



## Case Series

# The modified mini-open technique for repairing total ruptured Achilles tendon using fiber wire with calcaneal fixation. A prospective case series

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## ABSTRACT

**Background:** The purpose of this study was to evaluate clinical outcomes and complications of our modified Maffulli's mini-open technique for repairing acute Achilles tendon rupture using fiber wire and calcaneal fixation. **Material and methods:** Between January 2017 and August 2020, 21 patients with acute rupture of the Achilles tendon who underwent the modified mini-open Maffulli's procedure have been enrolled in the study. **Result:** All surgical incisions healed well without scar adhesions or infections. One year postoperatively, the ATRS score and AOFAS score were  $91.2 \pm 1.8$ ;  $97.2 \pm 1.6$  respectively; the range of ankle joint movement was normal. Patients could return to their work and their light sporting activities at the time of  $16.9 \pm 1.1$  weeks and  $19.7 \pm 0.9$  weeks postoperatively, respectively. 21 out of 21 patients were able to perform single heel raise. There were no sural nerve injuries, re-ruptures, tendon elongation, or deep vein thromboses. **Conclusion:** We have shown that the modified Maffulli's technique using fiber wire with a calcaneal fixation for repairing acute Achilles tendon ruptures to be a safe and reliable method without requiring specialized or expensive materials. It allows a durable repairing, a limitation of healing problems, and a quick return to physical therapy and full activity. This technique can be widely employed in a low-income country.

## 1. Introduction

The Achilles tendon is one of the most major tendons ruptured in young male adults. Ruptures usually occur at the relatively hypovascular area, that is between 2 and 6 cm of its calcaneal insertion [1,2]. Optimal treatment options for acute Achilles ruptures have not been defined. Conservative treatment had a high rate of re-rupture, tendon elongation, and weakness of the calf muscles [3,4]. Several operative treatments are classified as percutaneous repair, mini-open repair, and open repair. Open surgery allows a strong repair, a low risk of re-rupture and tendon elongation, but result in a high rate of complications of wound healing and infection [5–8]. The percutaneous repair technique was introduced by Ma and Griffith to avoid these complications [9]. The advantages of the operative and conservative methods were combined in this technique, however, it may not achieve satisfactory contact of the tendon stumps and adequate initial fixation [10]. The mini-open repair technique has been developed by Maffulli with minimal skin incision at the tear site, which permits a less invasive approach to the tendon, accurate opposition of the tendon ends, and reduces the rate of sural nerve

injury [11]. Mini-open repair using a suture-guiding device is another popular alternative to minimally invasive surgery. All the sutures were placed inside the paratenon without the requirement of a stab wound beside the tendon [12,13]. However, a risk of the sural nerve was reported [14,15], and both Maffulli's technique and mini-open repair using a suture-guiding device may not achieve adequate initial fixation in case of the short or severe tears of the distal stump of the Achilles tendon. This may be solved by performing our modified Maffulli's technique using fiber wire with calcaneal fixation.

The purpose of this study is to evaluate clinical outcomes and complications of our modified Maffulli's mini-open technique for repairing acute Achilles tendon rupture using fiber wire and calcaneal fixation.

## 2. Patients and methods

This is a prospective case series. Between January 2017 and August 2020, 21 patients (17 males and four females) with closed acute rupture of Achilles tendon underwent our modified Maffulli's technique for repairing Achilles tendon using fiber wire with calcaneal fixation in our

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hospital (Level I Institute of Trauma and Orthopaedics, Hanoi, Vietnam). Patients were included in the research group if they underwent surgery within 21 days after the index injury and had received no treatment before surgery, older than 18 years, ruptures at the non-insertional portion. The diagnosis of rupture was made clinically and radiologically. Written informed consent was obtained from all patients. The surgeons were Dr. L.V.N, B.L.N and G.N.N, who were senior surgeons in repairing Achilles tendon. All procedures were approved by our Hospital's Institutional Review Board.

### 2.1. Surgical technique

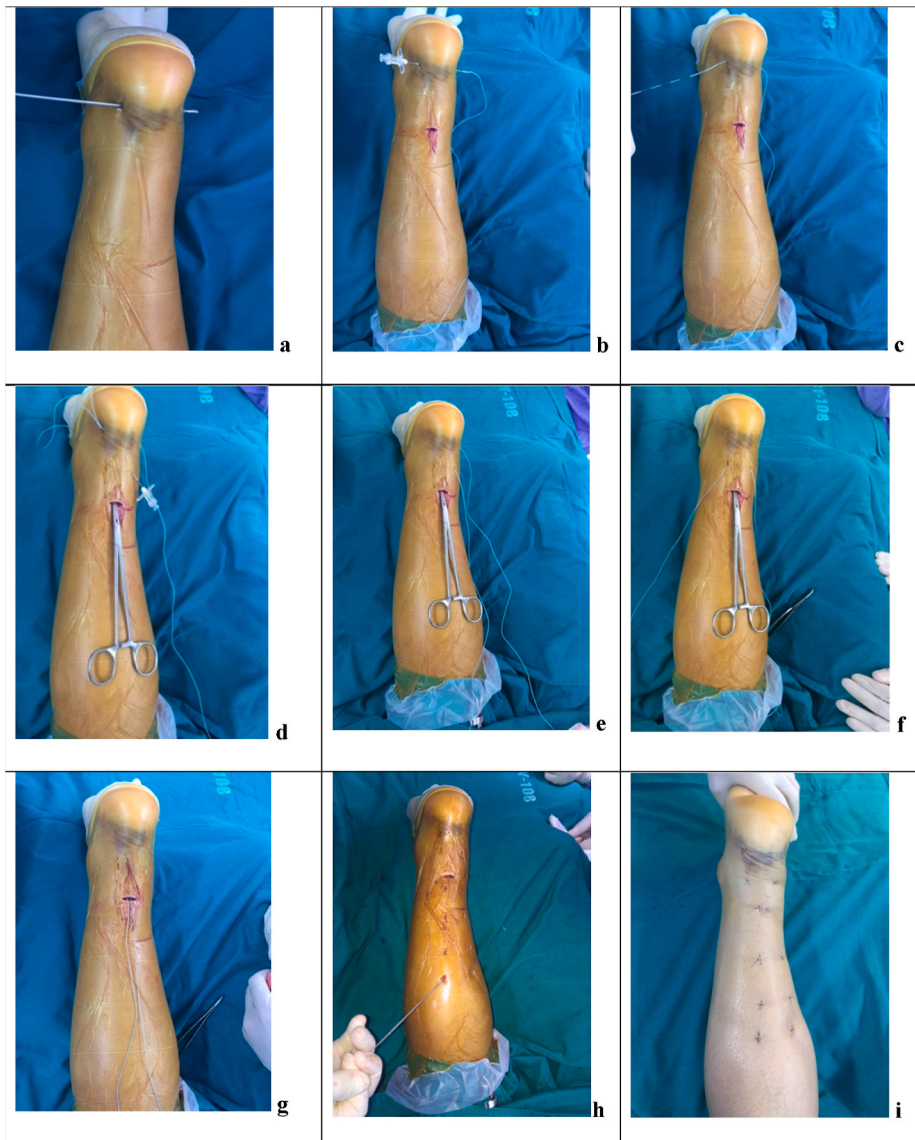
Patients underwent surgery in the prone position with spinal anesthesia. All patients have received a single dose of prophylactic antibiotics (Cefuroxim 1,5g) before thigh tourniquet inflation. An examination is performed to pad bony prominences and evaluate the location of the tendon defect. Two fiber wires and an 18G Touhy epidural needle catheter was required to perform this procedure (Figs. 1–3).

A small transverse incision (approximately 1 cm) was made approximately 1 cm proximal to the distal end of the palpable defect at the tendon rupture. The paratenon was incised to identify the proximal stump and distal stump of the tendon. Forceps were then used to

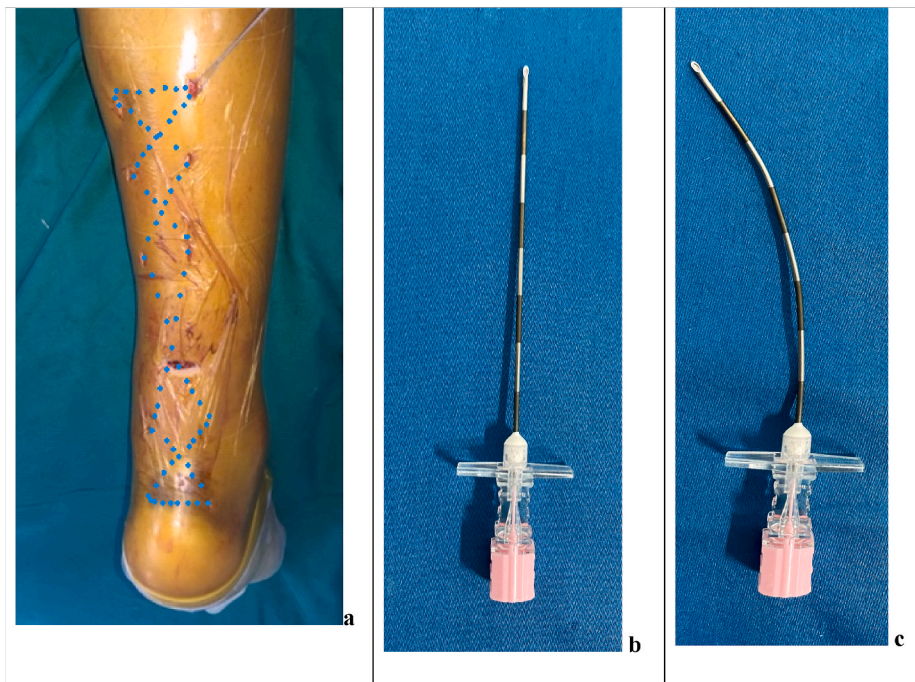
mobilize the tendon stump from beneath the paratenon. The sural nerve was identified at the expected location of the sural nerve on the skin. Eight longitudinal stab incisions were performed: four over the lateral aspect of the tendon and four over the medial aspect. Six of these incisions were over the proximal stump, and two of these incisions were 2 cm proximal to the Achilles calcaneal insertion. Care was taken while performing three lateral stab incisions to avoid sural nerve injury.

A transverse tunnel was made 2 cm below the Achilles tendon insertion in the calcaneum using a 2 mm drill bit. An epidural needle catheter was passed through the transverse tunnel at the calcaneum. The fiber wire was put through the catheter, then the catheter was withdrawn to pull the fiber wire through this tunnel. The fiber wire was passed diagonally through the Achilles tendon to the distal opposing stab incisions, then was passed diagonally to the transverse incision over the palpable defect using the Touhy catheter and the distal tendon stump was sutured with a Bunnell configuration (Fig. 1).

The fiber wire was then passed through the 6 proximal stab incisions using the catheter in a Bunnell fashion, crisscrossed through the proximal stump tendon, and retrieved from the additional stab wound between the tendon stump. The catheter again was used to deliver a suture passed transversely between the proximal stab incisions through the bulk of the tendon from lateral to medial (Fig. 1).



**Fig. 1.** Operative procedures of modified Maffulli's technique using two fiber wires and calcaneal fixation for Achilles tendon repair. **a**, A transverse tunnel was made 2 cm below the Achilles tendon insertion in the calcaneum. **b,c**, The Touhy catheter was put through the calcaneal tunnel, the fiber wire was put through the catheter, then the catheter was withdrawn to pull the fiber wire through the calcaneal tunnel. **d,e,f**, The fiber wire was then passed through diagonally the bulk of the tendon to the just proximal opposing stab incision using the epidural catheter. **g**, A fiber wire was again passed diagonally to the transverse incision. **h**, A fiber wire was then passed through the 6 proximal stab incisions in a Bunnell fashion, crisscrossed through the proximal stump tendon, then were tied together. **i**, Post-operative.



**Fig. 2.** Schematic diagram of our modified Maffulli's technique and the Touhy epidural needle  
**a** Schematic diagram of our mini-open Achilles tendon repair using the modified Maffulli's technique with two fiber wires and calcaneal fixation for Achilles tendon repair. **b**, the Touhy epidural needle. **c**, the Touhy epidural needle can be bent.



**Fig. 3.** Long-term clinical outcomes. **a**, 6 weeks post-operative. **b,c,d**, 12 months post-operative.

Another fiber wire was then used to suture the Achilles tendon using the same technique (Fig. 2).

The opposing ends of the two fiber wires were tied together as tightly as possible while the ankle was held in full plantar flexion. The tendon

stumps could be seen through the transverse incision. The paratenon was sutured with a Vicryl 3-0 suture and Nylon 3-0 sutures were applied for closure of the 4 medial and 4 lateral stab incisions and a transverse incision. Finally, a dressing was applied, and a below-knee brace at



25°–30° plantar flexion was applied being held in place.

### 2.2. Postoperative regimen

During 3 weeks post-operatively, patients have applied a below-knee brace at 25°–30° plantar flexion without weight-bearing. At the fourth week post-operatively, the brace was removed and replaced with an orthosis and patient partial weight-bearing, the ankle joint was allowed a range of motion from 0 to 30° plantar flexion. 6 weeks post-operatively, the orthosis was removed and replaced with shoes with a heel lift, the patient was allowed a full weight-bearing. 8 weeks post-operatively, patients were allowed a more intensive program of ankle motion such as raising on toes or heels. 12 weeks post-operative, patients were allowed to do stretching of the calf muscle. Full activities were avoided until 6 months post-operatively.

The characteristics of patients such as age, sex, mechanism of injury, injured side, tear site, the time between injury and operation, operative time, postoperative length of stay, associated diseases were recorded.

The ability to perform single heel raise, the time to work, the time to light sport, the Achilles tendon total rupture score (ATRS) [16], and AOFAS score [17] were recorded to evaluate clinical functional results. All complications such as scar adhesions, superficial or deep infections, nerve injury, tendon re-ruptures, tendon elongation, and deep vein thrombosis were assessed.

The maximum calf circumference at a level of 15 cm distally to the medial knee joint line and the ankle range of motion (ROM) of both the injured and the contralateral sides were documented.

The tendon elongation was defined according to Carmont [18] if the Achilles tendon resting angle (ATRA) difference between the injured and uninjured sides was more than 5°. ATRA is defined as the angle between the long axis of the fibula and the line from the tip of the fibula to the head of the fifth metatarsal. The ATRA was measured with the patient positioned pronely and the knee flexed to 90° at 12 months postoperatively.

This case series has been reported in line with the PROCESS Guideline [19]. We submit our work with a Research Registry unique identifying number is researchregistry7483. Hyperlink to our specific registration: <https://www.researchregistry.com/browse-the-registry#home/registrationdetails/61c595ed3487c5001fd605f9/>.

## 3. Results

### 3.1. Characteristics of the patients

The characteristics of patients enrolled in our study are reported in Table 1. The study included 17 male patients and 4 female patients. The

**Table 1**  
Characteristics of the patients.

Variable	Value
Age, years (mean ± SD)	35.3 (18–55)
Male/Female	17/4
Injured side	
Right	14
Left	7
Causes of injury	
Sport	15
Non-sports	6
Tobacco smoking	14
Diabetes mellitus	4
Tear site, cm (mean ± SD, (min-max))	2.7 ± 1.1 (1–4)
The time between injury and operation, days (mean ± SD, (min-max))	4.8 ± 2.6 (2–8)
The operative time, minute (mean ± SD, min-max)	46 (40–50)
The mean postoperative length of stay (days)	2.5 ± 0.3 (2–3)
The follow-up time, months (mean ± SD, min-max)	18 (12–36)

average age of patients was 35.3 years (range: 18–58 years). Among them, there were 14 right leg injuries and 7 left leg injuries. Regarding the mechanisms of injury, most were sports-related injuries. All 21 patients had acute injuries, the time between injury and operation was 4.8 ± 2.6 (2–8) days. 14 patients had a history of tobacco smoking and four patients had diabetes mellitus. The mean surgery time was 46 min (range: 40–50 min), while the mean postoperative length of stay was 2.5 days (range: 2–3 days). The average duration of follow-up was 18 months (range: 12–36 months).

### 3.2. Clinical outcomes

The mean range of movement of ankle joint at 6 months was 14.4 ± 2.8° dorsiflexion (range: 10°–18°) and 34 ± 3.3° plantar flexion (range: 30°–38°). The mean range movement of the ankle joint at 12 months was 21.4 ± 2.9° dorsiflexion (range: 15°–25°) and 38.4 ± 2.2° plantar flexion (range: 35°–42°). At one year postoperatively, the ATRS score was 91.2 ± 1.8 (range: 89–94), and the AOFAS score was 97.2 ± 1.6 (range: 95–100). All patients could return to their work and their light sporting activities at the time of 16.9 ± 1.1 weeks (range, 15–18) and 19.7 ± 0.9 weeks (range: 18–22) postoperatively, respectively (Table 2). 21 out of 21 patients were able to perform single heel raise and satisfied with their overall result. Functional and cosmetic outcomes at 1-year follow-up were as shown in Fig. 3.

### 3.3. Complications

There were no serious complications in the present study. All incisions healed well and without scar adhesions or superficial or deep infections (Fig. 3). There were no sural nerve injuries, re-ruptures, tendon elongation, or deep vein thromboses (Table 3).

## 4. Discussion

In our series, the sports-related injury was the most dominant cause of the injuries (15 out of 21 patients), followed by road traffic accidents (six out of 21 patients). Most of the patients were male (17 out of 21 patients). This result was similar to those of Assal [20], Calder [21], Maffulli [22,23], Rouvillain [24]. In our research, 14 patients had a history of tobacco smoking and four patients had diabetes mellitus, who were at risk of wound infection postoperatively.

Although there is still debate on the best method, operative treatment has been a tendency reported in the literature. Because open surgical repair was associated with high wound complication rates, minimally invasive techniques (mini-open and percutaneous technique) had been developed. The method of percutaneously repairing Achilles tendon ruptures was developed by Ma and Griffith et al. [9]. This technique consists of a Bunnell suture applied to the proximal tendon and a box suture distally in the stump. However, it supplied approximately 50% of the initial strength with a high risk of the sural nerve and re-rupture tendon than open repair [10,24,25]. Webb placed the most proximal incisions to the medial side away from the nerve [26]. The mini-open repair technique using a more secure suture configuration

**Table 2**  
Clinical outcomes.

Variable	Value	
	6-month	12-month
<b>ROM of ankle joint</b>		
Dorsiflexion	14.4 ± 2.8°	34 ± 3.3°
Plantar flexion	21.4 ± 2.9°	38.4 ± 2.2°
<b>AOFAS score</b>	85.2 ± 3.3	97.2 ± 1.6
<b>ATRS score</b>	83.7 ± 2.3	91.2 ± 1.8
<b>The difference in calf circumference, cm</b>	–2.1 ± 0.3	–0.2 ± 0.1
<b>Time to work (weeks)</b>	16.9 ± 1.1	
<b>Time to light sports (weeks)</b>	19.7 ± 0.9	

**Table 3**  
Complications.

Complications	Value
Incision infection	0
Skin necrosis	0
Adhesion	0
Achilles tendon re-rupture	0
Sural nerve injury	0
Vein thrombosis	0
Achilles tendon elongation	0

was developed by Maffulli et al. [11,27]. They used an 8-strand core repair of Number 1 Maxon inserted using a 9 cm Mayo needle round point spring eye. The needle was passed through stab paratendinous incisions in a Bunnell fashion emerging through a central stab at the rupture site. The good outcome of this technique in both elderly patients and elite athletes was reported [22,23]. Mini-open repair using a suture-guiding device was another popular alternative to minimally invasive surgery with a low wound complication rate [20,21,28–32], an early rehabilitation program. But expensive suture-guiding devices limited its clinical application in a low-income country like Vietnam. These techniques may not achieve adequate fixation in case of short or severe tear distal tendon stump. In our research, the tear site was  $2.7 \pm 1.1$  cm (1–4 cm) from calcaneal insertion. The tear site was shorter than two cm in eight out of 21 patients. Chronic Achilles tendinosis can result in an acute Achilles tendon rupture with a short severe tear distal stump. In such tendon ruptures, there was a limited amount of adequate tissue that can hold the suture. Hockenbury found percutaneous repair of Achilles tendon ruptures provided approximately 50% of the initial strength afforded by open repair [25]. Wagner [33] reported that the distal fixation site in this Achilles tendon repair with a triple nonlocking technique was significantly weaker than the proximal fixation site with a triple locking technique, a Bunnell-type technique, or a double Bunnell-type technique, the constructs tested were not strong enough to confidently allow weight-bearing in a walker boot. Patel [13] and Wagner [34] placed the proximal sutures into the calcaneus with a Push Lock anchor system to overcome this disadvantage. This anchor system allowed great tensioning and removed the need for knots at the tear site but the use of this specialized equipment increased the overall operative cost. This also may be overcome by performing the modified Maffulli's repair of ruptured Achilles tendon using fiber wire with calcaneal fixation. We describe a mini-open technique for repairing the ruptured Achilles tendon similar to that described by Maffulli [11] but using a fiber wire with calcaneal fixation. The present technique is cheap without specially designed tools and seems to allow a strong repair. Fixing the proximal repair distally to the calcaneus allowed a stable configuration repair and we did not have to worry about tearing of distal tendon stump. This allowed a rapid recovery, earlier physical therapy, and return to activity. As we could see from the study, the long-term results were excellent. At one year postoperatively, the range of movement of the ankle joint was normal, the ATRS score and AOFAS score were  $91.2 \pm 1.8$  (range: 89–94) and  $97.2 \pm 1.6$  (range: 95–100) respectively. All patients could return to their work and their light sporting activities at the time of  $16.9 \pm 1.1$  weeks (range, 15–18) and  $19.7 \pm 0.9$  weeks (range: 18–22) postoperatively, respectively. There was no difference in calf circumference between the operated and contralateral leg (Table 2). 21 out of 21 patients were able to perform single heel raise. The modified mini-open Maffulli's technique for repairing open Achilles tendon laceration using fiber wires with calcaneal fixation had been applied in our previous research with good results [35].

This result was similar to those of Assal and Calder who employed mini-open Achilles tendon repair using Achillon device. Assal [20] reported outcome in 80 repairs with Achillon, mean AOFAS score at 26-month follow-up was 96 points and all patients returned to previous work/sporting activities. Calder [21] published the outcome in 46

repairs with Achillon. An average AOFAS score of 98.4 was obtained and all patients returned to previous levels of sporting activities by six months.

We were also able to hold the tendon in the healthy region and not in the torn region bypassing the catheter through the healthy tendon ends, and then bringing the tendon together. Through the use of a 1 cm minimally invasive incision, we were able to avoid exposure of the tendon, which decreased scar formation and wound healing issues. It allowed a faster wound healing, therefore allowing a more aggressive rehabilitation program, which could potentially enhance the range of movement of the ankle and decrease the chance of calf muscle wasting.

The complication rates of mini-open Achilles tendon repair using fiber wire with calcaneal fixation were very low. There were no re-ruptures or tendon elongation in our research. We found that our technique was effective in decreasing re-rupture due to stable configuration repair, no gap was present in the repair, preservation of the paratenon, and without tension at the tendon tear repair. In addition, preservation of the paratenon, without tension at the tendon tear repair due to fixing the proximal repair distally to the calcaneus may permit improved vascularization and contribute to improved tendon healing. Rouvillain [24] reported a series of 60 repairs using the Ma and Griffith technique, two re-ruptures at two and five months respectively. Some authors reported Achilles tendon re-ruptures when using Dresden or Achillon devices such as Amlang [28] (two out of 62 cases) or Assal [20] (three out of 82 patients). Some authors didn't meet re-rupture [30–32]. Clanton [36] and Wagner [33] found that percutaneous techniques elongated the Achilles tendon 10 mm. Wagner [33] recommended pre-tensioning the repair. Clanton [33] found that the majority of elongation, regardless of repair, occurred within the first 10 cycles, so we recommended extensive flexion and extension of the ankle joint 10 times before definitive knotting suture.

There was no sural nerve injury in our research because we found out carefully safe sites of six stab incisions lateral proximal tendon stump and used of spread fashion according to Maffulli [11] for placement of a catheter to avoid sural nerve injury. The sural nerve passes down posteriorly to the calf and crosses the lateral border of the Achilles tendon at about 9.8 cm proximal from the calcaneal insertion. Distally, the nerve passes about 18.8 mm lateral to the lateral border of the Achilles tendon at the level of its calcaneal insertion [37,38]. We used a Touhy epidural needle with a large length and bending ability in our technique instead of a curved long needle in Muffilli's technique because we found it easier to suture the tendon and avoid the path of the sural nerve (Fig. 3). The use of spread fashion according to Maffulli [11], may also prevent nerve damage during suture placement. Blunt dissection above the tendon was done and the suture was passed out of and into the tendon using a Touhy catheter at the level of the stab incision, so the sural nerve was not transected by the suture. The knots of sutures were buried deep to the tendon at the proximal stab incision that minimized irritation of the overlying skin from the knot. Another advantage of our mini-open repair was cosmesis (Fig. 3).

The minimally invasive repair assisted with intraoperative ultrasonography was done recently, with good clinical outcomes, and fewer complications [39,40]. However, this technique requires a long learning curve, and a special machine, which is not available in a developing country.

The present study appears to be the first report using a modified Maffulli's technique using fiber wire with calcaneal fixation to repair acute Achilles tendon ruptures. We consider this technique as a safe and reliable method without increasing financial costs. Specially designed tools were unnecessary. We also consider this technique to be an attractive mini-open repair of the Achilles tendon in a low-income country.

Our study has some limitations. The number of patients studied was small and their follow-up was limited to 1 year. Further research should be based on the larger sample size, longer follow-up time. A biomechanical cadaveric study comparing the strength of this repair with

other percutaneous methods can further support the use of this technique.

## 5. Conclusion

We show the modified Maffulli's technique using fiber wire with a calcaneal fixation for repairing acute Achilles tendon ruptures to be a safe and reliable method without increasing financial cost and does not require a specialized tool or expensive materials. It provides a durable repair without healing problems, a quick return to physical therapy, and full activity. This technique can be widely employed in a low-income country.

## Ethical approval

All procedures were approved by the 108 Central Military Hospital's Institutional Review Board, Hanoi, Viet Nam.

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No financial support was received for the completion of this study.

## Author contribution

Please specify the contribution of each author to the paper, e.g. study concept or design, data collection, data analysis or interpretation, writing the paper, others, who have contributed in other ways, should be listed as contributors. L.V.N designed and conceptualized the study, conducted the data analysis, interpreted results, and prepared the manuscript. L.V.N, G.N.N, B.N.L surgery. All authors contributed to the critical revision of the manuscript regarding important intellectual content and read and approved the final manuscript.

## Consent

Written informed consent was obtained from the patient for publication of this case series and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

## Registration of research studies

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## Guarantor

Dr. Luong Van Nguyen.

## Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

## Provenance and peer review

Not commissioned, externally peer reviewed.

## Declaration of competing interest

The authors declare that they have no conflicts of interest.

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