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Mini-invasive technique for Achilles tendon rupture: BarTur technique. A new simple and inexpensive technique

Marco Baglioni[1], Rinaldo Tambasco[2], Luca Turelli[1]

[1] Department of orthopedic surgery, Azienda USL Toscana Centro, San Jacopo Hospital, Pistoia, Italy; [2] Department of orthopedic surgery, Azienda Universitaria Ospedaliera Careggi, Firenze, Italy

Summary

Objective. The aim of this study is to describe and evaluate clinical and subjective outcomes of our mini-invasive technique: the "BarTur technique", and to consider it as a viable surgical treatment option for Achilles tendon rupture (ATR).
Methods. We included 69 patients who underwent the Bartur technique from January 2019 to December 2022. We analyzed the rate of satisfaction, quality of life and functional clinical outcomes with a minimum of 6 months of follow-up.
Results. The final study population consisted of 69 patients with a mean age of 49 years and a mean follow-up of 16.5 months. During follow-up no complications were observed, and no workers changed their job. They returned at work after a mean of 3.2 months. Only 27 patients returned to practice sport after a mean of 8.8 months; 21 of these changed the type of sport. Our population had good results in clinical scores (92.6% AOFAS, 92.6% FAAM, 4.7% FFI, 91.4 ATRS); their satisfaction was 8.5 and they had a good quality of life (95 EQ-5L).
Conclusions. The BarTur method is a simple, inexpensive and good option for surgical treatment of ATR. This treatment offers a lower risk of complications, high rate of satisfaction, good clinical outcomes and a few limitations in sports.

Key words: mini-invasive, Achilles tendon, Bartur

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Correspondence
Luca Turelli
Department of orthopedic surgery, Azienda USL Toscana Centro, San Jacopo Hospital, via ciliegiole 97, 51100 Pistoia, Italy
E-mail: luca.turelli@uslcentro.toscana.it

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Introduction

The Achilles tendon, which measures approximately 12-15 cm in length and compromises both the gastrocnemius and the soleus tendons, is the thickest, strongest and largest tendon in the human body [1]. Achilles tendon rupture (ATR) is a common injury that significantly affects daily life with an annual incidence of 5 to 50 events for 100,000 [2]. This type of rupture accounts for 20% of all major tendon ruptures. ATR occurs primarily during sports activities, with a higher frequency observed in middle-aged men. The male-female ratio ranges from 2:1 to 12:1 [3].
The injury exhibits a bimodal age distribution with the first peak in patients between 25 years and 40 years of age and the second peak in those over 60 years. The incidence of ATR has increased in recent decades, which can be attributed to the growing elderly and obese populations, as well as the increase in recreation-

al sports among middle-aged individuals. ATR has long-term consequences that often limits patients' abilities, and many individuals are unable to return to their pre-injury level of sports performance [4].

Degenerative changes have been observed in acute ATR, likely resulting from various factors such as chronic overloading, microtrauma, pharmacologic treatments, reduced blood supply and previous rupture on the opposite side. Corticosteroids and fluoroquinolones have been associated with Achilles tendon degeneration and rupture [5].

After an ATR, the tendon heals by forming scar tissue, but it usually does not regain the same collagen structure, composition, and organisation as healthy tissue. Consequently, the mechanical properties of the tendon may decrease, and the risk of re-rupture can increase [6]. Various treatment options exist for ATR, including surgical and non-surgical approaches. However, there is currently no consensus on the optimal treatment protocol [7]. Surgical treatment has become more prevalent due to lower re-rupture rates and improved functional outcomes. Minimally-invasive techniques have reduced the risk of surgical site infections while retaining the advantages of surgery. These techniques allow for precise alignment of the tendon ends, improve cosmetic results, and minimise the risk of wound breakdown. However, there is a potential risk of damaging the sural nerve [8].

The purpose of this study is to describe and evaluate clinical and subjective outcomes of our mini-invasive technique, a simplified version of the surgical technique of Ma and Griffith, which was ideated by Marco Bardelli and is called the "BarTur technique", and to consider it as a viable surgical treatment option for ATR.

Materials and methods

Patients surgically managed at our Institution for ATR with BarTur technique from January 2019 to December 2022 were retrospectively recruited. Inclusion criteria were: age ≥ 18 years, ATR diagnosed by clinical exam and ultrasound, with a minimum follow up of 6 months, and undergoing the Ma and Griffith simplified surgical technique.

Exclusion criteria were: history of previous, concomitant or subsequent fractures or surgery of the affected lower limb, presence of pathologies affecting the function of the foot (lumbar radiculopathy, symptomatic flat foot, Morton's neuroma), peripheral and central neuropathies, and history of cancer.

We recruited 80 patients with ATR who were surgically treated in San Jacopo Hospital in Pistoia.

Surgical technique

We utilise a streamlined approach based on the Ma and Griffith technique for the suture procedure. This involves employing a sterile synthetic absorbable braid monofilament thread, 2 mm in diameter, made of polydioxanone PDS (Jonshon®) and a Kirschner bone wire with a loop to act as a carrier for this thread (Fig. 1). This Kirschner wire features a rounded terminal section, ensuring it avoids any harm to the sural nerve and soft tissues. The PDS thread is carefully guided through the tendon. To mark the rupture of the Achilles tendon and establish reference points, we utilise a skin pen. Four points are marked: two points at a distance of 11 cm from the superior extremity of calcaneal tuberosity (one on the medial side and one on the lateral side), and two points 1 cm above superior extremity of calcaneal tuberosity (one on the medial side and one on the lateral side). This technique involves establishing two entry points in the proximal region and two in the distal region. In our standard approach, we label these entry points as follows: A for the superior lateral entry point, B for the superior medial entry point, C for the inferior lateral entry point, D for the inferior medial entry point, and E for the surgical wound leading to the site of the Achilles tendon rupture. (Fig. 2) To begin, a transverse incision is made at the site of the Achilles tendon rupture using a lancet. Subsequently, a counterclockwise suture is performed, starting from the proximal to distal direction and moving from the medial to lateral direction. These steps constitute the fundamental surgical technique. Next, the

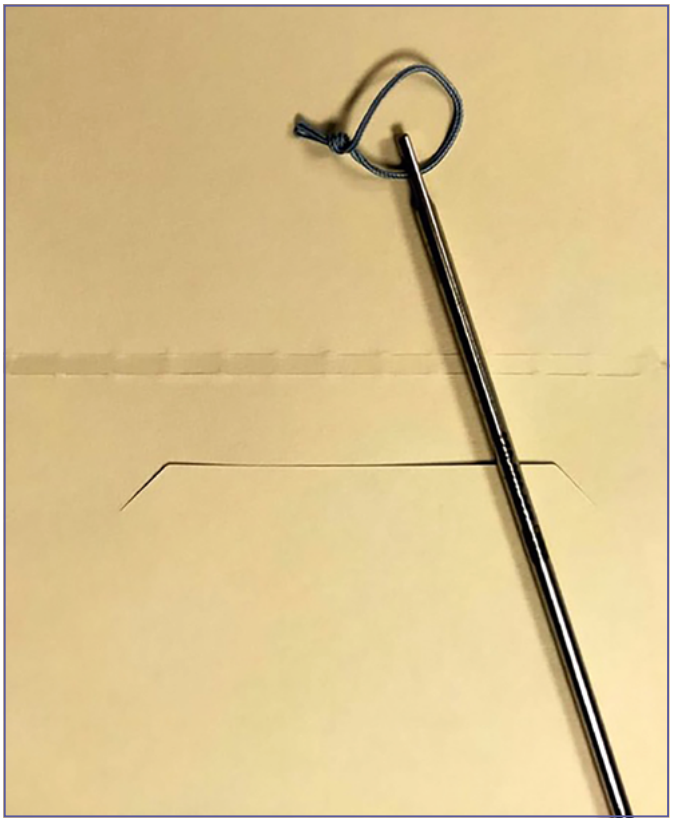

Figure 1. Kirschner bone wire with a loop to act as a carrier for PDS thread.

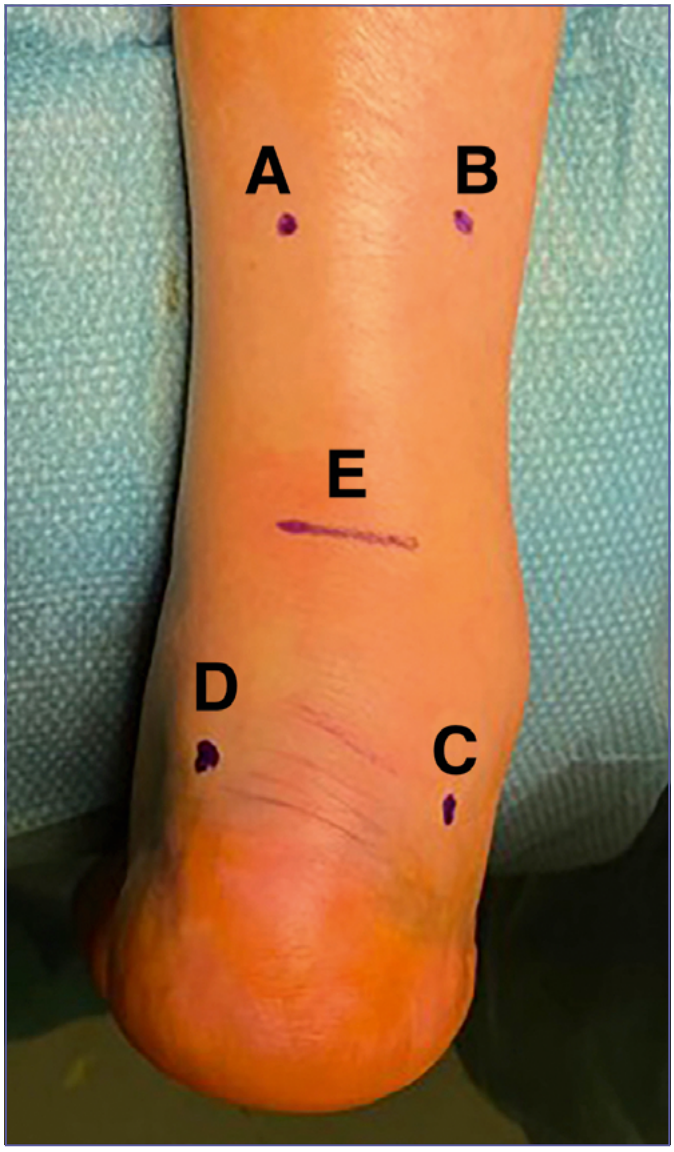

Figure 2. Entry points.

Kirschner bone wire with a loop is inserted at entry point A and threaded out through entry point B. The PDS thread is then passed through the loop of the Kirschner bone wire, guided from A to B, and its end is secured at B using Klemmer forceps. Following this, the Kirschner bone wire, now carrying the PDS thread, is threaded sequentially from A to E (Fig. 3), then from E to D, further from D to C, and finally from C back to E and E to B. This ensures that both ends of the thread are now outside entry point B. A knot is tied and positioned at B to complete this step. During the procedure the foot is maintained in slight plantar flexion (Fig. 4).

Once the suture and knot placement are completed, the surgical wound and entry points are carefully closed. Finally, a cast is applied at a 30° angle of plantar flexion to support the healing

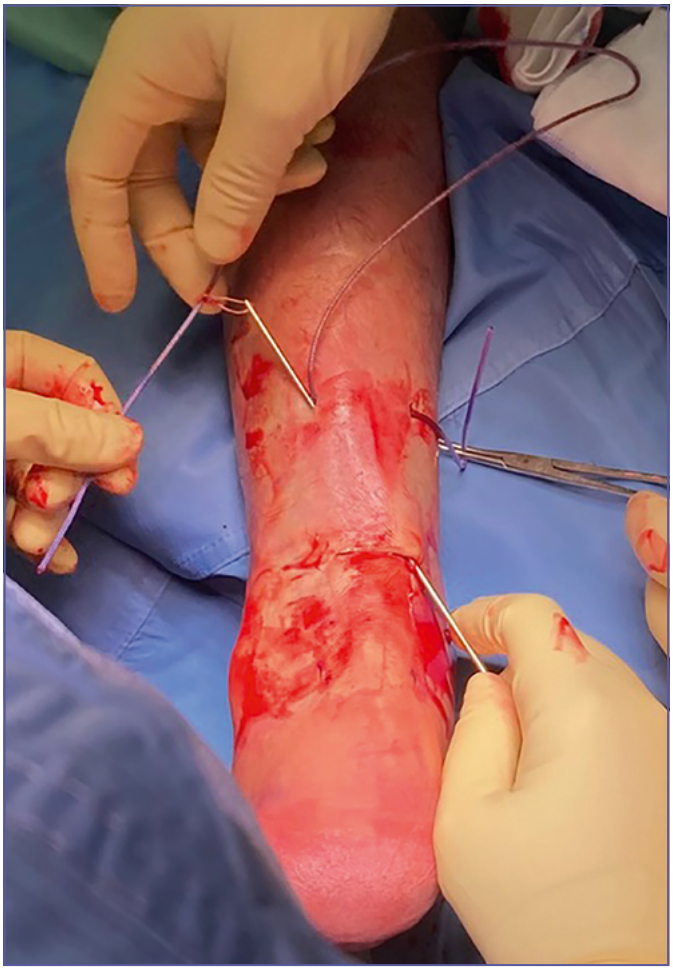

Figure 3. The Kirschner bone wire carries the PDS thread from A to E.

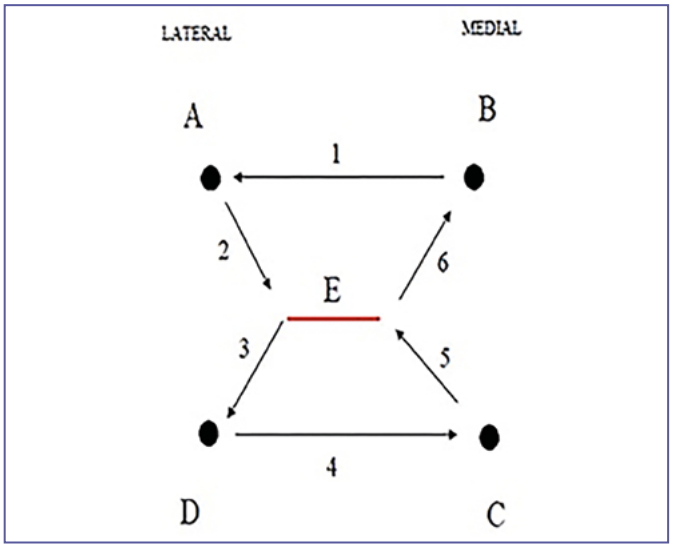

Figure 4. Surgical steps of Bartur technique.

process. The rationale for placing the knot at point B is to minimise the risk of iatrogenic sural nerve injuries. In contrast to the Ma and Griffith technique, in our method the thread does not cross in the upper part of Achilles tendon. This is an advantage because it does not cause ischaemia to muscular and tendon structures.

Post-surgical protocol

A cast at 30° of plantar flexion is positioned for 40 days with no weight bearing. After the cast is removed with no weight bearing for another 20 days. During these 20 days, patient starts to move the ankle to recover the range of motion. The patient has no weight bearing indication for at total of 60 days. Anti-thromboembolic prophylaxis with enoxaparin is prescribed throughout the period of non-weight bearing. After 60 days patients start with progressive weight bearing, gait rehabilitation and stretching.

Clinical evaluation

We assess comorbidities with the Charlson Comorbidity Index (CCI) and Functional Comorbidity Index (FCI). All patients underwent clinical evaluation at the end of follow-up. We used: American-Orthopedics-Foot-and-Ankle-Society's (AOFAS), Foot Functional Index (FFI), Foot and Ankle Ability Measures (FAAM) and Achilles tendon Total Rupture Score (ATRS). We used SF-36 and EQ-5D for analysis of quality of life. We ask patients to rate their satisfaction from 0 to 10. CCI considers: cardiovascular illnesses, cerebrovascular illnesses, dementia, chronic obstructive pulmonary disease, diabetes with or without organ damage, connective tissue disease, hepatic illnesses, hemiplegia, renal disease, tumour, metastases, and HIV. This score is from 0 to 37 points, with a decreasing estimated 10-year survival [9]. FCI investigates physical function, and includes 18 prevalent diagnoses related to physical function, resulting in a cumulative score: the number of comorbidities. This score is from 0 to 36 points, with a decreasing possibility of survival [10]. The American Orthopedic Foot and Ankle Society Score (AOFAS) was developed in 1994 and is one of the most widely used scoring systems to evaluate functional ability and physical examination incorporated into a numerical scale. The survey include a mixture of subjective and objective questions and each measure is comprised of nine questions cover three categories: Pain (40 points), function (50 points) and alignment (10 points). These are scored together for a total of 100 points. The AOFAS score has been widely adopted and has become the accepted standard to assess patients after foot and ankle surgeries [11]. The FFI was developed to measure the impact of foot pathology on function in terms of pain, disability and activity restriction. The FFI is a self-administered index consisting of 23 items that measure pain, disability and activity restriction. Scoring is based on a visual analog scale. The patient scores each question on a scale from 0 (no pain or difficulty) to 10 (worst pain imaginable or so difficult it requires help), that best describes their foot over the past week [12]. FAAM consists of the 21-item activities of daily living (ADL) and 8-item Sports subscales, which together produced information across the spectrum ability, in which the response options are presented as 5-point Likert scales (range 4 to 0). Scores for each subscale range from 0% (least function) to 100% (most function) [13]. The ATRS is a patient-reported instrument with high reliability, validity and sensitivity to measure outcomes after treatment in patients with a total ATR. ATRS was used to evaluate the limitation of calf, Achilles tendon, and foot movement after Achilles tendon injury, and systematically evaluates 10 problems such as pain, daily activity, medium-intensity exercise and high-intensity exercise after Achilles tendon injury. The full score of each item is 10, and the degree of functional limitation of Achilles tendon was classified according to slight, moderate, serious and severe [14]. Short Form 36 (SF-36) is a well-known and validated instrument of measuring the health-related quality of life that consists of 36 questions divided in eight domains: mental health (MH), general health (GH), bodily pain (BP), social functioning (SF), physical functioning (AF), role limitations due to physical health (RP), role limitations due to emotional problems (RE) and vitality (VT). Higher scores are related to better quality of life and health [15]. EQ-5D is a standardised instrument to measure generic health status and was first introduced in 1990 by the EuroQol Group [12]. The EQ-5D questionnaire has two components: health state description and evaluation [13]. In the description part, health status is measured in terms of five dimensions (5D); mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. In the evaluation part, the respondents evaluate their overall health status using the visual analogue scale. It is from 0 (minimum) to 100 (maximum) [16]. The rate of satisfaction is represented by a scale from 0 (minimum) to 10 (maximum).

Results

The final study population consisted of 69 patients, 60 men and 9 women, with a mean age of 49 years (range: 29-78 years old) and a mean BMI of 23.2 (range 19.1-32). No patient took antibiotics or corticosteroids for a long time before surgical treatment. In all, 24 patients smoked a mean of 12 cigarettes/day (range of 10-30). Three patients drank 1 glass of wine at meals every day, and another 9 patients drank alcoholic beverage occasionally. No patient had diabetes or hypothyroidism. Six patients were pensioners, and 63 were workers (12 heavy workers, 51 employees). In total, 48 patients played a sport before ATR. The mean follow-up was 16.5 months (range: 6-25 months). The clinical and functional scores at the end of follow-up are summarised in Table I. During follow-up, no wound infection, fistula, skin necrosis, sural nerve damage, deep venous thrombosis, or tendon re-rupture was found. No workers changed their job after surgical treatment, and returned at work

Table I. The clinical and functional scores at the end of follow-up.

Score	Mean result	Range
FCI[1]	0.3	0-3
CCI[2]	0.7	0-2
AOFAS[3]	92.6%	73-100
FFI[4]	4.7%	0-21
FAAM[5]	92.6%	83-100
ATRS[6]	91.4	89.9-94.3
SF-36[7]		
Physical functioning	85%	80-100
Role limitations due to physical health	75%	65-100
Role limitations due to emotional problems	33.3%	0-40
Energy/fatigue	60%	40-85
Emotional well-being	96%	72-100
Social functioning	99%	98-100
Pain	67.5%	50-80
General Health	85%	79-92
Health change	50%	0-100
EQ-5L[8]	95	80-100
Rate of satisfaction	8.5	7-10

[1] Functional Comorbidity Index; [2] Charlson Comorbidity Index; [3] American-Orthopedics-Foot-and-Ankle-Society's; [4] Foot Functional Index; [5] Foot and Ankle Ability Measures; [6] Achilles tendon Total Rupture Score; [7] Short Form - 36; [8] EuroQ – 5 Dimension

after a mean of 3.2 months (range 1.5-8 months). While 48 patients played a sport before ATR, only 27 patients returned to practice sport after a mean of 8.8 months (range 5-18 months); 21 of these patients changed the type of sport. Patients decided to change their sport or didn't play sport for fear a new ATR.

Discussion

ATR is a frequent injury and there is no consensus in the literature regarding its treatment. There are two options: surgical treatment and non-surgical therapies. Surgical treatment can be performed using either an open or closed technique. In our study, we investigated a specific type of closed technique that has not been previously studied in the literature. No studies have examined this technique. Deng et al., in their meta-analysis, found no significant difference between patients undergoing surgical and conservative treatment [17]. Mollert et al. [18] reported that the mean time to return to work in the surgical group was 54.9 days compared to 73.4 days in the conservative treatment group. In both of groups, we observed a higher prevalence of male patients who were not engaged in physically demanding work, with an average age of 38-39 years. The characteristics of our patient group align with those of the surgical group. Mollert et al. also examined the percentage of patients who did not return to sports, reporting 16% in the surgically-treated group and 14% in the non-surgically-treated group. In our study, 43.75% of patients who were previously involved in sports before ATR did not resume sports activities, primarily due to the fear of re-rupture. This difference in the return to sports may be attributed to the fact that our study initially included a smaller proportion of active individuals, only 30% of 69 participants. Moreover, this data is based on patients' subjective opinions, likely reflecting the true figures within a population mainly composed of recreational athletes. Many patients who chose not to resume sports cited a fear of experiencing another rupture. In Ochen et al.' [19] study comparing surgical and conservative treatment, they reported a FAAM score of 93.6 for the surgical group and 90.3 for the conservative group. In their study, the surgical group consisted of more men with an average age of 42 years and a CCI of 1.8, while the conservative group had men with an average age of 54 years and a CCI of 2.7. Our results (92.6) align with the surgical group, and overall, our patient group bears more similarities to the surgical cohort. Kinner et al. [20] investigated clinical outcomes at 3 years post-injury in patients who received either surgical or cast treatment. They found no significant difference between the groups

in terms of the AOFAS score, with the surgical group scoring 92 and the conservative group scoring 90. Using the SF-36 to assess the quality of life, they reported scores of 92 and 88 for the surgical and conservative groups, respectively, without any significant difference between the two. Our results show similarities to the surgical group, despite our follow-up being shorter. However, the sample population in our study shares similar demographic characteristics. Maepel et al. [21] evaluated the quality of life after conservative treatment and surgical treatment using the EQ-5D. The results in both groups were 85. In our study, the quality of life score was 95, but it is important to note that Maepel studied these patients after a minimum of 13 years. We endeavoured to compare our findings conducted with the Ma & Griffith technique. In the study by Biz et al. [22], they examined patients with ATR who underwent treatment using this technique. The majority of participants in their study were male, aged between 18 and 50 years, with a mean age of 39 years. The age range and mean were slightly lower than those in our study. The follow-up was an average of 9.7 years. In terms of post-operative results, the AOFAS score was 91.03, and the ATR rate was 90.70. Participants in their study returned to work after an average of 4.8 weeks and resumed sports activities after approximately 28 weeks. Their satisfaction level, rated from 0 to 10, was reported as 7. Around 10% of patients experienced complications during the post-operative period. Interestingly, both the AOFAS and ATR results in their study were similar to our findings (91.4 AOFAS and 92.6 ATR). However, there were some differences between their study and ours. In our study, participants returned to work and sports at an average of 13 weeks and 35 weeks, respectively, but this decision was solely based on the patient's own choice. Moreover, the level of satisfaction in our study was higher, rated at 8.5. Notably, we did not observe any complications. An important aspect to highlight is the longer follow-up period in Biz's study, spanning almost a decade. This prolonged observation may offer valuable insights into the long-term outcomes of the Ma & Griffith technique. The Ma & Griffith technique has been associated with iatrogenic sural nerve injuries, with Klein reporting a 13% rate of sural nerve involvement [23], while Rouvillain [24] reported a series of 60 repairs using this technique without sural nerve lesion. In our study, no iatrogenic sural nerve injuries were observed. Rouvillain reported two re-ruptures at 2 and 5 months, with a mean return to work time of 85 days and a return to sports at 5 months. In contrast, we had no cases of re-rupture. We also observed no nerve injuries, and patients returned to playing sports after a mean of 8.8 months. The variation in the rate of sural nerve involvement is likely attributed to differences in the surgical technique and the method of threading the thread through the leg. Therefore, our study is in agreement with the existing literature regarding patients who receive surgical treatment for ATR. The only point of difference is the time taken to return to sports activities. The delay in resuming regular activity may be associated with several factors. Firstly, it could be influenced by emotional factors stemming from the patient's fear. A patient might be hesitant to resume activity due to anxiety or concerns about potential reinjury or complications related to the surgical treatment. This emotional fear could impact the patient's willingness to fully engage in activity even if there are no clinical limitations or issues related to the surgical technique. Additionally, the delayed return to activities might be due to engaging in sports only occasionally as a hobby, leading to insufficient motivation to resume regular sporting activities. In conclusion, the delay in resuming regular activity after this surgical treatment could result from both emotional factors related to the patient's fear and the lack of motivation.

Conclusions

In conclusion, the BarTur method is a good option for surgical treatment in patients with ATR, and the operation is simple and inexpensive. This treatment offers a low risks of complication and a high rate of satisfaction. There are good clinical outcomes and few limitations in sports. Our study has some limitations. First, the patient population is limited to a small area instead of being multicentre. Second, the study had a small number of patients and may not have been representative of the general population. This is a pilot study, and a larger randomized study would be desirable to better understand the outcomes and limitations of the technique.

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Conflict of interest statement
The authors declare no conflict of interest.

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Author contributions
MB, RT, LT: writing original draft. All authors have read and agreed to the published version of the manuscript.

Ethical consideration
The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki. Oral informed consent was obtained from each participant/patient for study participation and data publication.

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