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Long-Term Results With the Use of Modified Percutaneous Repair of the Ruptured Achilles Tendon Under Local Anaesthesia (15-Year Analysis With 270 Cases)

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ABSTRACT

Controversy regarding the optimal treatment of fresh total Achilles tendon rupture remains. This article presents results with the use of modified percutaneous Achilles tendon repair under local anesthesia performed from January 1991 to December 2005 with a 2- to 10-year follow-up. There were 270 procedures in 247 male patients (92.51%) and 20 female patients (7.49%), mean ± SD age 38.7 ± 11.56 (range 20 to 83) years, in all consecutively treated patients within 7 days after acute total rupture; 3 patients sustained ruptures on both sides in different periods. Postoperative care consisted of wearing a cast or soft cast or functional immobilization for 6 weeks. The procedure was well tolerated in all patients. There were 3 (1.11%) complete and 5 (1.85%) partial repeat ruptures (8 [2.96%] altogether). Fourteen patients (5.18%) developed transient sural neuritis that spontaneously resolved in 2 to 10 months. One case (0.3%) of deep venous thrombosis was successfully treated. There were 25 (9.36%) major and minor complications altogether, with no cases of increased postoperative dorsiflexion, deep infection, or necrosis. Forty-four patients (16.48%) had a slightly decreased range of ankle motion, and 216 (80.89%) patients, including all high-caliber athletes, resumed all their previous activities. The mean American Orthopedic Foot and Ankle Society hindfoot-ankle score was 96.10 points. Long-term results of the analyzed modified method suggest a reasonable treatment option for acute total Achilles tendon ruptures, with a low number of complications and repeat rupture rate and return to preinjury activities comparable to those of open procedures.

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Despite the abundant literature, controversy about the optimal treatment of acute complete Achilles tendon rupture still exists. Open surgical repair, with or without augmentation, performed under general or spinal anesthesia, used to be the preferred method in the active population, as it contributes to a low reported incidence of repeat rupture, ranging from 1.4% to 4.4%, and offers the possibility of early functional treatment (1–13). As operative treatment is associated with a significant complication rate of 11.8% to 34.1% and high costs, many authors advocate conservative treatment (1,9,14–17). According to some authors, an accelerated (functional) rehabilitation nonoperative protocol brings acceptable and clinically similar results to operative treatment (11,12,18,19). Opponents to conservative care argue that this option carries a higher incidence of repeat rupture (6.6% to 18%) and allows the tendon to heal in a lengthened position with a subsequent loss of strength (1–4,8–11,13,18,20,21).

Percutaneous suturing, first described by Ma and Griffith (22), combines the advantages of both methods, allowing the use of local anesthesia and functional postoperative treatment (22–30). Many of these methods propose a semi-open (minimally invasive) principle, to visualize the approximation of the torn ends, but thus losing rupture hematoma with healing mediators (20,26,28–31). Percutaneous suturing has also been criticized as providing only 50% of the initial strength afforded by open repair, placing the sural nerve at high risk for injury (13% to 60%), and having a higher rate of repeat rupture (2.6% to 16.7%) than open operative repair (9,20,23,29,30,32–36).

Biomechanical studies (36,37) (with static and dynamic loading) demonstrated that a modified technique of percutaneous Achilles rupture repair provided almost double the strength of the Ma and Griffith (22) method. As there is a lack of long-term studies with a significant number of patients treated percutaneously, the purpose of the present prospective study was to evaluate long-term clinical results with the use of the modified percutaneous suturing technique of Achilles tendon ruptures under local anesthesia.

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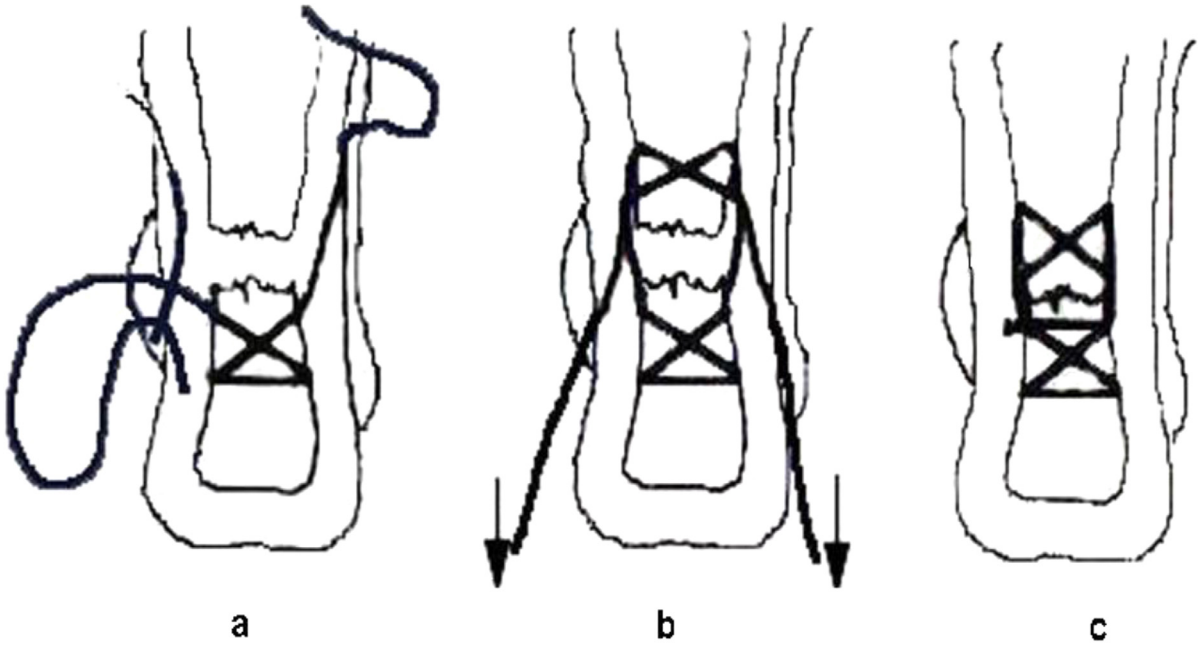

Fig. 1. Technique - schematically.

Patients and Methods

From January 1991 to May 1998 in the first center (general and teaching hospital) and from June 1998 to December 2005 in the second center (university clinical center), all consecutive patients who were treated for the Achilles tendon rupture were included in this study. The inclusion criteria were 1) patients ≥18 years of age; 2) closed Achilles tendon rupture; 3) a rupture that occurred ≤7 days before the procedure; 4) complete rupture; 5) a rupture that occurred in the tendinous portion (2 to 8 cm proximal to insertion); 6) informed consent (approved by the national ethics committee); 7) no previous operative procedures or history of partial or complete rupture of the involved tendon; and 8) no history of local, oral, or parenteral medications that might have weakened the tendon. No other operative or conservative treatment was performed, and thus no patient selection or randomization was made.

The diagnosis was based on the presented clinical criteria: 1) palpable gap in the tendon; 2) positive Thompson's test result (38,39); and 3) clinical signs of the rupture (patients unable to rise on their toes or heel). In any case in which there was some doubt, and in all cases in the first 3 and last 5 years of the study, ultrasonography was performed to confirm the diagnosis. In any case of persistent doubt, magnetic resonance imaging was routinely available since the year 2000.

Patients were assessed using the ankle-hindfoot scale of the rating system developed by the American Foot and Ankle Society (AOFAS hindfoot-ankle score) (40–42). In addition, we evaluated patients' return to the previous activity level and the presence of any associated complaints. The patient's subjective assessment of the treatment was scored as good, fair, or poor. All measurements and assessments were done by the authors (A.C., M.K., and R.K.).

Objective factors specific to repair of an Achilles tendon rupture were also examined (15,17,29,43,44). The neutral zero method was used for assessment of ankle motion, with the maximum dorsiflexion considered to be 20° and plantarflexion to be 50° (45). We also measured the thickness of the tendon at its widest diameter in comparison to the noninjured tendon. Thickness of <1 cm in diameter was assessed as mild, <2 cm as moderate, and ≥2 cm as great. Plantarflexion function (strength) was tested using the standing heel-rise test, to require 25 repetitions for a grade of normal (46). Patients were instructed to stand straight and to rise and lower on the balls of their feet in rhythm of 1 heel-rise every 2 seconds. They were asked first to raise 25 times on their toes with both legs simultaneously (test 1), then with the noninjured leg followed by the injured leg (test 2). They could balance with their hand at the edge of the table but were not allowed to place weight on the hand. Complications were divided into 2 groups: major complications and minor complications (Table 1) (1,8,14).

Surgical Technique

The operation was performed with the patient in the prone position and with the injured foot in approximately 25° plantarflexion, under local anesthesia without a tourniquet according to the brief description with drawings and photos in the cited literature (27,36). No antibiotic nor antithrombotic prophylaxis was given. Before starting the procedure, the rupture and location of the diastasis (gap) were localized. Using 15 to 20 mL of 1% plain lidocaine, the skin, subcutaneous tissues, and peritendineum were infiltrated 5 cm proximal to the palpated gap and 4 cm distal to the gap through 8 puncture holes, which were later used for needle entry. No other medications, nerve blocks, or other types of anesthetics were given. Special attention was paid to the lateral side of the Achilles complex, particularly proximally, where the sural nerve lies in the vicinity and crosses the Achilles tendon (according to the literature from 8.7 to 12.4 cm proximally to the Achilles tendon insertion) (47). The infiltration site must therefore not cross the lateral edge of Achilles tendon in this area; it should instead lie slightly medial. The patient was warned to report if any changes or soreness were felt in the area of the sural nerve during the puncture or infiltration. In that case, the puncture site was moved 0.5 to 1 cm medially. The tendon was then repaired with the modified repair configuration using Vicryl (polyglactin) No. 2 (Ethicon, Inc., a division of Johnson & Johnson, Sommerville, NJ) (Fig. 1) (27,36).

The procedure was started and finished medially and distally. First, the suture on the long, semi-curved needle was transversely passed through the tendon (see *scheme a* in

Table 1
Complications of the Modified Percutaneous Achilles Tendon Repairs

Major complications	n (%)
Repeat rupture	
Complete	3 (1.11)
Partial	5 (1.85)
Together	8 (2.96)
Second repeat rupture	0
Chronic fistula	0
Permanent equinus position of the foot	0
Extreme lengthening of the Achilles tendon	0
Deep infection	0
Necrosis of the skin	0
Deep vein thrombosis	1 (0.37)
Embolism	0
Death	0
Major together	9 (3.33)
Minor complications	
Superficial infection	1 (0.37)
Wound hematoma	0
Delayed wound healing	0
Adhesions of the scar	0
Suture granuloma	1 (0.37)
Disturbances of sensibility	14 (5.18)
Suture rupture	0
Minor together	16 (5.92)
All complications together	25 (9.25)

Fig. 1), proceeding with the cross (diagonal) suture. At every site of the first needle entrance or exit, the incision was widened in longitudinal direction by pushing the scalpel blade (no. 11) on the thrust-in needle to enable the surgeon to sink the thread subcutaneously (on the paratenon) when proceeding the suture through the same hole (Fig. 2). A small haemostat can also be used to widen the hole and enable sinking of the thread through the same hole. The thread was then led longitudinally, subcutaneously to extratendineously (see *scheme a* in Fig. 1), and the next cross through the tendon was done proximally (see *scheme b* in Fig. 1). After, both ends were led extratendineously back through the third and second hole distally (see *scheme b* in Fig. 1) and pulled symmetrically back with careful tension until both ends of the torn Achilles tendon were completely approximated and the defect was no longer palpable (see *arrows* in Fig. 1). After approximating the torn Achilles tendon ends, as verified by ultrasonography, the lateral end of the thread was passed medially (see *scheme c* in Fig. 1) (both ends of the thread must be held tightened at that time) where, after final tightening, the suture was tied (see *scheme c* in Fig. 1) and the knots were sunk (buried) subcutaneously through the previously widened second medial stab wound distally. At the end, nothing can be seen on the surface, except 8 small stab wounds and the folds of skin that later completely disappeared (27,36). Small stab wounds can be closed with very fine sutures, but this was not routinely done.

A sterile dressing and cast were applied with the foot in 20° of plantarflexion. Initial reevaluation was performed 2 days postoperatively, and a new cast, soft cast, or functional orthosis was applied with the foot in 20° of plantarflexion for 3 weeks. The type of immobilization was the patients' choice, as they were responsible for the cost. Patients used crutches for assistance, and careful weightbearing of 5 to 10 kg was allowed. A heel lift was mounted onto the immobilization device to facilitate walking. After 3 weeks, new immobilization was applied with the foot in neutral position. The device allowed plantarflexion but prevented dorsiflexion. For example, if a cast was used, the plantar aspect distal to the heel lift was cut out, but the dorsal aspect was maintained to restrict dorsiflexion over neutral position. The soft cast was similarly designed as a rigid splint on the dorsum and a soft bandage on the plantar portion. The functional orthoses were custom made from plastic materials with fixation strips as proposed by Carter et al (5). If neutral position could not be achieved immediately, the immobilization was revised to neutral after 1 week. Patients were encouraged to perform range-of-motion exercises as much as their immobilization allowed. During this period, patients could bear weight without crutches as tolerated. Soft cast immobilization routinely softened with weightbearing, so there was no need to exchange this type of immobilization to achieve neutral position of the foot (this was also a way of controlling patients about weightbearing).

At 6 weeks postoperatively, all immobilization was removed, and patients could walk and begin careful rehabilitation with range-of-motion exercises, whirlpool, progressive resistance exercises, loads with an elastic band, et cetera. Special attention was given to correct any antalgic gait pattern. No additional heel pad or cushion was recommended. Patients were encouraged to start swimming and walking in the pool with weightbearing as much as tolerated in water. Careful stretching exercises were allowed after 8 weeks with gradual increasing of the load. Rising on toes or heels was allowed 12 weeks postoperatively, and limited sports activities were individually allowed after 3 months, with recommended full loading 6 months after operation. Patients were followed regularly at 3 and 6 weeks postoperatively and then at 2, 3, and 6 months and a minimum of 2 years.

Results

There were 270 patients who met the inclusion criteria and underwent the procedure. Follow-up was not possible in 3 patients, so finally the results of 267 (98.89%) patients were evaluated. Three patients (1.11%) sustained rupture of both tendons at different times, so 270 procedures were performed. There were 247 male patients (92.51%) and 20 female patients (7.49%), with a mean ± SD age of 38.70 ± 11.56 (range 20 to 83) years. One hundred forty-four patients (53.33%) sustained left-side rupture and 126 (46.66%) right-side rupture. In 187 patients (70.03%), rupture occurred during a sports-related activity, with soccer as the most frequent activity in 80 patients (42.78%), followed by basketball (58 patients [31.01%]), tennis (17 patients [9.09%]), volleyball (10 patients [5.34%]), handball (5 patients [2.67%]), and gym (4 patients [2.13%]). Nine patients (3.33%) were high-caliber athletes.

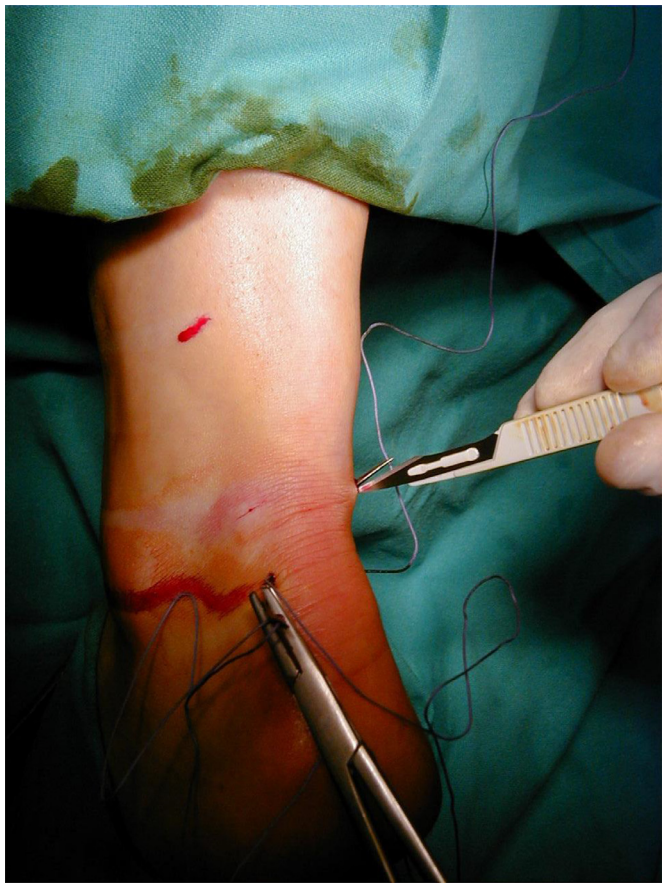

Fig. 2. Needle exit widening with blade No. 11.

Since 1998, all the patients (49.43%, n = 132) were treated in an outpatient manner and immediately after they came to the clinic for medical help. The average time from injury to operation was 1.8 days. The procedure was well tolerated in all patients, with no intraoperative pain. There were no allergic reactions to lidocaine or problems with suture breakdown. At latest follow-up visit, the Thompson's test (38,39) was negative in all patients. Complications are listed in Table 1.

In the group of minor complications, 1 patient (0.37%) developed superficial cellulitis that completely resolved after 5 days of oral antibiotic therapy. Fourteen patients (5.18%) claimed (transient) sural nerve disturbances (paresthesias). Ten of these patients exhibited significant palpable fibrous thickening at the operative site. These patients were encouraged in careful rehabilitation with cryomassage, friction massage, emollient creams, nonsteroidal antiinflammatory drugs, and B complex vitamins. All cases of sural nerve disturbances resolved without any operative procedures after a period of 3 to 10 months. In 1 patient (0.37%), partial suture extrusion occurred, which was healed by simple pulling 5 weeks after the operation. There were no other minor complications. In the group of major complications, 1 patient (0.37%) (wearing a cast) sustained deep vein thrombosis (with no embolism) 7 weeks after the operation, which was successfully treated with oral anticoagulants for 3 months with no further consequences.

Three patients (1.11%) sustained a complete repeat rupture that occurred immediately after the immobilization was removed 6 weeks postoperatively, 1 by stumbling and placing full weight on the injured extremity, and in 2 cases, by similar mechanisms, while slipping on the wet floor near the swimming pool. Open operative suturing and immobilization for another 6 weeks was needed. They all regained all previous (including sports) activities, with no problems nor any other complications, within 6 months.

Five (1.85%) patients sustained partial re-ruptures 6, 8, 9, 10, and 20 weeks after the operation. Again, the mechanism was uncontrolled, full loading during a fall on the stairway, on the slippery floor, on the wet floor near the swimming pool during the rehabilitation, and in the last case, by making a false step. In each of these repeat ruptures, the diagnosis was confirmed by ultrasonography. Clinical examination and ultrasound showed in the patients with the partial rupture a preservation of the continuity of the tendon, but tenderness and in 3 patients hematoma, with a palpable (shallow) depression. One of these patients was treated with below-the-knee cast with the foot in 20° of plantarflexion for 1 week and the other patients for 3 to 6 weeks with changing into neutral position after 3 weeks. Immobilization was removed after patients felt no more pain and no depression was palpable any longer. After this course of immobilization, they started with careful walking and rehabilitation according to the standard protocol, but without jumping or similar sports activities for 3 months. One patient resumed his previous activities in 6 months, 2 of them in 8 months, 1 in 10 months, and 1 in 12 months. The main concern for each of them to overcome was a fear of repeat rupture during full weightbearing. There were no other major complications. The mean AOFAS hindfoot-ankle score was 96.10 (range 44 [0.73%, n = 1] to 100 [69.28%, n = 185]) points. Functional results are listed in Table 2.

One (0.37%) patient assessed the treatment as poor (as described in the following paragraphs), 14 (5.24%) patients as fair, and all the rest (252 [94.38%]) as good. They were very pleased with the cosmesis and absence of incisional scars. One hundred twenty-eight patients (47.94%) had thickening of the operated tendon <1 cm in diameter, whereas 135 (50.56%) patients demonstrated thickening of 1 to 2 cm in diameter. Four (1.49%) patients had thickening of >2 cm in diameter. The thickness of the operated tendon was diminishing in some patients even more than a year after the operation. Two hundred sixty-six patients (99.62%) finally regained normal pattern of walking without limping, but more than one third of them needed the help of physiotherapists to overcome this problem. There was 1 patient (0.37%) (as described in the following paragraphs) in whom limping remains, despite additional open operative revision and intensive rehabilitation with many physical therapies and medical support. There were 30 patients (11.23%) with diminished plantarflexion of the foot between 5° and 10°, and 14 patients (5.24%) who had 5° to 10° diminished dorsiflexion of the foot at the final exam. No patient had >10° loss of dorsiflexion or plantarflexion; there was also no increase in dorsiflexion of the foot.

Table 2
Functional Results of the Modified Percutaneous Achilles Tendon Repairs

Result	n (%)
Subjective assessment	
Good	252 (94.38)
Fair	14 (5.24)
Poor	1 (0.37)
Diameter of tendon	128 (47.94)
<1 cm	
(Increase) 1 to 2 cm	135 (50.56)
>2 cm	4 (1.49)
Walk	266 (99.62)
Normal	
Mild limping	0
Limping	1 (0.37)
Plantarflexion	
Normal	237 (88.76)
Loss 5° to 10°	30 (11.23)
Loss >10°	0
Dorsiflexion	
Normal	253 (94.75)
Loss 5° to 10°	14 (5.24)
Loss >10°	0
Heel-rise test	
Symmetrical	184 (68.91)
(Test 2): weakness	51 (19.10)
Not possible: operated leg	32 (11.98)
Not possible: nonoperated leg	26 (9.73)
Return to activities	
To all	216 (80.89)
With some difficulties	45 (16.85)
Not	6 (2.24)
Complaints	
No	216 (80.89)
Minor	50 (18.72)
Considerable	1 (0.37)

All patients were able to pass the heel-rise test (raising on their tiptoes) (46) with both legs simultaneously (test 1). Thirty-two patients (11.98%) were not able to pass the test (25 repetitions in rhythm of 1 heel-rise every 2 seconds) with the single operated leg (test 2), but 26 (9.73%) of them (difference = 6 patients [2.24%]) were not able to pass the test with the nonoperated leg, either (test 2). There were 51 patients (19.10%) who passed test 2 but showed some asymmetry (particularly at the end of test), whether with diminished power (height of lift) or more slowly (but still within the demanding rhythm or height) in comparison to the nonoperated site. One hundred eighty-four patients (68.91%) passed the heel-rise test symmetrically (test 2).

Two hundred sixteen patients (80.89%) returned to all their previous activities. Forty-five patients (16.85%) reported returning to their activities with some limitations, and 6 patients (2.24%) did not return to their preinjury activities. In some patients, it took a long time (even more than a year) to overcome their fear of full weightbearing and the possibility of repeat rupture. Two hundred sixteen patients (80.89%) reported no complaints at the final exam, and 50 patients (18.72%), some complaints. One patient (0.37%), 23 years old at the time of rupture, constantly complained of problems at the operative site including swelling after weightbearing, occasional severe pain, weakness, difficulty rising onto her tiptoes even with both legs, limping, and inability to return to work. She had 5° diminished plantarflexion with no limitations of dorsiflexion of the foot or trouble with sural nerve. An open operative

revision was later performed, where mild degenerative attenuation and small nodular changes were found, but otherwise continuity and normal tendon length were present. Debridement of the nodules and partial reinforcement with triceps surae strips was done. Rehabilitation was restarted, but she continued to complain of the same problems. Work and insurance compensation may have had some role in these issues. She also demonstrated the lowest AOFAS hindfoot-ankle score (44 points).

There were no complications and a full return to activity level in 3 to 6 months in all 9 high-caliber athletes. Two of them were professional handball players, 3 were basketball players, and 4 were soccer players. Three of these patients returned to their full activity level already after 3 months. All achieved a maximum AOFAS hindfoot-ankle score of 100.

Discussion

Despite many different studies and metaanalyses, the appropriate treatment of acute total Achilles tendon rupture remains controversial. The optimal treatment should enable restoration the original length and firm connection of the torn ends, with possible preservation of all the natural healing potential and functional treatment with restoration of the preinjury level of function, and with as few complications as possible.

Percutaneous repair offers the possibility of combining benefits of both conservative and operative treatment. Many different percutaneous methods have been proposed. Generally, they could be divided into closed percutaneous (20,22,27,48,49) and semi-open (minimally invasive) methods, using different instruments, special devices, anchors, or endoscopic control (28-31,50–55).

The torn ends are often friable and uneven, and pulling them together to achieve a good approximation has proven difficult (20,22,26,27,36). The majority of the proposed percutaneous techniques enable pulling the torn ends only at 1 side, which might leave a gap on the opposite side (so-called fishtail effect) or cause tearing and cutting a tendon with the thread because of an attempt to reapproximate both sides. This is also a reason that we recommend more "rough" material, such as Vicryl instead of for instance PDS no. 2 (polydioxanone), which is more smooth, with a greater risk of cutting a tendon during stronger pulling. In the types of "crossing technique" (20,48,49), interference with the approximation at the site of the rupture, with a potential residual gap that is healed with weaker fibrous tissue and lengthening of the tendon, could occur. The proposed modified technique is at the moment the only percutaneous technique that enables approximation of torn ends by pulling them symmetrically at both sides and simultaneously, using the principle of "double pulley technique" (27,36,37). Although this technique is more demanding, it enables the need for less force to make a good apposition of the torn ends, with less risk of cutting the tendon during pulling, and minimizes the pullout forces at the junction of the suture–tendon interface. It is very important to approximate the torn ends until the defect is no longer palpable, and plantarflexion of the foot during reapproximation probably assists in this maneuver. Approximation can also be assisted (and controlled) by ultrasonography, which we recommend during initial use of this method until the surgeon is comfortable with the technique and the proper pulling strength (27,36).

Biomechanical (cadaveric) static and dynamic testing (37) have shown almost double strength of the proposed method in comparison to the technique of Ma and Griffith (22) and superior strength to other percutaneous methods using a Kessler or Bunnell type of repair, comparable even to some open methods (Table 3) (55–64).

Semi-open methods with the Achillon tendon repair system (Integra Life Sciences Corporation, Plainsboro, NJ) and percutaneous Achilles jig system (PARS; Arthrex, Naples, FL) showed in some (but not all) biomechanical testing (57,62–64) stronger repair in comparison to the proposed method, but demand special instruments and more (generally 6) sutures (with anchors) and thus higher costs with the potential risks, as described in the following paragraphs. Of note, besides the technique itself, the strength of tendon repair depends on 3 factors: the coefficient of friction between the suture material and the tendon (i.e., the holding capacity of the suture within the tendon), the strength of the knot, and the strength of the suture material itself (62). More strands and knots

Table 3
Comparison of Achilles Tendon Repairs Ranked by Load to Failure

Technique	Suture Material	No. of Strands	Load to Failure (N)	Reference
Bunnell	0 Ticron	2	78	Mortensen and Saether (55), 1991
Kessler	1 Ethibond	2	85	Watson et al (56), 1995
Bunnell	1 Ethibond	2	93	Watson et al (56), 1995
Ma-Griffith	2 Vicryl	2	111	Čretnik et al (37), 2000
Kessler	2 Ticron	2	123	Ismail et al (57), 2008
Krackow locking loop	1 Ethibond	4	147	Watson et al (56), 1995
Achillon	2 Ticron	6	153	Ismail et al (57), 2008
Double Kessler	1-0 Silk	4	154	Gerdes et al (58), 1992
Krackow locking loop	1 Ethibond	4	161	Jaakkola et al (59), 2000
Bone anchor repair	1 Panacryl	4	166	Zandbergen et al (60), 2005
Continuous 6-strand suture	0 Ticron	6	175	Mortensen and Saether (55), 1991
Bone anchor repair	1 PDS-II	4	185	Zandbergen et al (60), 2005
Calcaneal tunnel	1 Panacryl	4	186	Zandbergen et al (60), 2005
Calcaneal tunnel	1 PDS-II	4	195	Zandbergen et al (60), 2005
PARS	2 FiberWire	6 (sutures)	206	Cottom et al (64), 2017
Bunnell (open)	1 PDS-II	4	211	Zandbergen et al (60), 2005
Modified (Cretnik)	2 Vicryl	4	214	Čretnik et al (37), 2000
Double Kessler with flap	1-0 Silk	4	218	Gerdes et al (58), 1992
Krackow locking loop	2 Ethibond	4	222	Benthien et al (61), 2006
Krackow suture	1 Ethibond	4	276	Hufard et al (62), 2008
Krackow suture	2 FiberWire	4	283	Cottom et al (64), 2017
Krackow suture	2 FiberWire	4 (+ epitendinous)	313	Dekker et al (63), 2017
Achillon	1 Ethibond	6	342	Hufard et al (62), 2008
PARS	2 FiberWire	6 (sutures)	353	Dekker et al (63), 2017
PARS	2 FiberWire	6 (anchors)	385	Cottom et al (64), 2017
Triple bundle technique	1 Ethibond	6	453	Jaakkola et al (59), 2000
Krackow locking loop	2 FiberWire	4	582	Benthien et al (61), 2006

with locking-type sutures thus do have impact on the strength of the repair, but also on the biological potential of healing (diminished tendon blood supply) and possible complications such as suture extrusion and friction within the paratenon; they may even be palpable under the skin (particularly if performed in an open or semi-open way and with nonresorbable thread), which might result in the need for reoperation (31).

The strength of the repair together with the residual gap after approximation of the torn ends might have an impact on the repeat rupture rate. Fibrous tissue that is not as strong as tendon and fills the gap, which is always present owing to retraction of the triceps muscle after complete Achilles tendon rupture (27,36), might be responsible for a higher number of repeat ruptures in conservative treatment. Deng et al (65) found in their systematic review and meta-analysis of randomized controlled trials 8 eligible randomized controlled studies involving 762 patients and rerupture in 14 of 381 (3.7%) surgically treated patients and in 37 of 377 (9,8%) nonsurgically treated patients. According to the literature, functional rehabilitation, even in conservative treatment, reduces the number of repeat ruptures (12,17–19). Early ankle motion, combined with early weightbearing, was proposed to become the standard rehabilitation protocol after surgical treatment of acute Achilles tendon ruptures, as it is associated with a lower complication rate and achieves superior and more rapid functional recovery than conventional immobilization (66). This concept should be accepted also in percutaneous (minimally invasive) treatment. During early ankle motion combined with early weightbearing, repaired Achilles tendons are exposed to a lot of (cyclic) loading. Resistance to elongation together with resistance to rupture under cyclic (repetitive) loading was intensively studied in biomechanical testing of open and percutaneous types of repair (61,64,67–69). Manent et al (67) evaluated the double Kessler, double Bunnell, Krackow, and percutaneous Ma and Griffith techniques and recommended double Bunnell sutures for the surgical treatment of acute Achilles tendon rupture. Van Dyke et al (68) found giftbox-modified Krackow repair superior to Bunnell technique for midsubstance Achilles tendon ruptures. Clanton et al (69) found comparable ultimate strengths of repairs (cycles to failure) across the open repair (3 modified Kessler suture repairs) and 3 minimally invasive percutaneous Achilles tendon repair techniques (Achillon system, PARS system, and Achilles midsubstance Speed Bridge repair variation [Arthrex, Naples, FL]). According to their findings, Cottom et al (64) recommended stronger constructs, such as a modified knotless technique, using the suture anchor. Stronger repair could thus support more confidence and resistance against widening of the gap during the functional rehabilitation and healing with elongation of the ruptured Achilles tendon (70,71), which might be beneficial also in reducing the incidence of repeat rupture. Patients in our series could start with partial weightbearing (5 to 10 kg) within the first 3 weeks after the procedure and to put weight as much as tolerated (until pain) after 3 weeks. They were encouraged to start immediately with range-of-motion exercises as much as their immobilization allowed, which was designed in a way that immediately enabled plantarflexion but restricted dorsiflexion. There was no increase in dorsiflexion or loss of plantarflexion for >10° observed in our patients at the final examination (which could be the consequence of tendon elongation).

Percutaneous repair is associated with a repeat rupture rate from 2.6% to 16.7% (9,23,29,30,32–36), although some articles about percutaneous repair without this complication can be found (20,22,31). Hsu et al (31) reported in their retrospective cohort study no reruptures in treatment of 101 patients with PARS system and 169 patients in an open manner. Bartel et al (72) reported in a systematic review of incidence of complications after Achillon system in 8 eligible of 33 studies a repeat rupture incidence of 3.2% (8 of 253). In our series, the repeat rupture rate for complete ruptures was 1.11% (3 of 270) and 1.85% (5 of 270) for partial repeat ruptures (2.96% altogether in 98.8% finally analyzed patients), which could be compared to the rerupture rate in meta-analyses for the open operative reconstruction (1.4% to 4.4%) (4,6,8–11,13,65).

Semi-open methods were introduced to reduce problems with sural nerve entrapment as well as for the control of approximation of torn ends. Opening the site of the rupture and introducing different types of (costly) devices or surgical instruments (forceps) (28–31,54) can indeed reduce the occurrence of sural nerve problems, but it leads to the same concerns as with the open fractures—losing (biological) healing potential with mediators and molecules in hematoma and increasing risk of infection and wound dehiscence (27,31,36,73,74). There were attempts to solve this problem with biological enhancement, such as adding platelet rich plasma, but there is still lack of evidence to support this solution (75).

Severe wound infection is, along with repeat rupture, the most important complication with lasting negative effect on outcome (9,10,13,36,72–74,76,77). Meta-analyses in open procedures revealed a deep infection rate of 2.36% (10,13). Reports of infection rate with the use of percutaneous and semi-open methods differ quite a lot, from 0% to 13.3% (9,22,23,27,31,35,36,75). Bartel et al (72) reported in the systematic review of incidence of complications after Achillon system an infection rate of 0.8% (2 of 253). Saxena et al (77) reported that the overall incidence of wound infections in surgeries pertaining to the Achilles tendon was 3.1% (7 of 219). In our series, no patient received antibiotic prophylaxis, including patients with diabetes, corticosteroid use, and smoking, which were found together with age to be major risk factors for infection (73,77), and 1 superficial infection (0.3%) occurred. The oldest patient was 83 years old; there were no complications in his treatment.

Some authors reported complete elimination of sural nerve problems using semi-open methods (29,30,31), but this problem occurs according to meta-analysis in 0.78% in conservative treatment (10) as well as in open operative repair in up to 8.76% of cases, despite the ability to preserve the sural nerve through cautious operative technique (10,78). Assal et al (29) reported no sural problems in the first article using Achillon system, but Bartel et al (72) reported in a systematic review of incidence of complications after using the same system 1.2% (3 of 253) sural nerve injuries. In the presented series, transient sural nerve problems, which spontaneously resolved in 2 to 10 months, occurred in 5.18% (14 of 270 patients). As the sural nerve crosses the lateral border of the tendon 8.7 to 12.4 cm proximally to the Achilles tendon insertion (47), from that area toward proximal, the position of the entry site of the thread should not cross the lateral edge in performing percutaneous suturing. If operating under local anesthesia, patients should be warned to immediately report if any changes in sensation occur within the area of anesthetic infiltration. In such cases, the entry point of the needle should be moved medially. In our series, we used resorbable thread (Vicryl no. 2), and there was no need to perform any surgical revision or release in patients with sural nerve problems, as they all spontaneously resolved. This material was strong and rough enough to enable good apposition without cutting the tendon ends during the pulling maneuver, with spontaneous further biodegradation and thus probably relieving the sural nerve problems, which might be entrapped in the scar formation in the first weeks in the healing process (36,65), and that might benefit the procedures such as stretching and friction massage during physiotherapy after final healing.

Besides palpation, approximation of the torn ends can be verified by ultrasonography (27,36). A transducer can be simply put in a sterile glove or sack for arthroscopic cameras with the use of sterile lidocaine for urinary catheterization as medium (27,36). Ultrasonographic control in our series confirmed good approximation of the torn ends, and even in the cases with friable ends and questionable clinical (palpable) diastasis, ultrasound demonstrated that the diastasis never exceeded 0.5 cm. This amount of diastasis has been considered acceptable in functional conservative treatment (79,80). It seems therefore that in terms of controlling apposition of the ends, there is no real need to open this

area or to use an arthroscope, particularly if keeping in mind loss of biological potential and increased risk of infection.

There is no clear consensus about venous thromboembolism (VTE) prophylaxis in patients after Achilles tendon rupture (12,81,82). The reported overall incidence for VTE in foot and ankle surgery with and without chemoprophylaxis was 0.6% (95% confidence interval [CI] 0.4% to 0.8%) and 1% (95% CI 0.2% to 0.7%) (81). Calder et al (82) found greater risk of VTE in patients with Achilles tendon rupture, with a clinical incidence of 7% (95% CI 5.5% to 8.5%). Patel et al (81) reported lower overall rates in patients with Achilles tendon rupture for deep venous thrombosis of 0.43% (5 of 1172) and for pulmonary embolism of 0.34% (4 of 1172). The American College of Chest Physicians' most recent review recommends against chemical prophylaxis in lower leg injuries requiring immobilization (83). Functional treatment with early ankle motion and early weightbearing could diminish the negative effect of immobilization, and thus the risk for deep vein thrombosis. It is necessary that patient-specific risk factors for VTE be used to assess patients individually (82,83). In our series with no routine thromboprophylaxis (there were no patients on routine anticoagulant therapy) and enhancement of early ankle motion with early weightbearing in patients, there was 1 case of deep venous thrombosis (0.37%) and no case of pulmonary embolism. As the operation was performed in local anesthesia with infiltration, patients who might have been on peroral anticoagulants should be switched to low molecular weight heparin and reverted to peroral anticoagulants in the days after the surgery.

Percutaneous techniques are associated with a lower number of overall and particularly major complications in comparison to conservative and open operative techniques (9,13,31,36,72,84). According to meta-analysis by Khan et al (9), the overall incidence of complications for the open technique was 30.4%, the closed technique 15.3%, and the percutaneous technique 10.3%. Hsu et al (31) reported the lowest overall complication rate of 5.0% (5 of 101) using the PARS system. All cases were operated under regional and general anesthesia with a thigh tourniquet and required 2 reoperations (2%) because of foreign-body reaction to FiberWire® (Arthrex, Naples, FL) suture (31). Bartel et al (72) reported in the systematic review of incidence of complications after Achillon system an overall complication rate of 8.3% (21 of 253). Saxena et al (77) reported an overall incidence of complications in surgeries pertaining to the Achilles tendon of 10.0% (22 of 219). The incidence of overall major and minor complications in our study was 9.25% (25 of 270), with no deleterious complications such as deep infection and no allergic reaction to lidocaine (all the patients were operated under local anesthesia with no additional analgesia [blocks, etc.]), which makes the presented method comparable to previously mentioned studies and indicates almost no contraindications for this type of treatment, even in elderly patients with comorbidities (85).

Many different scoring systems have been proposed for assessment of clinical outcome after Achilles tendon rupture treatment, but none has been universally accepted, and thus, a comparison of results is rather difficult (1,3,17,29,40–44,86). There are many reasons for that, including subjective parameters in some scales and high technical demands and costs in others (12,27,36,41). AOFAS hindfoot-ankle score (40) was an attempt to solve this dilemma, showing good reliability and validity compared with other scoring systems, despite still including some subjective determinations and parameters less relevant to Achilles tendon rupture treatment (27,41,42). Some adapted scores such as the Achilles Tendon Total Rupture Score (86) had not been developed and reported when our prospective study started, so we stayed with AOFAS hindfoot-ankle score, which has been used in many other studies (29,30,53,87). The average AOFAS hindfoot-ankle score of 96.10 in our study shows comparable results to other percutaneous and minimally invasive methods (29,30,53,87).

One valuable objective assessment of tendon strength is isokinetic testing (17,44,88). As this is associated with many, particularly logistic, technical and financial factors, this testing is not universally accepted in assessment scores (3,17,36,44). Isokinetic studies in other studies showed no statistically significant difference in strength, power, or endurance between open and percutaneous repair (23,24,89). It should be stressed that the return of strength in the patients following Achilles tendon rupture is very dependent on the patient's interest, motivation, and insurance demands. These factors may also influence the more objective evaluation techniques, such as isokinetic measurements, and not only the type of treatment or postoperative rehabilitation.

The Achilles tendon, together with soleus and both gastrocnemius muscles (musculotendinous complex), provides the ability to rise on toes (90,91). This is the basic idea of clinical testing of the strength and functional outcome with heel-rise test (46,70,71). Lunsford and Perry (46) proposed 25 repetitions for a grade of normal when using the standing heel-rise test. Silbernagel et al (70,71) found good validity and greater ability to detect differences between the injured and the uninjured sides with the heel-rise test that measures not only the number of heel-rise repetitions, but also the height of heel-rise repetitions and comparison to the noninjured side (limb symmetry index). Using these criteria, we found in our series 68.91% of patients who regained symmetric strength after percutaneous repair and completed rehabilitation, but also 9.73% of patients who were not able to pass the heel-rise test (test 2) even with the uninjured leg. Only 2.24% (6 of 267) patients exhibited reduced strength in a way that they were not able to pass the heel-rise test with an injured leg but were able to do so with a noninjured leg.

Assessment of a patients' functional recovery in comparison to their previous activities could be also a useful approach in assessment of different methods and outcome. Lea and Smith (15) took a very basic approach to outcome; if the patient returned to the preinjury activity level, the outcome was considered good. The results of our study were encouraging in this respect, as 94.38% of patients were satisfied with their treatment, and 80.89% of them returned to all their previous activities without problems. There were an additional 16.85% patients who returned to their previous activities but reported some difficulties, and only 2.24% were not able to return to previous activities (these were the patients who were not able to pass the heel-rise test with a noninjured leg, as well). Hsu et al (31) reported 88% of patients who were able to return to baseline activities by 5 months after surgery. Almost 20% of patients in our study who were not able to return to all previous activities without difficulties seems a high number, particularly for athletes, but there might be some other factors affecting the outcome (such as motivation or litigious and compensation reasons), as all 9 professional athletes (with high motivation) returned to all their previous activities without complaints or limitations within 6 months, some of them already within 3 months.

Long-term studies bring some weaknesses and limitations, too. There were many changes in the 15-year period, particularly about technical facilities—ultrasonographic machines and particularly magnetic resonance imaging in 1991 were not in routine daily practice as today, and intraoperative control with ultrasonographic transducers was at that time not so easily available. Different surgeons performed procedures and had to gain experience and skill in the modified method. Soft casts and functional orthoses were costlier and not popular at the beginning, and it was not easy to achieve good patient compliance, as there was (and still is) no universal assessment protocol, and there were many concerns from "senior surgical authorities," particularly about local anesthesia and functional rehabilitation. All these problems might have caused some heterogeneity and (somehow) influenced strategy and possibly end results, but with many answered issues, so that future results could only be better.

In conclusion, long-term results with the use of proposed modified percutaneous repair of the ruptured Achilles tendon under local anesthesia support this method as a reasonable option for the treatment of acute total Achilles tendon rupture. It provides biomechanically strong

repair and offers a possibility for good adaptation of torn ends, with restoration of original length and postoperative functional treatment in an outpatient manner with almost no contraindications, including elderly persons with comorbidities. It carries a low incidence of complications and has a repeat rupture rate comparable to open procedures, with the encouraging results of our patients' return to preinjury activities.

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