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Minimally invasive internal splinting technique for acute closed Achilles tendon rupture

Songlin Liu[1] and Liang Ma[1*]

Abstract

Background Although non-surgical and surgical approaches have been developed to repair acute closed Achilles tendon ruptures, the medical community still lacks a definitive consensus on which approach is superior. This study describes a new minimally invasive internal splinting technique combined with knotless anchors for the treatment of 22 patients with acute closed Achilles tendon rupture.

Methods A retrospective study was conducted involving 22 patients with acute closed Achilles tendon rupture who were treated with a minimally invasive internal splinting technique at Jingzhou Hospital of Yangtze University between January 2022 to October 2023. The study recorded and compared various metrics, including the Visual analogue scale (VAS), American Orthopedic Foot and Ankle Society (AOFAS), Achilles tendon total rupture score (ATRS), and range of motion (ROM) of the plantar-flexor-extensor foot, both preoperatively and at the final follow-up.

Results We bridged the intact portion of the Achilles tendon proximal to the rupture site and the calcaneal bone using a Krackow locking loop suture technique and a knotless anchor staple technique. Twenty-two patients were monitored over a period from 10 to 12 months, with an average follow-up duration of (11.6 ± 0.67) months. At the last follow-up, all patients had successfully resumed their sports activities and work without experiencing any complications, such as Achilles tendon rupture, postoperative infection, and peroneal nerve injury. The VAS score postoperatively was recorded at (0.14 ± 0.35), representing a significant reduction from the preoperative score of (4.05 ± 0.58). The AOFAS-AH score improved to (97.41 ± 4.00), a notable increase compared to the preoperative score (52.82 ± 4.43). Similarly, the ATRS score reached (98.23 ± 2.98), also significantly higher than the preoperative score (56.95 ± 4.62). Furthermore, the range of motion (ROM) was measured at (44.27 ± 1.08), significantly surpassing the preoperative value of (26.91 ± 2.09), with all differences being statistically significant ($p < 0.05$).

Conclusion The procedure is simple. Two small incisions are placed over the intact proximal Achilles tendon and the calcaneus without surgical invasion of the rupture site, which promotes the natural repair of the ruptured Achilles tendon. The intact proximal Achilles tendon and the calcaneus are securely bridged with high-strength sutures and knotless anchors, reducing complications and promoting healing of the Achilles tendon.

Keywords Achilles tendon, Acute, Minimally invasive, Krackow locking suture

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Introduction

Achilles tendon rupture is a prevalent injury in sports, particularly affecting middle-aged individuals who participate in recreational activities. This type of injury has seen an increase in frequency in recent years [1, 2]. Conservative treatment tends to result in a prolonged recovery period and may give rise to long-term complications, including lengthening and weakness of the Achilles tendon [3–6], compared with surgical treatment, which is more effective [7, 8]. Surgical treatment of Achilles tendon rupture is varied, with ongoing innovations in suture methods that increasingly favor minimally invasive techniques. Additionally, percutaneous suture methods have been gaining traction as they can achieve complete closure of the tendon tear through small incisions [9]. However, the effectiveness, benefits, and drawbacks of various suture techniques remain controversial. While conventional incisional suture technique can provide excellent alignment of the severed ends, it increases the risk of near-term complications such as poor incision healing and infection [10]. Conversely, while purely closed percutaneous suture methods considerably reduce the incidence of incisional complications, they are limited by their inability to achieve precise alignment of the severed ends and may lead to more significant long-term complications [11, 12]. The development of arthroscopy has led to the adoption of arthroscopically assisted Achilles tendon repair by researchers [13]. This technique minimizes surgical trauma; however, its implementation in primary care settings is challenged by the significant requirements for specialized instruments, the advanced skills needed from physicians, and the overall complexity of the procedure due to the extremely high requirements for instrumentation and physician skills and the complexity of the procedure. Therefore, the objective of this study was to highlight 22 patients who underwent successful treatment repair using a minimally invasive internal splinting technique.

Table 1 General information about the patient

Variable	Study subjects ($n=22$)
Age, years (mean ± SD)	26.00 ± 5.87
Gender(n%)	20(91)
Male	2(9)
Female	
BMI(kg/m^2)	23.95 ± 3.00
Cause of injury (n,%)	6(27)
Badminton	12(55)
Basketball	4(18)
Running	
Injury side(n%)	6(27)
Left	16(73)
Right	
Smoker(n%)	5(23)

Methods

Subjects

This retrospective study involved 22 patients who were treated for acute Achilles tendon rupture at Jingzhou Hospital of Yangtze University from January 2022 to October 2023. An ethical approval was issued by the Jingzhou Hospital of Yangtze University Ethics Committee. All the participating patients signed a consent form for surgery. The general information of the patients is shown in Table 1. The study included 20 male patients and 2 female patients, comprising 16 right Achilles tendons and 6 left Achilles tendons. The participants were aged between 20 and 45 years, with an average age of (26.00 ± 5.87) years. The mean body mass index recorded was (23.95 ± 3.00) kg/m^2. The Inclusion criteria were: (1) Unilateral closed Achilles tendon rupture that occurred within the last 2 weeks; (2) A palpable gap in the Achilles tendon and a positive Thompson test; (3) Rupture of the Achilles tendon located 2–6 cm above where the calcaneus stops; (4) Confirmed diagnosis of Achilles tendon rupture through preoperative ultrasound or MRI examination; (5) No absolute contraindications to surgery confirmed by preoperative examination. The exclusion criteria were: (1) Multiple and open injuries; (2) The combination of Achilles tendonitis and calcification of the Achilles tendon; (3) A history of local hormonal injection therapy for Achilles tendon treatment; (4) Unilateral closed Achilles tendon rupture of exceeding two weeks in duration; (5) A combination of an avulsion fracture of the Achilles tuberosity.

Surgery

Surgical procedures were conducted by the same surgeon for all patients. Epidural anesthesia was administered, and the patients were placed in a prone position. An airbag tourniquet was tied at the base of the affected thigh, and the location of the tear was identified through palpation. The surgical area for the foot and ankle was systematically disinfected and covered in accordance with standard protocols for foot and ankle surgery.The affected lower limb was elevated for 1 min and the tourniquet was inflated to a pressure of 55 kpa for 60 min. The preoperative plan is illustrated in Fig. 1, while Fig. 2 presents the schematic of the operation.

The affected foot was elevated to maintain plantarflexion. A 3-cm longitudinal incision is made approximately 3 cm proximal to the Achilles tendon rupture (Fig. 3a). One Orthocord suture(purple, with a needle, Depuy Mitek, USA) was used to suture the medial Achilles tendon using Krackow locking suture [14]. Additionally, a second Orthocord suture was used to suture the lateral Achilles tendon using Krackow locking suture (Fig. 3b).

A 1-cm incision was made at the Achilles tendon insertion to the calcaneus. The anchor bone channel

Fig. 1 Surgical planning. The distal black line depicts the Achilles tubercle incision, the proximal black line depicts the proximal Achilles tendon incision, and the middle of the double arc is situated at the Achilles tendon rupture

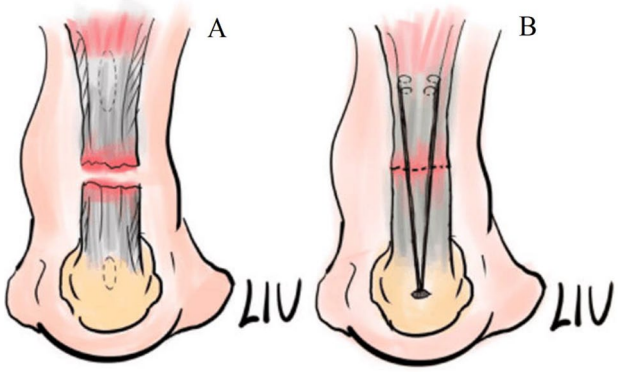

Fig. 2 Schematic diagram of the operation. (**A**) small skin incisions (dotted circles) were placed proximal to the Achilles tendon rupture site and at the calcaneus to avoid skin incisions at the rupture site and to minimize wound complications. (**B**) Firm bridging between the intact proximal Achilles tendon and the calcaneus over the site of the Achilles tendon rupture, promoting natural repair of the ruptured Achilles tendon

was then opened by drilling with a 4.0-mm Kirschner wire (Fig. 3c). An arthro-pierce instrument (straight 90°, Rejoin, Hangzhou, China) was inserted through the distal incision and penetrated the distal and proximal portions of the ruptured Achilles tendon until it emerged from the proximal incision. A PDS™ cord (Ethicon, Johnson & Johnson Inc., USA) was advanced retrogradely through the instrument. When the end of the PDS cord emerged from the tip of the instrument, it was folded back and then advanced antegrade through the instrument to form a loop (Fig. 3d). Subsequently, the four tails of two Orthocord sutures were threaded through the loop and pulled to emerge from the distal incision using the loop. After this procedure, the arthro-pierce instrument was extracted from the Achilles tendon. The two Orthocord sutures were then tightened until the severed ends of the Achilles tendon were fully brought together, and the four tails of the two Orthocord sutures were simultaneously threaded through the knotless anchor (4.75 mm, PEEK suture anchors, Knotless, Rejoin Hangzhou China or 4.75 mm HEALIX ADVANCE BR, Depuy Mitek, USA) (Fig. 3e). The anchor was then fixed to the calcaneal bone channel. It is essential to verify the appropriate depth of the knotless anchors before pressing them into the bone channel for secure fixation (Fig. 3f). Finally, the incision was sutured, a sterile dressing was applied, and the limb was immobilized in a short leg plaster with a plantarflexion of 20°.

Rehabilitation

Following the surgical procedure, the impacted limb was secured in a position of 20° plantarflexion with the aid of a short leg brace, and weight-bearing activities were prohibited, while early knee and toe activities were encouraged. Partial weight-bearing with crutches was required for the first 4 weeks, after which the brace was removed and replaced by an Achilles tendon boot allowing for full weight-bearing. Subsequently, rehabilitation commenced, incorporating isometric contraction, isometric cycling, and proprioceptive neuromuscular facilitation training. After three months, depending on the recovery of muscle strength, low-intensity exercise, such as jogging, can be attempted gradually. However, participation in competitive sports is strictly prohibited for six months after surgery and until complete regrowth of the Achilles tendon is confirmed by MRI.

Clinical result evaluation

Perioperative data including operative time, average hospital stay, incision length, intraoperative blood loss, intraoperative complications, incision healing, and hospital stay were recorded. The pain visual analogue scale (VAS), American Orthopedic Foot and Ankle Society (AOFAS), Achilles tendon total rupture score (ATRS), and range of motion (ROM) were used to evaluate clinical outcomes.

Statistical analysis

Statistical analysis was performed using SPSS 26.0 software, with patient descriptive statistics reported as number (n) and percentage (%) for categorical variables, and mean ± standard deviation (SD) for continuous variables, with $P < 0.05$ being statistically significant.

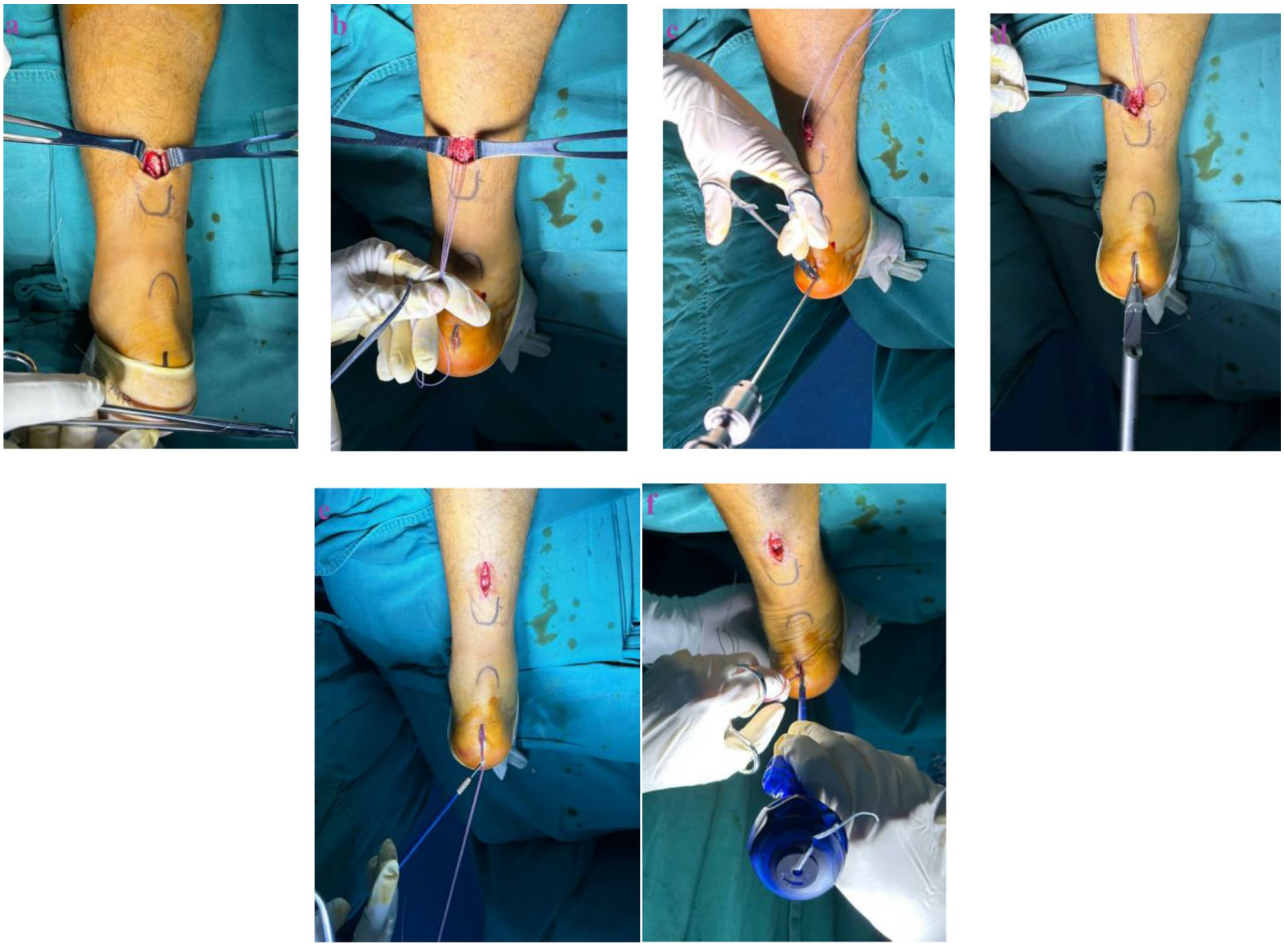

Fig. 3 Operation procedure. (**a**) The proximal incision was made. (**b**) The medial and lateral portions of the Achilles tendon were sutured using the Krackow locking suture. (**c**) A distal incision was made, and the anchor bone channel was opened by drilling. (**d**) The arthro-pierce instrument was inserted and penetrated through the Achilles tendon, and the four tails of the two Orthocord sutures were pulled to emerge from the distal incision site using a PDS™ cord loop in the instrument. (**e**) The four tails of the two Orthocord sutures were simultaneously threaded through the knotless anchor. (**f**) The anchor was fixed to the calcaneus. It is essential to verify the appropriate depth of the knotless anchors before pressing them into the bone channel for secure fixation

Table 2 Perioperative indexes

Variable	Study subjects ($n=22$)
Average length of hospitalization (days)	6.8 ± 0.50
Surgical time (min)	17.8 ± 3.43
Intraoperative bleeding (mL)	11.4 ± 1.82
Proximal incision length (cm)	3.0 ± 0.24
Distal incision length (cm)	0.9 ± 0.15
Average follow-up (months)	11.6 ± 0.67

Results

All 22 patients were followed up after surgery for 10 to 12 months, with an average of (11.6 ± 0.67) months. All patients successfully completed the operation and were discharged from the hospital 5–7 d after the operation, with an average hospitalization time of (6.8 ± 0.50) d. The operation time was 15–30 min, with an average of (17.8 ± 3.43) min; intraoperative bleeding was 10–15 mL, with an average of (11.4 ± 1.82) mL. The length of the proximal incision was 2.5–3.5 cm, with an average of (3.0 ± 0.24) cm. The distal incision length was 0.5–1 cm, with a mean of (0.9 ± 0.15) cm (Table 2). During the follow-up period, all 22 patients returned to sports and work without complications like Achilles tendon rupture, postoperative infection, or peroneal nerve injury. Postoperative function improved significantly, and MRI results indicated satisfactory healing of the Achilles tendon (Fig. 4). At the final follow-up, the patients' VAS scores were significantly lower, while the AOFAS scores, ATRS scores, and ROM were significantly higher (Table 3), and these differences were statistically significant ($P<0.05$).

Discussion

In this study, we used two small incisions combined with knotless anchor nailing and Krackow locking suture technique. This new technique involves firm bridging between the intact Achilles tendon proximal to the ruptured Achilles tendon and the Achilles insertion to the calcaneus to minimize re-rupture of the Achilles tendon.

Fig. 4 Postoperative recovery. (**a**) Last follow-up incision. (**b**) Functional foot position at last follow-up. (**c**) Dorsiflexion at last follow-up. (**d**) Plantarflexion at last follow-up. (**e**) Preoperative MRI of Achilles tendon rupture. (**f**) MRI scan three months post-surgery. (**g**) Last follow-up MRI

Table 3 Comparison of preoperative and postoperative VAS score, AOFAS score, ATRS score, and ROM°($\bar{x} \pm s$)

Evaluation indicators	1-month postoperative	3-month postoperative	final follow-up
VAS score	4.05 ± 0.58	0.77 ± 0.43	0.14 ± 0.35
AOFAS score	52.82 ± 4.43	89.00 ± 3.07	97.41 ± 4.00
ATRS score	56.95 ± 4.62	86.41 ± 3.11	98.23 ± 2.98
ROM°	26.91 ± 2.09	40.45 ± 1.57	44.27 ± 1.08

It avoids surgical intervention at the rupture site to facilitate the natural healing process of the damaged tendon. Additionally, a small skin incision was made at the intact area, deliberately avoiding any incision at the site of the rupture to mitigate the risk of wound complications and to prevent complications such as peroneal nerve injury. All 22 patients in this study have returned to sports and work without complications such as Achilles tendon re-rupture, postoperative infection, or peroneal nerve injury, Additionally, the patients exhibited significantly reduced VAS scores, while their AOFAS scores, ATRS scores, and ROM measurements were significantly higher.

This study used a new approach that significantly reduced the incidence of soft tissue complications such as wound infection, skin necrosis, and deep infection. Conventional surgery has a high incidence of soft tissue complications and affects wound healing due to large incisions, trauma, and post-suture skin adhesions that disrupt the blood supply around the ruptured Achilles tendon [15, 16]. Yin and Jiang et al. reported that the application of banded anchors in the minimally invasive treatment of acute Achilles tendon rupture wounds led to a significant decrease in wound-related complications [17, 18]. However, the surgical technique exposes the site of rupture, with most Achilles tendon ruptures occurring in the mid-section, where the blood supply is weakest and is mainly supplied by the peroneal artery [19, 21]. In this study, avoiding skin incisions at the Achilles tendon rupture site improved healing by reducing medically induced trauma to the tendon rupture site, which likely played a role in decreasing the rates of wound rupture and infection.

However, although minimally invasive repair offers certain benefits, the potential for re-rupture of the Achilles tendon represents a significant drawback of this technique. Biomechanical research indicates that the risk of re-rupture is greater with percutaneous repair in comparison to open repair methods [22, 23]. The main reason for this is that the involved in the rupture repair are less robust than those associated with a conventional

incisional repair, resulting in a reduced resistance strength [24]. We addressed the disadvantage of percutaneous Achilles tendon repair with internal splinting.Sarman reported [25] that minimally invasive internal splint fixation utilizing transverse Achilles tunnels was used for the treatment of acute Achilles tendon ruptures, and only one case of re-rupture was encountered. However, the safety of the Achilles tunnel technique still needs to be evaluated to fully understand its risks and benefits. In this study, the intact proximal Achilles tendon above the ruptured Achilles tendon was securely bridged to the Achilles bone by high-strength sutures and knotless anchors. This approach aimed to improve the biomechanical stability of the torn end while minimizing the risk of re-rupture, a complication that was not observed in any of the 22 patients involved in the study.

Peroneal nerve entrapment remains an occasional problem in percutaneous repair procedures. Research indicates that the incidence of this complication ranges from 0 to 27%, with certain patients potentially necessitating reoperation to address the injury [26, 27]. The possibility of peroneal nerve injury exists with this surgical procedure. As the peroneal nerve remains unexposed during the operation, suturing is typically conducted without direct visualization of the nerve, which heightens the risk of direct damage. Furthermore, the friction caused by the suture against the nerve may worsen the injury. The technique employed in this study is considered more invasive compared to percutaneous repair; however, the peroneal nerve is positioned laterally to the channel utilized in this procedure. The longitudinal incision made in the Achilles tendon contrasts with the transverse incisions typically associated with most percutaneous repair methods. Furthermore, this procedure is predominantly conducted under direct visualization of the peroneal nerve, resulting in a minimal occurrence of peroneal nerve injuries. Notably, there were no instances of peroneal nerve injury reported among the 22 patients in this series.

We believe this surgical technique is comparable to the similar arthroscopic technique by Wei et.al [28]. In their study, Wei et al. employed a modified Krackow suture for the repair of Achilles tendon ruptures, utilizing arthroscopic assistance for visualization. This approach also avoided making an incision at the rupture site of the Achilles tendon, thereby minimizing the risk of peroneal nerve injury. Additionally, they implemented two anchors to bridge and secure the intact portion of the Achilles tendon over the rupture, which effectively reduced complications. However, the complexity of the arthroscopic procedure by Wei and the associated costs were heightened due to the necessity for specialized instruments and the high level of skill required from the physician. The use of a single knotless anchor in this study, coupled with the absence of specialized minimally invasive tools, is expected to lower the cost of care. Furthermore, the use of knotless anchors should provide a strong repair, which should reduce the risk of treatment failure, again leading to lower costs.

There are limitations to this study. First, the sample size was small. Second, our study was a case series study with no control group. Third, the follow-up period was relatively short, and long-term follow-up should be completed to further assess the exact risk of re-rupture.

Conclusions

This procedure is short and simple. Two minor incisions are placed over the intact proximal Achilles tendon and Achilles insertion to the calcaneus.avoiding any surgical intervention at the rupture site. This approach facilitates the natural healing process of the ruptured Achilles tendon. The portions of the ruptured Achilles tendon are firmly internal-splinted using high-strength sutures and knotless anchors, thereby minimizing complications and enhancing the healing of the Achilles tendon.

Abbreviations

VAS	visual analogue scale
AOFAS	American Orthopaedic Foot and Ankle Society
ATRS	Achilles tendon total rupture score
ROM	Range of motion

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05550-4.

Supplementary Material 1

Supplementary Material 2

Author contributions

Songlin Liu performed the data collection and data analysis and wrote the paper; Liang Ma conceived, designed, performed the experiments and revised the paper. All authors reviewed the results and finalized the final version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Jingzhou Hospital of Yangtze University. All patients signed a consent form for surgery. Informed consent was obtained from all individual participants included in the study.

Consent for publication

All patients provided written informed consent for the publication of their identifying photographs.

Competing interests

The authors declare no competing interests.

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