



Minimally invasive versus open surgery for acute Achilles tendon rupture: a systematic review

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Abstract

Introduction: This review provides a comprehensive description of clinical, functional outcomes, and complications after open and minimally invasive surgery for Achilles tendon ruptures.

Sources of data: We systematically searched Medline (PubMed), EMBASE, CINAHL, Cochrane, Sports Discus and Google scholar databases using the combined keywords 'open repair', 'percutaneous surgery', 'minimally invasive surgery', 'Achilles tendon rupture', 'complications', 'infections', 'wound disorders' to identify articles published in English, Spanish, French and Italian.

Areas of agreement: Twelve studies fulfilled our inclusion criteria. Six studies were retrospective, five were randomized controlled trials and one was a prospective investigation. Of a total of 781 patients, 375 underwent open repair and 406 percutaneous surgery. Different procedures were performed for open and minimally invasive repair.

Areas of controversy: The range of motion was significantly greater after percutaneous repair than open surgery. The number of complications that occurred after open surgery was higher than after minimally invasive surgery.

Growing points: Minimally invasive surgery is less expensive and less time demanding.

Areas timely for developing research: Minimally invasive and open surgery of the Achilles tendon are grossly equivalent. However, iatrogenic neurological complications are more frequent after percutaneous repair. Novel percutaneous repairs have been proposed to minimize the risk of sural nerve injury.

Key words: Achilles tendon rupture, minimally invasive surgery, open repair surgery

Introduction

The Achilles tendon is the strongest and thickest tendon in the human body, but acute ruptures are frequent in young athletes and middle-aged subjects who practice recreational activities.^{1,2} Most of these injuries occur in soccer, tennis, badminton and squash players³ but 25% of ruptures take place in sedentary patients.⁴ The incidence rate ranges from 6 to 18 per 100 000 per year.^{5,6} Even though the rupture seemingly occurs as consequence of a traumatic insult on a nevertheless healthy tendon, in reality it may be the end result of a single eccentric contraction on a tendinopathic yet often clinically asymptomatic tendon.⁷ Management of acute ruptures of the Achilles tendon is still controversial.^{8,9} The conservative approach, usually preferred for older low demand patients, should be weighed against the relatively high risk of re-rupture and long time to return to pre-injury activities offered by surgery.^{10,11}

However, Willits *et al.*,¹² in a randomized controlled trial, showed acceptable and clinically similar outcomes of patients with acute Achilles tendon ruptures, who had been treated with accelerated functional rehabilitation alone compared with those who had received operative repair and accelerated functional rehabilitation.

A recent meta-analysis demonstrated that non-operative management using functional bracing with early mobilization has similar re-rupture rates and has the advantage of a decrease number in other complications.¹³

Open, percutaneous or minimally invasive procedures have been used successfully, especially in young subjects. Open surgery provides good strength to the repair, low re-rupture rates and reliably good

endurance and power to the gastrocnemius-Achilles tendon complex.¹⁴ However, major complications such as deep infection and wound necrosis may occur.¹⁵ Therefore, minimally invasive procedures^{16–20} have been successfully used to avoid these complications.

We compared clinical and functional outcomes after open and minimally invasive surgery to the Achilles tendon. The modified Coleman score (CMS)²¹ was used to assess the methodological quality of the articles included in the present study. This system is reliable and validated, and it has widely been used in the orthopaedic literature.^{22–27}

We point out that this is not a meta-analysis, but a descriptive quantitative review, and, according to the literature and relatively short-term available studies, it is not possible to draw definitive conclusions.

Search and study selection

Relevant studies were searched in Pubmed, Medline, Ovid, Google Scholar and Embase databases since their inception, combining keywords ‘Open repair’, ‘Percutaneous’, ‘Minimally invasive surgery’ and ‘Achilles Tendon ruptures’. We included studies published in English, Italian, French and Spanish in peer reviewed journals that reported clinical and functional outcomes of patients who had undergone open or percutaneous surgery for repair of Achilles tendon ruptures. Percutaneous procedures were included into the spectrum of minimally invasive surgery. Biomechanical reports, studies on animals, cadavers, *in vitro* or animal studies, case reports, literature reviews, technical notes, letters to editors and instructional courses were all excluded. Two authors

(A.V. and A.D.B.) independently assessed the abstract of each publication, selecting on the basis of its content, and excluding articles if the abstract was not available. When inclusion or exclusion was not possible based on the abstract, we downloaded the full-text versions. The reference lists of articles selected were fully reviewed by hand to identify articles not included at the first electronic search.

We first identified the abstracts of 64 articles and downloaded the full text of 20 articles. To avoid bias, all the authors retrieved, reviewed and discussed all the 20 articles. At the end of the study selection process, we included 12 relevant publications (Fig. 1).

Quality assessment

Two investigators (A.V. and A.D.B.) evaluated blindly and separately each study on two separate

occasions 14 days apart, using the Coleman methodology score (CMS), a 10 criteria scoring list for methodological assessment of the quality of selected studies.²¹ The criteria included are study size, mean follow-up, number of different surgical procedures included in each reported outcome, type of study, diagnostic certainty, description of surgical procedure given, description of post-operative rehabilitation, outcome criteria, procedure for assessing outcomes and description of subject selection process. This list gives a final score from 0 to 100, in which a perfect score of 100 would represent a study design that largely avoids the influence of chance, various biases and confounding factors. Two authors scored the methodological quality of the studies twice, with a 10-day interval between assessments. If disagreements were encountered, the two investigators debated controversial scores until a consensus was reached.

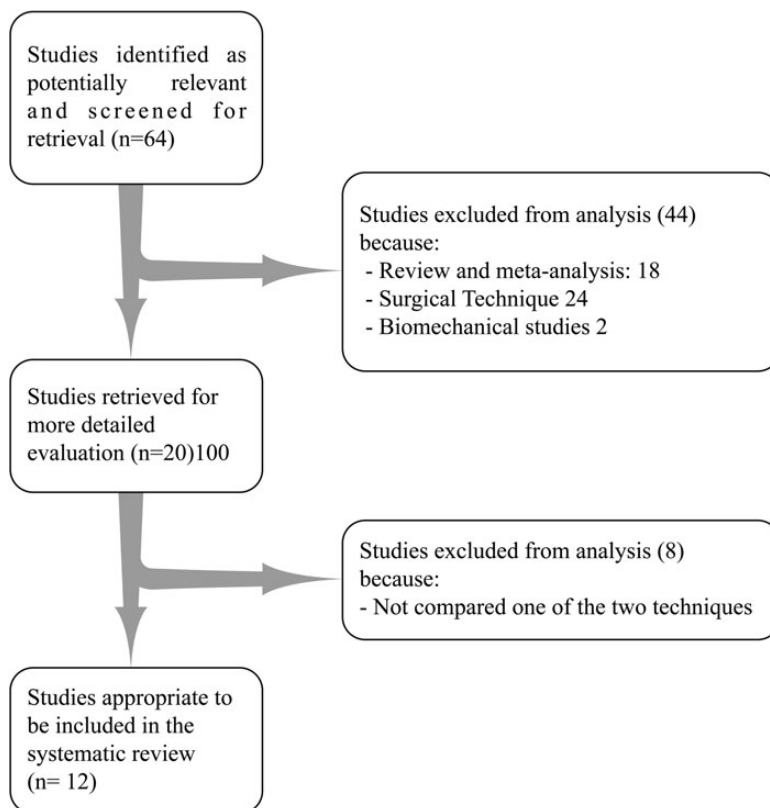


Fig. 1 Study selection process.

Data extraction

We extracted the data from each study included. We considered as major complications Achilles tendon re-ruptures. Furthermore, data on rates and kind of complications were extracted to assess safety, effectiveness and reliability of such procedures. We also extracted information on subjective functional outcomes such as range of movement, strength, circumference of the ankle, AOFAS score, Holz score, patient returned to work, pain, size of the scar and gait analysis.

Results

Twelve studies compared open and minimally invasive repair after Achilles tendon tears, from 2001 to 2012. The total number of patients ranged from 19²⁸ to 237,²⁹ for a total of 781 repairs: 375 patients underwent open repair and 406 percutaneous surgery. Pre-operative features, study size, follow-up and the modified Coleman score are reported in Table 1. The mechanism of injury was described in six studies. Most patients were injured during sports activity, from 23³⁰ to up 70%.^{28,29,31,32} Specifically, soccer,^{29,31,32} badminton^{28,33} and basketball^{29,31} were the main types of sports.

The incision length was remarkably different: it averaged a total of 3.4 cm after minimally invasive surgery and 12 cm after open repair. Therefore, the cosmetic appearance was different. Most patients operated in a minimally invasive fashion were satisfied with the status of the scars, and rated their condition as 'good' or 'excellent'. However, the method for assessing the status of the skin was not standardized.

Ebinesan *et al.*³³ evaluated the cost of a single procedure per each method: open surgery £1681, percutaneous surgery with general anaesthetic £862 and percutaneous surgery with local anaesthetic £558.

Coleman score

The modified Coleman methodology score averaged 57.5 (range from 39³⁰ to 80²⁹) (Table 1).

Six studies were retrospective, five were randomized controlled trials and one was a prospective investigation. The surgical technique was adequately described in almost all studies. Postoperative rehabilitation was scored 10/10 in 6 studies^{19,28,29,33–35} 5/10 in 1,³⁶ and 0 in 5.^{30–32,37,38}

Subject selection criteria scored 15 in 2 studies,^{28,29} and 10 in the remaining studies. The diagnosis was mainly based on clinical criteria: palpable gap in the tendon,^{28,29,32,34,36,38} positive calf squeeze test,^{28,29,32,34,36,38} clinical signs of the rupture (patients were unable to raise on their toes or heels),²⁹ ultrasonography^{29,36,38} and MRI scan.³⁸

The categories 'mean duration of follow-up', 'description of surgical procedure' and 'outcome measures' had the highest scores, whereas the categories 'study size' and 'type of study' had the lowest scores.

Surgical techniques

Three hundred and seventy five patients underwent open surgery. Specifically, a Kessler end-to-end repair^{29,35,36} and a Krakow end-to-end suture^{28,32,34} were undertaken in three studies each and the modified Kessler suture,³¹ Lynn's,³⁸ Bosworth,¹⁹ Bunnell³⁷ and Lindholm³⁰ repairs were performed in one study each.

Four hundred and six patients underwent minimally invasive surgery. Specifically, a percutaneous Ma and Griffith repair was performed in two studies,^{19,30} the modified percutaneous technique by Ma and Griffith in four studies,^{29,31,33,37} and the Achillon suture system in five studies.^{28,32,34,35,38}

All procedures were performed with the patients prone. Different materials were used (Table 2).

Functional outcomes

Range of motion (ROM) and ankle function showed better outcomes after minimally invasive surgery in two studies,^{19,38} and comparable outcomes in seven studies.^{28,29,32,34–37}

Active plantarflexion and dorsiflexion of the ankle was measured with a goniometer with patients supine and the knee extended.^{19,32,35,36}

Table 1 Cohort features and CMS

Study	Date of publication	Sample size		Mean age (years)		Sex ratio (M:F)		Minimum follow-up (months)		Coleman score (CMS)
		Open surgery	Minimally invasive surgery	Open surgery	Minimally invasive surgery	Open surgery	Minimally invasive surgery	Open surgery	Minimally invasive surgery	
Lim <i>et al.</i> ³¹	2001	33	33	36.9	40.1	20/13	19/14	6	6	64
Rebeccato <i>et al.</i> ¹⁹	2001	15	37	Data not reported	Data not reported	Data not reported	Data not reported	12	12	66
Haji <i>et al.</i> ³⁷	2004	70	38	42.8	41.2	Data not reported	Data no reported	24	24	40
Cretnik <i>et al.</i> ²⁹	2005	105	132	37.6	40.2	99/6	124/8	24	24	80
Gigante <i>et al.</i>	2007	20	19	Data not reported	Data not reported	Data not reported	Data not reported	24	24	63
Ebinesan <i>et al.</i> ³³	2008	20	31	Data not reported	Data not reported	11/9	26/5	9	9	46
Valencia and Alcalà ³⁸	2009	28	28	Data not reported	Data not reported	Data not reported	Data not reported	4	4	48
Aktas and Kocaoglu ³⁴	2009	20	20	40.6	39.2	17/3	18/2	12	10	71
Chan <i>et al.</i> ²⁸	2011	9	10	42.44	41.7	Data not reported	Data not reported	6	6	44
Henriquez <i>et al.</i> ³⁵	2011	15	17	Data not reported	Data not reported	Data not reported	Data not reported	6	6	58
Grubor and Grubor ³⁰	2012	15	19	Data not reported	Data not reported	Data not reported	Data not reported	12	12	39
Kolodziej <i>et al.</i> ³²	2012	25	22	47.1	44.8	24/1	22/1	24	24	71

Table 2 Type of surgical techniques and materials

Study	Open surgery (technique)	Material used for open procedure	Minimally invasive surgery (technique)	Material used for minimally invasive procedure
Lim <i>et al.</i> ³¹	Kessler end-to-end	Polydioxanone No. 1	Modified percutaneous technique by Ma and Griffith	Polydioxanone No. 1
Rebeccato <i>et al.</i> ¹⁹	Bosworth technique	Data not reported	Kakiuchi and Ma and Griffith technique	Non-absorbable suture
Haji <i>et al.</i> ³⁷	Bunnell technique	Data not reported	Modified percutaneous technique by Ma and Griffith	PDS No. 1
Cretnik <i>et al.</i> ²⁹	Kessler end-to-end	Vicryl [®] Nos 2 and 4	Modified percutaneous technique by Ma and Griffith	Vicryl [®] No. 2
Gigante <i>et al.</i>	Kessler end-to-end	Vicryl [®] No. 1	Tenolig [®] system	Non-absorbable thread
Valencia and Alcalá ³⁸	Lynn technique	Vicryl [®] No. 1	Achillon [®] instrument	Data not reported
Aktas and Kocaoglu ³⁴	Krakow end-to-end	Ethibond No. 2	Achillon [®] instrument	Ethibond No. 2
Chan <i>et al.</i> ²⁸	Krakow end-to-end	Ethibond (non-absorbable)	Achillon [®] instrument	Ethibond No. 2
Henriquez <i>et al.</i> ³⁵	Kessler end-to-end	FiberWire [®] No. 2	Achillon [®] instrument	FiberWire [®] No. 2
Grubor and Grubor ³⁰	Lindholm technique	Data not reported	Ma and Griffith technique	PDS or Vicryl [®] (No. 0-1)
Kolodziej <i>et al.</i> ³²	Krakow end-to-end suture	PDS, Ethicon or Maxon, Covidien	Achillon [®] instrument	PDS, Ethicon or Maxon, Covidien
Ebinesan <i>et al.</i> ³³	Data not reported	Data not reported	Modified percutaneous technique by Ma and Griffith	Data not reported

Table 3 Functional outcomes measures

Study	Plantarflexion open	Dorsiflexion open	Plantarflexion minimally invasive	Dorsiflexion minimally invasive	AOFAS post-op open	AOFAS post-op minimally invasive
Rebeccato <i>et al.</i> ¹⁹	-15%	-20%	-10%	+13%	Data not reported	Data not reported
Cretnik <i>et al.</i> ²⁹	Data not reported	Data not reported	Data not reported	Data not reported	96.1	96.3
Valencia and Alcalá ³⁸	40.3° ± 0.59°	13.9° ± 0.12°	50.0° ± 0.42°	18.9° ± 18.2°	Data not reported	Data not reported
Aktas and Kocaoglu ³⁴	Data not reported	Data not reported	Data not reported	Data not reported	98.7	96.8
Chan <i>et al.</i> ²⁸	36.6° ± 5.8°	16.9° ± 2.9°	34.9° ± 5.3	18.5° ± 3.8°	Data not reported	Data not reported
Henriquez <i>et al.</i> ³⁵	40° [30–50°]	15 [5–30°]	40° [25–50°]	15 [5–30°]	Data not reported	Data not reported
Kolodziej <i>et al.</i> ³²	41.6°	12.6°	39.6°	14.2°	Data not reported	Data not reported

In two studies,^{29,34} the ROM of the ankle was measured using a goniometer with the patients supine and the knee at 90° flexion.

Haji *et al.*³⁷ used a subjective analysis of ROM, defining as normal 0°–15° of dorsiflexion and 0°–45° of plantarflexion, subdividing the reduced movement into mild, moderate and severe.

Active dorsiflexion was significantly improved after percutaneous repair than after open surgery^{19,28,32,37,38} (Table 3).

Plantarflexion and dorsiflexion averaged 41.1° and 16.6°, respectively, after minimally invasive surgery and 39.6° and 14.6° after open repair.

Strength was considered normal if patients were able to stand on tip toes on the operated leg. Specifically, it was normal in 92% of patients undergoing percutaneous repair and in 83% of those undergoing open surgery.³⁷

The isokinetic strength of the ankle muscles was tested in one study. The peak torque and total work were assessed with a Biodex System 3 dynamometer at 60° and 120°. At 12 months, there were no statistically significant differences between the two groups ($P < 0.01$).³⁶

The Kaiuchi repair resulted in a side-to-side difference of the calf circumference: on the operated side, it was 2% (0.67 cm) lower than contra-laterally. In addition, at MRI assessment, the volume of the calf was 91% of the uninjured side.¹⁹ At US imaging, the antero-posterior and cross-sectional diameters of the Achilles tendon were not statistically different at 4 and 12 months after surgery.³⁶

The average circumference of the ankle measured 25.7 cm after percutaneous repair³⁶ and 24.5 cm after open surgery ($P < 0.01$).³⁶

The American Orthopedics Foot and Ankle Society (AOFAS) hindfoot clinical outcome score was often used, although this scale has not been validated for Achilles tendon ruptures. The mean AOFAS ranged from 96.3 to 96.8 after percutaneous repair,^{29,34} and from 96.1 to 98.7 after open procedures.^{29,34} The Holz score assessment showed good results in 91% patients after percutaneous surgery and 88% after open repair.²⁹

Patients returned to work from 4.8 weeks³² to 2.8 months³⁵ after a minimally invasive operation

and from 5.5 weeks³² to 5.6 months³⁵ after open repair.

Pain was assessed in two studies; 1 month after the operation, the average VAS (Visual Analog Scale) score was 2.75 in the minimally invasive surgery group and 4.1 in the open group ($P < 0.001$),³⁸ after 24 months the average VAS score was, respectively, 1.6 and 1.7 ($P > 0.05$).³²

The average size of the scar was 12 cm (from 9.5³⁵ to 14.5 cm³²) long for patients undergoing open repair and 3.4 cm (range from 2.9³⁵ to 4.0 cm³²) long for those in whom percutaneous surgery had been undertaken ($P < 0.05$ ³²). These latter patients were also significantly more satisfied in terms of cosmetic appearance of the scar.^{32,35}

Gait analysis showed comparable stance duration, step length and stance time to both legs, after both operations.²⁸

Post-operative rehabilitation

Different post-operative rehabilitation protocols were applied. However, the protocol was identical in both surgical groups in almost studies, except in one.³⁶

After surgery patients were immobilized with a below knee cast in equinus for 2,^{28,33,36} 3,^{29,34,35,37} 4^{19,31} weeks, or with an above knee cast from 2³⁰ to 4³⁶ weeks. Immobilization in neutral position was then undertaken for 2,^{28,30} 3,^{29,34,35,37} 4^{19,33} or 6³¹ weeks.

Kolodziej *et al.*³² used a below knee cast that provided ~20° of plantarflexion for 6 weeks.

Full weight bearing was encouraged from 3,^{34,36} 4^{33,37} weeks to 6^{29,30,32,35} weeks following the surgical repair.

Only one study²⁸ reported the duration of rehabilitation: it was 3.60 months after percutaneous repair versus 4.56 months after open repair, on average.

Complications

The number of complications that occurred after open surgery is higher than after minimally invasive surgery (Table 4).

Table 4 Complications

Complications (781 patients)	Open (375 patients)	Minimally invasive (406 patients)
Re-ruptures	13	9
Deep infection	9	0
Deep vein thrombosis	3	3
Wound necrosis	17	1
Scarce tissue adhesions	4	0
Nerve injuries	7	12

Table 5 Details of nerve injury in the minimally invasive surgery group

Study	Date of publication	Type of nerve injury
Im <i>et al.</i>	2001	1 persistent paresthesia in the sural nerve territory
Haji <i>et al.</i> ³⁷	2004	4 transient sural nerve lesions
Cretnik <i>et al.</i> ²⁹	2005	6 disturbances in the sural nerve territory
Grubor and Grubor ³⁰	2012	1 transitory paresis of peroneal nerve

Re-rupture occurred in 3.4% of patients after open surgery and 2.2% after minimally invasive procedures.

Deep infections were defined by the identification of the micro-organism from the wound site, while in the superficial infections the diagnosis was made clinically.

The deep infection and superficial infection rates were, respectively, 2.4 and 4.3%, seen mainly in patients with open surgery.

Nerve injuries were more common in the minimally invasive than in the open surgery group (respectively 2.9 and 1.8%) (Table 5).

Six studies^{29–31,34,35,38} reported a significantly lower complication rate after minimally invasive repair.

Discussion

There are several limitations to the present investigation. Since individual authors have not been

contacted directly, a possible weakness is that methodological assessment does not necessarily reflect the scientific validity of the study, but is biased by the quality of reporting. The linguistic capabilities of the research team were limited to English, Spanish, Italian, French and German, possibly missing papers published in other languages. Finally, all the studies in this investigation lack long-term information.

The Coleman methodology score has been successfully validated to assess studies that have the highest levels of methodological quality.

The main finding of the present study is that in open and percutaneous repair of acute Achilles tendon ruptures, indications and outcomes, both clinical and functional, are grossly comparable. However, after minimally invasive repair, re-rupture rate is lower, and secondary postoperative complications, such as deep and superficial infections, and wound disorders are less frequent.

Deep infections did not occur in subjects who had undergone minimally invasive repair. On the other hand, the rate of superficial infections was 0.5 and 4.3% after minimally invasive and open surgery, respectively. The reason for this is that, when performing an open repair, the surgical trauma may add insult to injury. In addition, vascularization of the skin and surrounding soft tissues may be compromised and, inevitably, the healing process altered.^{39,40} In addition, the extent of the longitudinal wound incision and the exposure of soft tissue are crucial for the postoperative recovery.³⁵

On the other hand, iatrogenic neurological complications are more frequent in patients undergoing percutaneous repair, occurring in 2.9% of them, versus 1.8% of those undergoing open surgery. A plausible reason is that it is impossible to completely visualize local structures when the repair is minimally invasive. In fact, the sural nerve may be entrapped within the suture or damaged by the needle if it transfixes the nerve.²⁹ To reduce this, Amlang *et al.*⁴¹ and Henríquez *et al.*³⁵ proposed a percutaneous repair in which, through a small paramedial incision, the tendon was sutured to the muscle fascia, without injuring the sural nerve. However, it should be recognized that a 1%

difference in the rate of iatrogenic neurological complications, though statistically significant, does not bear much clinical relevance.

The hospitalization time of patients undergoing percutaneous repair is shorter, as is the average time to return to working activities. Also, 80% of recreational athletes may return to pre-injury activity level after a percutaneous repair.²⁰

Functional outcomes were not significantly different after minimally invasive and open surgery, even though active dorsiflexion of the ankle was seemingly improved after percutaneous repair.

On the other hand, clinical findings were markedly improved after minimally invasive surgery,¹⁹ in terms of strength, dorsiflexion^{28,32,38} and calf atrophy ($P < 0.01$).

On isokinetic assessment, peak strength and total work were comparable 1 year after minimally invasive and open surgery, whereas the ankle circumference was greater in patients undergoing percutaneous repair.³⁶ This finding probably depends on the increased thickness of the construct after minimally invasive repair.

Minimally invasive surgery is nevertheless a viable alternative to traditional more invasive open Achilles tendon repair, but biomechanical and clinical issues need to be further assessed and substantiated by future long-term studies. Compared with traditional open surgery, these data suggest that minimally invasive surgery provides lower re-rupture rate and general complications, and involves lower costs.

Conclusion

Minimally invasive and open surgery of the Achilles tendon are grossly equivalent, but more data examining the long-term functional status, recovery to pre-injury daily and sports activities are needed. Some concerns arise from the lack of data and information regarding the potential damage on the sural nerve in minimally invasive procedures, but the recent evidence is that minimally invasive surgery results in a lower rate of complications than open surgery, with a comparable functional outcome to traditional open procedures.

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