ORIGINAL ARTICLE

Minimally Invasive Achilles Tendon Repair Confers Faster Recovery and Reduced Complications Compared to Open Achilles Tendon Repair

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Abstract

Current literature shows that minimally invasive (MIS) tendo-Achilles (TA) repairs carry a lower risk of infection compared to open repairs. Our study aimed to assess whether MIS TA repair also contributed to improved patient outcomes as well as lowered infection and wound complication rates. Between January 2017 and December 2019, 19 patients underwent minimally invasive TA repairs performed by two fellowship-trained foot and ankle surgeons at a tertiary institution. A retrospective review of registry data was performed. Outcomes were measured to include AOFAS Score, RAND36 Scores as well as patient-reported satisfaction scores and visual analog scale (VAS) for pain assessment. Statistical analysis was performed using a Student's *t*-test for continuous variables and Pearson's Chi-squared test for categorical variables. The overall results showed that patients who underwent MIS TA repair had much faster recovery when compared to traditional open TA repairs. Of the 19 patients who underwent MIS TA repair, there were two cases of superficial wound infection compared to six in the open group ($p < 0.05$). The MIS TA repair arm of the study also had higher patient-reported satisfaction rates, lower VAS pain scores ($p < 0.05$), with better AOFAS and SF36 quality of life measures. Overall, the rate of superficial infection, wound complication and length of stay were all reduced in the MIS group with similar deep infection rates. Our study concludes that where possible, TA rupture should be repaired minimally invasively and by an experienced foot and ankle surgeon as this will yield the best outcomes for the patient.

Level of evidence: III

Keywords: Achilles tendon repair, Foot and ankle, Functional outcomes, Minimally invasive.

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Introduction

The Achilles tendon (tendo-Achilles or TA) is both the largest and strongest tendon in the human body and yet is the most commonly ruptured.[1–3] Tendo-Achilles rupture is noted to occur more commonly in men, with a peak incidence between 30 years and 39 years of age.[3–5] The literature reported incidence of acute TA rupture is up to 18 per 100,000 per year and this number will likely increase as more people partake in sporting and fitness activities.[4,5] Several reasons have been described for the predisposition of this tendon to rupture with three main mechanisms proposed. The first, being a sudden pushing off from the weight-bearing forefoot with the knee in extension, as seen in jumping sports such as basketball, badminton.[4,6,7] Second, when the ankle undergoes sudden dorsiflexion and thirdly during violent dorsiflexion in a plantarflexed foot.[4,6,7] In a study by Suchak et al., it was found that 75% of ruptures occurred from sporting activities, while 11% and 5% were from traumatic accidents and activities of daily living, respectively.[5] The treatment of acute TA rupture can be broadly classified into operative and nonoperative management. Conservative management usually involves cast immobilization or functional bracing with a progressive range of motion (ROM) and strengthening-exercise-focused physiotherapy.[8] Operative management has seen significant growth in recent years and can be further subclassified into open, percutaneous, or minimally invasive surgical (MIS) repairs.

Several studies in the current body of literature have demonstrated that both open surgical repair and conservative management can produce favorable outcomes. Zhang et al. found in their systematic review that conservative management may even be preferred at centers capable of offering functional rehabilitation as it demonstrated lower re-rupture risks compared to surgical intervention.[9,10] One key benefit of conservative management is that the patient can avoid surgical complications and associated costs.[11,12]

Several studies that have compared minimally invasive to open surgical TA repair have shown differing results. In a meta-analysis by Grassi et al., their study concluded that MIS repair lowers the risk of surgical complications without increasing re-rupture risk.[12] Our study aims to further elucidate whether patients who underwent MIS repair had better outcomes as evidenced by standardized outcome scores compared to patients who underwent open repairs.

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Our study hypothesized that MIS TA repair would demonstrate more favorable outcomes in our local population compared to the traditional open repair. We hypothesized that this technique will also result in fewer surgical complications such as wound breakdown, infection, and re-rupture.

Materials and Methods

Our study was approved by the hospital's ethics committee (CRIB 2020/3125) and carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Between January 2017 and December 2019, 89 patients with acute Achilles tendon rupture underwent surgery by a consultant surgeon at a tertiary institution. Among these patients, 19 underwent minimally invasive surgery (MIS) Achilles tendon repair performed by a fellowship-trained foot and ankle surgeon. Each patient in the treatment group was matched to another patient in the nontreatment group with the closest propensity score using the nearest-neighbor method and a 2:1 matching without replacement was performed. Patients who suffered from polytrauma, bilateral TA rupture, or lacking outcome scores at 12 months and 24 months or lost to follow-up were excluded from this study. After meeting the above inclusion criteria, 19 patients remained who underwent MIS TA repair and 38 who underwent open repair.

MIS Achilles Tendon Repair

Minimally invasive surgery was performed in all patients under general anesthesia by an experienced fellowship-trained foot and ankle surgeon at our tertiary center. All patients received prophylactic antibiotics (Cefazolin or Clindamycin if allergic to penicillin) and were operated on in the prone position with the use of a tourniquet for hemostasis control.

The patient was first positioned with the leg in neutral rotation and the foot left hanging off the bed to allow control of ankle movement. Examination under anesthesia was performed and the defect in the Achilles tendon was palpated and marked out. A transverse incision was then made over the rupture site. After careful dissection down to the para-Tenon, the tendon is then mobilized, and the percutaneous Achilles repair system [PARS (Arthrex, Inc, Naples, Florida)] guide is introduced.[10] Fiberwire (Arthrex, Inc, Naples, Florida) sutures are then passed through the limbs of the device and this is repeated for both the proximal and distal stump ends. The suture ends were organized and tied accordingly (proximal pair of sutures on the proximal stump with the most distal pair of sutures on the distal stump).

Open Achilles Tendon Repair

Open repair was performed by one of five experienced, orthopedic surgeons at our tertiary institution under general anesthesia. All patients again received prophylactic antibiotics (Cefazolin or Clindamycin if allergic) and were operated on in the prone position. A posteromedial skin incision was made over the rupture site, and the para-Tenon was then carefully identified before further incision. The tendon was repaired end to end using core suturing with two strong semi-absorbable sutures utilizing a modified Kessler technique.

Postoperative Rehabilitation Protocol

All patients underwent the same postoperative rehabilitation protocol and received care from an experienced physiotherapist at our tertiary institution. Patients were placed in a below-knee cast in 30° of plantarflexion for at least 2–3 weeks. This was followed by gradual progressive dorsiflexion to neutral with immobilization using a pneumatic walker boot (Aircast XP Diabetic Walker, DJO, Vista, California). The patients are kept on non-weight-bearing for at least 6 weeks. Return to sports is generally started after about 3 months when they have achieved enough strength and ROM.

The patients were prospectively followed up for 24 months. Two independent healthcare professionals, who were not involved in treatment, assessed the patients preoperatively and at 3, 6, 12, and 24 months postoperatively. The primary outcomes measured in this study was the American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale (AOFAS Score) and RAND36 Health Survey 1.0 (RAND Health, Santa Monica, California, United States)[14] patient questionnaire to assess measures of health-related quality of life. Secondary outcomes measured included patient-reported satisfaction scores and visual analog scale (VAS) for pain assessment. Patients were also assessed for complications such as wound breakdown, superficial or deep infection, repair failure, and length of hospital stay.

Visual analog scale was used for the assessment of pain, with 0 being no pain and 10 being the worst possible pain.[15] It had been shown to have good validity and internal consistency when used as a measurement of pain.[16] Hindfoot-specific outcome measure utilized the American Orthopaedic Foot and ankle society ankle-hindfoot scale (AOFAS).[17] A maximum of 100 points is possible in a patient with no pain and functional limitation. Forty points were assigned to pain, 50 to function, and 10 to alignment.

The quality of life of patients was assessed with the use of RAND 36-Item Health Survey 1.0 (RAND Health, Santa Monica, California, United States),[18] which consisted of eight subscales: physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health. Two higher-order summary scores: physical component score (PCS) and mental component score (MCS), were developed to aggregate the most highly correlated subscales and to simplify analyzes without substantial loss of information. The scoring approach for these summary scores was based on the assumption that the physical and mental health factors were correlated. Therefore, only four subscales contributed to the PCS and the other four to the MCS. These two summary scores were found to have good validity in discriminating among clinically meaningful groups, as well as high test–retest reliability estimates when utilized in a general population.[14,19]

Statistical Analysis

Statistical analysis was carried out using SPSS® 26.0 (IBM, Armonk, New York, United States). Statistical analysis was performed using Student's *t*-test for continuous variables, Pearson's Chi-squared test for categorical variables. A *post hoc* power analysis was performed with $a = 0.05$ calculated for AOFAS scores at 24 months follow-up yielding power of 0.51. Statistical significance was defined as a p value of <0.05 in this study.

Results

Patient Demographics

Both the MIS and open groups had similar gender distribution ($p < 0.001$) and mean body mass index BMI ($p = 0.29$). The MIS group's mean age was 38.8 compared to 48.9 in the open group ($p = 0.009$). The average operating time for the MIS group was 97.5 minutes

compared to 71.2 in the open group ($p = 0.021$). The mean length of stay for the MIS group was 1.7 days compared to 3.7 days in the open group ($p = 0.040$) (Table 1).

Pain

While comparing VAS, the MIS and open groups both had significant reductions compared to preoperative with mean scores of 0.4 and 0.7, respectively, at 6 months ($p = 0.280$). At 24-month follow-up, average patient satisfaction was 4.0 out of 5 for the MIS group compared to 3.0 for the open group ($p = 0.028$) (Table 2).

Outcome Scores

At 24-month follow-up, both MIS and open groups had similar AOFAS scores with 98.5 and 97.0, respectively, with significant improvements compared to preoperative scores ($p = 0.667$). Similarly, at 24 months, the MIS group had higher scores in the RAND 36 physical function and general health component scores compared to the open repair group; however, all other scores were comparable (Tables 2 and 3).

Complications

The MIS group suffered two superficial wound infections compared to six in the open repair group which were all managed conservatively with oral antibiotics ($p < 0.001$). There were no wound breakdowns in the MIS group, however, the open repair group had three wound breakdowns (7.9%) which required IV antibiotics and formal debridement ($p = 0.008$). Neither group suffered any neurovascular injury or deep infection. In terms of reinjury, the MIS group suffered 1 retear as diagnosed by either US or MRI within 24 months of index surgery compared to two in the open repair group ($p = 0.076$). At 24-month follow-up, one patient in the MIS group complained of scar hypersensitivity compared to four patients in the open repair group ($p = 0.182$) (Table 4).

Table 1: Patient demographics, surgical time, and length of stay (SD)

	MIS (n = 19)	*Open (n = 38)*	*p value*
Gender (%)			
Male	14 (73.6%)	26 (68.4%)	<0.001
Female	5 (26.3%)	12 (31.6%)	<0.001
Age	38.8 (8.7)	48.9 (11.4)	0.009
BMI	25.3 (3.8)	26.5 (2.8)	0.29
Surgical time (minutes)	97.5 (37.0)	71.2 (4.6)	0.021
Length of stay (days)	1.7 (0.8)	3.7 (1.9)	0.040

Table 2: Visual analog pain score, satisfaction, and AOFAS scores (SD)

	MIS (n = 19)	*Open (n = 38)*	*p value*
VAS			
Preoperative	6.6 (1.7)	4.9 (1.9)	0.038
3 months	2.2 (3.0)	1.0 (1.4)	0.026
6 months	0.4 (1.4)	0.7 (1.1)	0.280
12 months	0.1 (0.5)	0.1 (0.3)	0.102
24 months	0 (0.3)	0 (0.2)	0.343
Satisfaction scores			
3 months	2.0 (1.8)	3.0 (0.6)	0.011
6 months	3.7 (0.48)	3.4 (0.55)	0.553
12 months	4.0 (1.1)	2.0 (0.78)	0.004
24 months	4.0 (0.4)	3.0 (0.89)	0.028
AOFAS score			
Preoperative	16.2 (16.2)	36.9 (18.2)	0.042
3 months	67.5 (24.9)	84.0 (11.3)	0.081
6 months	95.9 (4.5)	89.5 (8.4)	0.094
12 months	99.3 (1.5)	93.0 (2.8)	0.020
24 months	98.5 (2.1)	97.0 (2.3)	0.667

Table 3: RAND36 quality of life health survey scores (SD)

	Preoperative	*3 months*	*6 months*	*12 months*	*24 months*	*p value*
MIS ($N = 19$)						
PF	13.3 (24.5)	87.0 (6.7)	97.3 (4.4)	98.8 (2.5)	97.5 (3.5)	0.333
RF	13.1 (29.2)	40.0 (16.9)	95.4 (7.5)	97.6 (16.4)	87.5 (17.7)	0.816
BP	20.8 (21.6)	69.6 (11.6)	94.6 (10.8)	99.8(14.5)	99.8 (15.4)	<0.001
GH	81.4 (19.5)	89.6 (10.4)	95.6 (8.0)	98.5 (3)	98.9 (18.9)	0.034
Vit	77.9 (17.0)	88.0 (7.6)	95.4 (9.9)	98. 8 (2.5)	95.0 (7.0)	0.045
SF	30.9 (35.9)	85.0 (22.4)	100 (0)	99.4 (13.4)	99.4 (14)	0.089
RF E	90.5 (17.0)	95.0 (14.5)	98.85 (3.0)	99.7 (8.9)	99.1 (3.6)	0.011
MH	84.7 (10.8)	93.6 (8.3)	97.9 (4.2)	98.0 (4)	96.0 (5.6)	0.028
Open ($N = 38$)						
PF	24.4 (32.3)	85.0 (1.1)	91.7 (5.2)	92.5 (3.5)	97.5 (3.5)	0.333
RF	11.1 (33.3)	50.0 (25)	75.0 (41.8)	87.5 (17.7)	87.5 (17.7)	0.816
BP	32.4 (17.1)	61.5 (14.8)	76.3 (21.1)	86.0 (19.8)	99.8 (15.4)	<0.001
GH	84.2 (16.7)	45.0 (21.2)	83.5 (19.6)	72.0 (28.3)	98.9 (18.9)	0.034
Vit	83.3 (11.5)	47.5 (10.6)	78.3 (19.1)	85.0 (7.1)	95.0 (7.0)	0.045
SF	37.7 (43.3)	87.5 (17.7)	87.5 (20.9)	99.5 (4.7)	99.4 (14)	0.089
RF E	100.0 (18.9)	66.5 (47.3)	100 (0)	99.9 (6.5)	99.1 (3.6)	0.011
MH	80 (16.9)	64.0 (28.3)	86.0 (13.3)	90 (2.8)	96.0 (5.6)	0.024

PF, physical function; RF, role functioning; BP, bodily pain; GH, general health; Vit, vitality; SF, social functioning; RF E, role functioning emotional; MH, mental health

Table 4: Complications

	MIS (19)	*Open (38)*	*p value*
Superficial wound infection	2 (6.25%)	6 (16.7%)	< 0.001
Wound breakdown	0 (0%)	3 (7.9%)	0.008
Neurovascular injury	0 (0%)	0 (0%)	
Deep infection	0 (0%)	0 (0%)	
Re-injury	1 (5.3%)	2 (5.3%)	0.076
Scar sensitivity	1 (5.3%)	4 (10.5%)	0.182

Discussion

Minimally invasive techniques have allowed for faster recovery and reduced complication rates. Not surprisingly, the MIS arm had an increased operating time compared to the open group; however, there was a significant reduction in the LOS with the MIS group being discharged on average 2 days earlier than the open group. Patient-reported satisfaction not only improved with the MIS group, but it also leveled out compared to the open group which had a faster increase, with a subsequent drop-off in satisfaction. The reasons for this are likely multifactorial as several factors play a role in the healing of the TA.

Management

The management of TA rupture can be broadly classified into operative or nonoperative management.[3,11,20,21] Nonoperative management involves cast immobilization of the affected foot in plantar flexion, to allow the opposition of the ruptured tendon ends to undergo biological healing. This is followed by gradual, progressive weight-bearing and rehabilitation to strengthen the ankle with or without functional bracing.[22,23] Operative management can further be subclassified into open or percutaneous repairs. Literature reported complications are higher in operative repairs compared to nonoperative repairs, although long-term outcomes do not show significant differences.[1,3,11,24] Open repairs have been associated with higher complication rates ranging from wound complications, infections, and re-rupture.[2,9,20,25] Interestingly, in our study, the main difference between the open and MIS repairs was in the operative times which were longer for the MIS group.

Re-rupture

In their recent meta-analysis of 8 studies comprising a total of 182 patients, Grassi et al. found that patients who underwent MIS TA repair had a re-rupture rate of between 0% and 4% compared to open repairs whose re-rupture rate was between 0% and 6%.[12] Similarly, Garrick et al. found that re-ruptures tended to occur within the first 3 months of the initial injury at a rate of 3.2% in the operative group compared to 4.6% in the nonoperative group.[22] Yang et al. also found that in patients who underwent percutaneous treatment, the re-rupture rate was 3.1% compared to 2.7% in the conservative arm.[9] In their systematic review of 667 patients, Wilkins et al. found that patients treated with surgical intervention (be it open or MIS) had a pooled re-rupture rate of 3.6%, whereas those treated conservatively had a re-rupture rate of 8.8%.[24] In concordance, Jiang et al. also found that only 4.31% of patients in their operative arm suffered re-ruptures compared to 9.71% in the conservatively managed group.[1] These findings echo that of our study in that re-rupture rates were similar between both MIS and open groups occurring in 1 and 2 (5.3%) patients respectively.

Infection

One of the major considerations in foot and ankle surgery is that of surgical site infection. In their study, Marican et al. found that surgery on the foot is associated with a higher rate of superficial infection with surgeries on the TA being most commonly involved.[26] While comparing surgical TA repair *vs* conservatively managed TA ruptures, it is of little surprise to see that several studies show rates of deep infection are higher (2.36%) in surgically managed TA ruptures compared to conservative (0%).[1,23,24] While comparing the rates of infection between open TA repair and percutaneous repair, a study by Yang et al. found that the percutaneous arm had far lower infection rates (0.6%) compared to open repair (3.6%).[9]

With regard to preoperative use of antibiotics, Zgonis et al. noted in their study that postoperative outcomes (either wound complication or infection) were not affected by the use of preoperative antibiotics.[25] No patients suffered any deep infection in our study, however, the rate of superficial wound infections was higher in the open repair group with 6 (16.7%) having a superficial wound infection requiring treatment with oral antibiotics compared to just 2 (6.25%) in the MIS group.

Wound Complications

Incisions along the posterior leg are notable for their increased risk of wound healing complications.[2,27] The literature reported wound complication rate is between 8.2% and 14.6%.[2,12,28] Highlander et al. observed several risk factors associated with wound-related complications including advancing age, in particular patients over 50, use of tobacco, corticosteroids, and female gender.[27] In their study, Sorrenti et al. found that infection and wound complication rates increased significantly when the time to surgery after TA rupture increased.[8] Ademoglu et al. reported a complication rate between 3% and 7% for open TA repairs and noted that although satisfaction rates were high, skin and tendon necrosis associated with wound infections had the potential to be catastrophic.[28] These findings are in keeping with the angiosome theory of vascular supply to the lower extremity as an increased inflammatory response and reduced vascular perfusion will delay adjacent angiosome directed reperfusion *via* choke vessels.[29,30] In our study, there were no deep infections even at 2-year follow-up; however, the open group had far more superficial infections compared to the MIS with incision size likely playing a major factor. Again, our study findings echo that of existing literature in that there were no wound breakdowns in the MIS group but there were 3 (7.9%) in the open repair group that required formal debridement.

Nerve Involvement and Functional Outcomes

In their meta-analysis of 12 studies, Yang et al. observed that the rate of sural nerve injury in patients who underwent percutaneous TA repair was 5.5% compared to 1.2% in the open repair.[9] Functional outcomes after percutaneous repair appear to be comparable to that open repair.[1] Yang et al. found that the AOFAS score on average was 95.9 for the percutaneous group compared to 98.4 for the open group.[9] While assessing strength, patients who underwent operative and nonoperative repair were able to achieve a mean of 80% of plantar flexion and 100% of dorsiflexion strength of the unaffected limb.[1] The mean time taken for sick leave was also significantly shorter in the operative arm compared to the nonoperative.[1] Neither group complained of any numbness or neuropathic pain at 2-year follow-up. This is in contrast to current literature which shows that the rate of nerve involvement is higher

in percutaneous/MIS surgery as there is a lack of direct visualization. Our study shows that with careful selection of incision sites, the higher risk of neve involvement can be mitigated.

Our study findings are similar to previous studies in that complication rates remained low for both groups with only six patients suffering complications in the MIS group. In terms of LOS, both had relatively short hospitalizations with the MIS group spending on average 2 days less than the open repair group. Interestingly, the short-term outcomes favored the open repair group, however, scores either tailed off or did not improve further compared to the MIS group. One possible reason is that the MIS group likely started off at a lower score compared to the open group, perhaps because they tended to be younger with a higher expectation of activity tolerance. While comparing pain, satisfaction, and outcomes as measured via AOFAS and RAND36 health questionnaire, both groups had comparable outcomes with marginally better physical function and general health scores in the MIS group although the operating time was significantly longer compared to the open group. The reasons for this are again multifactorial, with patients who underwent open repairs deemed to be higher risk and therefore not suitable candidates for the MIS approach.

There are likely several key factors that contributed to these results. Firstly, the MIS group was exclusively performed by fellowship-trained foot and ankle surgeons with significant experience in MIS techniques. The MIS technique is also more technically challenging with a steeper learning curve. The open technique allows for better exposure and visualization of the ruptured TA ends and therefore likely accounts for the faster surgical time.

Even with the same postoperative rehab and physiotherapy regime, the MIS cohort returned almost maximum AOFAS and RAND36 physical function scores after just 6 months with scores leveling off after 12 months compared to the open cohort.

One key limitation of this study was its small sample size. It is likely that with a larger cohort, more statistically significant differences will be detected at the various time points between both groups. This can be seen in our *post hoc* power analysis using 24 months AOFAS scores yielding power of 0.51.

Another limitation of this study was that the surgeries were not carried out by a single surgeon, but rather multiple surgeons utilizing variations in techniques that may have affected outcomes. There was also a discrepancy in experience between the surgeons carrying out the minimally invasive techniques compared to the surgeons performing the open surgeries. Future studies can hopefully assess outcomes comparing surgeons with similar levels of experience.

One strength of this study was that the MIS group was performed by two very experienced, fellowship-trained foot and ankle surgeons. Another advantage is that outcome scores were measured prospectively by our diagnostic center with several key metrics collected pre- and postoperatively allowing for easy collection, collation, and interpretation of registry data.

Conclusion

The TA is a unique structure in that it is both a very robust, crucial tendon with an ever-increasing incidence of injury. Although the literature reported outcomes of both surgically and non-surgically managed ruptures show promising results, our study demonstrated that MIS performed by a fellowship-trained foot and ankle surgeon yielded better outcomes when compared to open repairs. The reasons for this have been highlighted above and are multifactorial, however, likely, reduction in incision size, tissue trauma, and disruption to vasculature all play an integral role. The patient selection seems to be just as important as comorbidities play a significant role in patient outcomes, as those with underlying health conditions had longer hospital stays and slower return to work which not only contributes to a slower recovery but increased healthcare costs. Although the sample size for this study is relatively small, it is a case in point that while comparing TA repairs, MIS should be considered the gold standard approach if the surgeon is an experienced foot and ankle surgeon, the patient does not have any significant comorbidities that may affect the skin, vascular, or tendon integrity and the institution has available to it a high-quality functional rehabilitation program.

Declarations

Our study was approved, and a waiver of consent was obtained by the hospital's ethics committee (CRIB 2020/3125) and carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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