation, the characteristics of the tendons surrounding the synovial tissues, paratenon and tendons are noted. The data acquired are used to classify the cases:

- **Grade I:** minimal disruption of the surrounding synovial tissues of the tendon, linear tear at the paratenon, and minimal degeneration at the ends of the Achilles tendon (Fig. 2a);
- **Grade II:** marked corruption of paratenon continuity, degenerative rupture of the paratenon, marked degeneration at the ruptured ends of the Achilles tendon, and signs of tendinitis (Fig. 2b);
- **Grade III:** defective rupture at the paratenon, marked tendinosis at the tendon, and advanced signs of tendinitis at the ruptured ends (Fig. 2c).

Biopsy of the ruptured area has to be performed routinely throughout the repair procedure. The plantar tendon is then observed and two medial and two midline lateral incisions of 1 cm

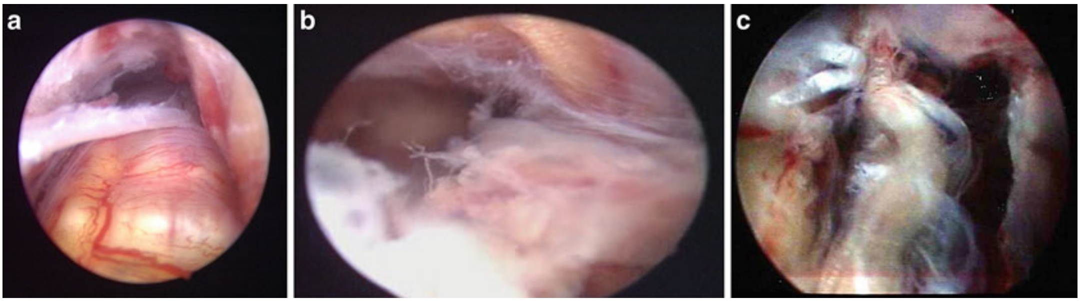

Fig. 2 Endoscopically evaluation of Achilles paratenon (**a**) Intact paratenon with a minimal degeneration. (**b**) Corruption of paratenon continuity, degenerative rupture of paratenon. (**c**) Defective rupture at the paratenon

Fig. 3 The sutures were tied in a manner to end in the proximal lateral end at the ankle at neutral position

each are made on the proximal and distal of the rupture level followed by suturing starting from the proximal using a modified Bunnell technique using PDS™ No. 5 (Ethicon Inc., Johnson & Johnson, Somerville, NJ, USA) (Ahluwalia et al. 2013). The sutures are tied in a manner that ends at the proximal lateral end of the ankle 90° of the neutral position (Fig. 3). This procedure has to be repeated once or twice. Attention should be paid to check the 90° position on the ruptured side after prompting the patient to set the foot to a neutral 90° throughout suture fastening. After fastening the sutures, the patient is instructed to activate the ankle while the knee is in a 90° position. The final check-up is then performed and, if needed, the second knot is tied. After dorsiflexion performed willfully by the patient and plantar flexion, strikingly, the "gap" vanishes. The intratendinous bracing performed is then evaluated for functionality. Finally, the skin incisions are closed and a walking brace holding the ankle in a neutral position is applied for 3 weeks.

Rehabilitation

A standard rehabilitation program for percutaneous repair of Achilles tendon has been developed based on data from the Departments of Orthopaedics and Sports Medicine and section of Rehabilitation of Hacettepe University. On the first day after surgery, early tolerated weight-bearing is initiated and alternated with a passive range of motion exercises. This physiotherapy approach includes an electrical stimulation technique for re-education of the gastrocnemius and soleus muscles; application of ice and therapeutic ultrasound around the Achilles tendon to relieve the edema; and transverse friction massage to promote scar and tendon reformation. Patients are instructed to move the ankle four times a day between 20° of plantar flexion and 10° of extension. Patients complete neuromuscular exercises as flexion and extension of the toes in a supine position; plantar flexion of the ankle and dorsiflexion to neutral in a supine position; extension of the knee in a sitting position; flexion of the knee in a prone position; and extension of the hip in a prone position within the first 3 weeks. From the sixth week to the third month, the rehabilitation program includes advanced exercises such as ankle extension against a Thera-band®; rotation of the ankles; standing on the toes and heels; ankle stretching exercises to flexion with the help of a rubber strip; stretching of the calf muscle by standing with the leg stretched straight behind and the other leg bent in front while leaning the body forward, with support from a wall or physiotherapist; stretching exercises for the toes and ankle against the hand in a sitting position; balance and proprioception exercises using a different surface from bilateral to unilateral; and controlled squats, lunges, bilateral calf raises (progress to unilateral), toe raises and controlled slow eccentrics versus body weight. After 3 months, patients start training such as jogging/running, jumping and eccentric loading exercises, non-competitive sporting activities, sports-simulated exercises and return to physically demanding sports and/or work.

Follow-Up Evaluation

At the follow-up visit, it is recommended that the calf diameter of the injured and uninjured side is measured, the ankle range of motion is examined with goniometry, and a detailed neurological examination focused on the sural nerve is performed. As suggested by Kitaoka et al. (1994), other factors more specific to the repair of an Achilles tendon rupture are assessed, namely the strength of ankle plantar flexion with the patient standing on tiptoe, the ability to perform repeated toe raises and single-limb hopping, and the neurological status of the foot. For single-limb hopping, patients are asked to hop as many times as possible until they cannot lift the heel off the floor. The integrity of the paratenon of the Achilles tendon and subgroup is noted.

Authors' Experience

Sixty-two patients (58 males, four females, mean age 32 years) were treated by percutaneous suturing with a modified Bunnel technique under endoscopic control within 10 days after acute total rupture. Physiotherapy was initiated immediately after the operation and patients were encouraged to return to weight-bearing ambulation with a walking brace moon boot as tolerated. Full weight-bearing without a brace was allowed at a minimum of 3 weeks post-operatively. The procedure was tolerated in all patients. There were no significant range of motion limitations observed. Two patients experienced transient hypoesthesia in the region of the sural nerve that spontaneously resolved in 6 months. Fifty-nine patients (95 %), including professional athletes, returned to their previous sports activities, while 18 (29 %) had some minor complaints. The interval from injury to return to regular work and rehabilitation training was 11.7 weeks (range 10–13 weeks). At the latest follow-up (mean 46 months; range 12–78 months), all patients had satisfactory results with a mean American Orthopaedic Foot and Ankle Society's ankle–hind foot score of 94.6. No re-ruptures, deep venous thrombosis or wound problems occurred (Doral et al. 2009). For the last 4 years, we have injected platelet-rich plasma to stimulate the biologic repair process at the end of suturing. It should be note that, while there is thought to be a benefit of biological stimulation after mechanical repair, not enough evidence supports this belief yet. Thus, this is an issue that should be further investigated and needs to be evaluated with long-term results.

Conclusion

Rupture of the Achilles tendon is a common injury encountered by the orthopedic surgeon that is prevalent in the athletic population and much more common in the aging athlete (Assal et al. 2002). In patients who have no history of steroid treatment or systemic disease, the etiology of spontaneous rupture of the Achilles tendon is uncertain. The results of some investigations support the theory of chronic degenerative changes based on histological examination of material obtained from the ruptured area during the operation (Kannus and Józsa 1991; Hansen et al. 2013). On the other hand, Inglis et al. (1976) performed a histological examination of acute Achilles tendon rupture and found evidence of acute pathological changes such as hemorrhage and inflammation rather than chronic tendonitis. Hypoxia due to a vascular lesion, aging and repeated microtraumas

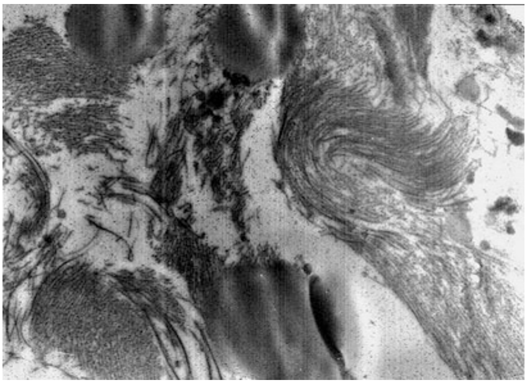

Fig. 4 Electron micrograph showing the course of collagen fibers in different directions in a patient with ruptured Achilles tendon. No blood vessels were seen in the micrograph (Original magnification ×7,500)

from overuse are the factors most commonly considered (Kannus and Józsa 1991; Kannus 1997). Hypovascular areas have been found around the ruptured tendon side by electron microscopy in Grade III patients (Fig. 4). Also, Zantop et al. (2003) examined this subject via immunohistochemical methods and concluded that diminished vascularization in the middle part of the Achilles tendon may play a role in the reduced healing of microruptures, leading to degeneration and spontaneous rupture of the Achilles tendon.

Because of the increasing incidence of Achilles tendon ruptures during the last decade, they have been the subject of focus in many studies and meta-analyses and there is no consensus regarding the optimal management strategy for acute total Achilles tendon rupture (Lim et al. 2001; Möller et al. 2001). Conservative treatment has worse functional results and higher re-rupture rates (Wong et al. 2002; Khan and Carey Smith 2010). However, Nistor (1981) found only minor differences between the results of surgical and non-surgical treatment.

Numerous open surgical procedures have been proposed for repairing ruptures of the Achilles tendon, but there is no single, uniformly superior technique. Delayed wound healing, necrosis, suppuration and adhesions are potential complications of open procedures that are not rare (Ma and Griffith 1977; Bradley and Tibone 1990; Lo et al. 1997). Augmented open procedures have to be performed for neglected or defective Achilles tendon ruptures (Abraham and Pankovich 1975; Gerdes et al. 1992; Takao et al. 2003). Percutaneous repair can avoid the risks of open procedures but results in a higher number of re-ruptures and is thus considered a weaker repair than open suturing. Therefore, it is not recommended for patients with high sportive demands (Inglis et al. 1976; Bradley and Tibone 1990; Maffulli 1999). On the other hand, in endoscopy-assisted percutaneous repair, suturing of the tendon is observed (Fortis et al. 2008), which not only eliminates some of the disadvantages of the percutaneous repair, particularly difficulties in evaluating the contact status of the torn ends, but is also a safer method than open surgery due to its minimally invasive approach (Turgut et al. 2002). For that reason, recent recommendations tend towards using percutaneous techniques for elite or non-elite athletes (Maffulli et al. 2011b; Chiu et al. 2013). In addition, endoscopy-assisted percutaneous repair allowed early active ankle mobilization and weight-bearing after a short period of cast immobilization and also prevents complications due to the prolonged immobilization such as arthrofibrosis, joint stiffness, calf atrophy, damage of the articular cartilage and deep vein thrombosis (Mortensen et al. 1999; Kangas et al. 2003). Also, van der Eng et al. (2013) reported that the re-rupture rate is not increased with early weight-bearing after surgery. Considering these advantages, it can be said that endoscopy-assisted percutaneous repair of the Achilles tendon seems to prevent certain problems experienced with open, conservative or percutaneous techniques (Halasi et al. 2003). On the other hand, Turgut et al. found that this technique did not help prevent the risk of damage to neural structures by facilitating the visual observation of the sural nerve (Turgut et al. 2002); they used mid-lateral portals in order to keep expanse with sural nerve. In endoscopic repair, the synovia of the tendon is protected, providing biomechanically strong biological healing through intratendinous reinforcement (Hockenbury and Jones 1990). Nevertheless, Momose et al. showed that preservation of the paratenon decreases the gliding resistance of the extra synovial tendons after repetitive motion in vitro (Momose et al. 2002). As in the example of synovial covering in the healing process of the posterior cruciate ligament, a mechanically strong Achilles tendon is achieved. Achilles tendoscopy made a more definitive repair possible. Hematoma protection, exact incision points and controlled adaptation created better circumstances for tendon healing without damaging the paratenon of the Achilles tendon. Doral et al. emphasized the importance of endoscopic repair with a protected paratenon on biological healing of Achilles tendon ruptures (Doral et al. 2002) and also the importance of biologic stimulation of the healing process, and recommend the use of platelet-rich plasma after the repair processes. However, in ruptures associated with Achilles tendinitis, the synovia is weak. Therefore, mechanical sutures maybe more effective in healing than biological healing. In light of these data, it should be kept in mind that ruptures of the Achilles tendon may be secondary to Achilles tendon disease. Such patients should also be evaluated for possible systemic diseases in the contralateral Achilles tendon and other tendons. This will ensure an optimal treatment approach as well as contribute to decision making regarding the post-operative physiotherapy and time before returning to sports activities.

The percutaneous technique seems to contribute to tendon lengthening. This may be due to a lack of close approximation of the tendon ends. Nevertheless, direct visualization of the tendon ends through the middle incision should reduce or eliminate this phenomenon. The main disadvantage of this procedure is the requirement of soft tissue endoscopy experience.

In conclusion, percutaneous repair of Achilles tendon with endoscopic control surpasses the disadvantages of open and percutaneous repair only and provides excellent results with an earlier return to pre-injury activities.

Future Directions

There are only a few percutaneous suture techniques currently, and development is still underway for new suture types (McCoy and Haddad 2010). In addition, new studies are being performed for adjuvant treatment modalities for surgery, such as PRP (a thrombocyte concentrate), Platelet-rich growth factors (PRGF), growth factors (GF) and neuropeptide preparations (Aspenberg 2007; Mammoto et al. 2008; Anitua et al. 2009; Jelinsky et al. 2011; Tohidnezhad et al. 2011; Kaux et al. 2012; Shah et al. 2013). Furthermore, tissue engineering could be an integral part of surgical treatment in light of new developments (Chen et al. 2012; Huang et al. 2006, 2013; Uysal et al. 2012). Better understanding of pathomechanisms and healing processes will enable treatment modalities to make big steps going forward (Sharma and Maffulli 2006; Gaida et al. 2012). In addition, ideal post-operative rehabilitation programs and optimum weight-bearing timing (Wang et al. 2013) should be studied to improve sensation, especially proprioception (Kaya et al. 2013).

Cross-References

- ▶ Achilles Tendinopathies
- ▶ Advantages of Endoscopy-Assisted Repair for Achilles Tendon Ruptures
- ▶ Biomaterials in Musculoskeletal Conditions: Classification, Design, and Regulatory Aspects
- ▶ Biomedical Engineering and Orthopedic Sports Medicine
- ▶ Clinical Relevance of Gene Therapy and Growth Factors in Sports Injuries
- ▶ Functional Tissue Engineering for Tendinopathies: What's New on the Horizon?
- ▶ Minimally Invasive Surgery for Achilles Tendon Pathologies
- ▶ Platelet-Rich Plasma: From Laboratory to the Clinic
- ▶ Primary Anterior Cruciate Ligament Repair in Athletes with Mesenchymal Stem Cells and Platelet-Rich Plasma
- ▶ Proprioceptive and Functional Exercises After Ankle Surgery
- ▶ Tissue-Engineered Approach to Tendon and Ligament Reconstruction: Current Trends
- ▶ Total Achilles Tendon Ruptures: Current Trends

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