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A Two-year Follow-up Study of Accelerated Functional Rehabilitation Combined with Percutaneous Minimally Invasive Suture in the Treatment of Acute Closed Achilles Tendon Rupture

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Abstract: *To explore the effect of fast functional rehabilitation combined with percutaneous minimally invasive suture treatment for acute closed Achilles tendon rupture (ACATR) through 2-year follow-up study.We collected 32 patients with acute closed Achilles tendon rupture operated in our hospital, they were divided into early accelerated functional rehabilitation group(EAFR) and traditional rehabilitation group(TR). AOFAS Ankle Hindfoot Scale (AOFAS), Achilles tendon Total Rupture Score (ATRs) and the Muscle Strength recovery Rate (MSR) were used as follow-up evaluation. No incision-related complications or Achilles tendon rupture re-occurrence in both two groups. ATRS scores and AOFAS scores of the EAFR group were higher than those of the TR group in the 6th and 12th month after surgery, respectively (P<0.05), while no statistical significance in the 24th month when compared the two groups (P>0.05). In the EAFR group, the scores attained in the 12th month were higher when compared with those attained in the 6th month (P<0.05), lower when compared with those assessed in the 24th month (P<0.05). In the TR group, the scores attained in the 24th month were higher than those assessed in the 12th month (P<0.05), no statistical significance between the 6th month and the 12th month after surgery (P>0.05). The rate of muscle strength recovery was higher in the EAFR group in the 12th month after sugery (P<0.05), no statistical significance between the two groups in the 24th month (P>0.05). Percutaneous minimally invasive suture combined with early accelerated functional rehabilitation in treating the ACATR can accelerate the Achilles tendon function recovery without increasing the incidence of complications.*

Keywords: *Acute closed Achilles tendon rupture; Percutaneous minimally invasive suture; Early accelerated functional rehabilitation; Traditional functional rehabilitation; Follow-up*

1. Introduction

Acute closed Achilles tendon rupture (ACATR) is defined as less than 2 weeks of injury with intact skin on the affected side.With the development of economy and sports, the incidence of ACATR in different populations ranges from 0.007%-0.04% and shows an increasing trend [1-3]. It seriously affects the quality of life and productivity of patients and causes social burden [4,5]. The optimal treatment for ACATR is still controversial. Current approaches include open surgery, minimally invasive treatment is widely used clinically due to its minimal trauma, preservation of microcirculation, and low risk of wound infection and Achilles tendon re-rupture. There have been a lot of research focused on the effect of non-surgical and surgical treatment as well as various operative methods on the ACATR [6-8], but research on the post-injury rehabilitation scheme is less. Postoperative rehabilitation plays an important role in functional recovery after ACATR, among which the early accelerated functional rehabilitation shows a good prospect in clinical practice[9-11]. However, this conclusion was mainly reached through meta-analysis, and the means of rehabilitation are relatively simple, lacking data support from randomized controlled trials. It is still controversial whether the percutaneous minimally invasive repair combined with early accelerated functional rehabilitation or traditional functional rehabilitation treatment ACATR is the better program. In order to compare the clinical efficacy of percutaneous minimally invasive suture combined with early rapid functional rehabilitation or traditional functional rehabilitation treatment of ACATR, we retrospectively analyzed 44 patients who received ACATR

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treatment in our hospital from June 2017 to December 2019 for a 2-year follow-up observation.To study the effect of early accelerated functional rehabilitation on postoperative function in patients with minimally invasive suture treatment of acute closed Achilles tendon rupture.

2. Data and Methods

2.1. General Information

This paper retrospectively analyzed 32 patients who met the inclusion criteria, according to the rehabilitation content of the department and the actual needs of patients divided them into Early Accelerated Functional Rehabilitation group (EAFR) and Traditional Rehabilitation group (TR). In EAFR group, there were 15 males and 2 females, aged 19-42 years old (mean 27.4±4.4 years old). The average Body Mass Index (BMI) was 25.9±2.7 Kg/m^2. In TR group, there were 13 males and 2 females, aged 18-49 years old (mean 28.7±3.8 years old). The average BMI was 26.3±3.3 Kg/m^2. There were no significant differences in gender, age and BMI between the two groups, which were comparable.

Table 1: Basic information of patients

	EAFR group	TR group
Sample size	17	15
Gender		
male	15 (88.2%)	13 (86.7%)
female	2 (11.8%)	2 (13.3%)
age(years)	27.4±4.4 (19-42)	28.7±3.8 (18-49)
BMI(Kg/m^2)	25.9±2.7	26.3±3.3
Achilles tendon rupture		
right	5 (29.4%)	5 (33.3%)
left	12 (70.6%)	10 (66.7%)

2.2. Inclusion and exclusion criteria

According to the 2009 Guidelines for the Management of Acute Achilles Tendon Rupture published by the American Association of Orthopaedic Surgeons (AAOS).

The inclusion criteria included: the participants with no absolute contraindications to surgery, had a closed complete Achilles tendon rupture less than 2 weeks, and had complete follow-up.

The exclusion criteria included: patients with open Achilles tendon rupture, or non-body insertion avulsion of the Achilles tendon rupture, local severe skin lesions, mental disorders, metabolic diseases, nerve injury on the affected side, fracture, the affected side hip knee muscle strength below grade V, the distance between the broken end of Achilles tendon and calcaneal insertion less than 2cm or greater than 8cm, a history of systemic or periachilles use of corticosteroids within six months prior to injury and quinolone use within three months, unable to complete the follow-up.

All patients in the two groups were with closed Achilles tendon rupture. This study was approved by the Ethics Committee of the Sport Hospital of China Instiute Sports Medicine and all patients involved in the experiment were required to sign informed consent. All patients admitted to hospital met at least the following two results [1]: (1) Thompson test showed that the ankle plantar flexion strength was weakened, there was subcutaneous space under palpation, and mild exertion could increase the passive activity of ankle dorsiflexion. (2) X-ray examination showed no calcaneal fracture or ankle fracture. (3) MRI examination confirmed the interruption of Achilles tendon continuity.

2.3. Surgical Methods

All patients were admitted to hospital on the day of injury and underwent surgical treatment. The same surgical procedure was performed by the same deputy chief physician of hand and foot surgery in both groups. After the intraspinal anesthesia was satisfactory, tourniquet was applied to the affected limb and the patient was placed in prone position. A 1cm longitudinal incision was made on each side of the plane of the broken end of the Achilles tendon, and a 1cm longitudinal incision was made on both sides of the Achilles tendon respectively, 2.5cm from the distal and proximal side of the broken end of the Achilles tendon. A total of 6 incisions were made. Attention was paid to identifying and protecting the sural nerve. The route of the sural nerve at the incision was indirectly calibrated by preoperative MRI labeling of the small saphenous vein [12].The percutaneous minimally invasive

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technique described by Ma-Griffith[13]was used to suture the broken end of the Achilles tendon. The functional position of the healthy ankle joint was taken as a reference to adjust the plantar flexion Angle of the affected ankle joint and restore the continuity of the broken end of the Achilles tendon. Thompson test was carried out to confirm the adjustment. Postoperative analgesia and anticoagulant therapy were given to all patients, and the patients in each group received rehabilitation treatment in strict accordance with the preoperative group rehabilitation program.

2.4. Postoperative management and rehabilitation

Table 2: Postoperative rehabilitation plan of each group

Postoperative time	EAFR group	TR group
< 1d	Plantarflexion 30°,A1	Plantarflexion 30°
< 1w	Plantarflexion 25°-30°,A2,B1	Plantarflexion 25°-30°
< 2w	Plantarflexion 25°-30°,A3,B2	Ditto
< 3w	Plantarflexion 15°-20°,Active Plantarflexion,Partial weight bearing,A3,B2	Ditto
< 4w	Plantarflexion 5°-10°,Active Plantarflexion,Partial weight bearing,A3,B2	Ditto
< 5w	Partial load bearing 5°,Active Plantarflexion,Partial weight bearing,A3,B2	Ditto
< 6w	0°,Active Plantarflexion,Partial weight bearing,A3,B2	Ditto
< 7w	0°,Active Plantarflexion,Partial weight bearing,A3,B2,C,D,F1	Plantarflexion 25°-30°,Active Plantarflexion, Passive stretching
< 8w	0°,Active Plantarflexion,Full weight bearing,A3,B2,C,D,F2	Plantarflexion 15°-20°,Active Plantarflexion,Passive stretching
< 9w	0°,Active Plantarflexion,Full weight bearing,A3,B2,C,D,E1,F3	Ditto
< 10w	0°,Active Plantarflexion,Full weight bearing,A3,B2,C,D,E2,F4	Plantarflexion 5°-10°,Active Plantarflexion,Passive stretching
< 11w	0°,Active Plantarflexion,Full weight bearing,A3,B2,C,D,E2,F5	
< 12w	0°,Active Plantarflexion,Full weight bearing,A3,B3,C,D,E2,F6	
A:Straight leg Heel Raise(1:Recumbent position;2:Sitting position;3:Sitting resistance) B:Bicycle Crunches(1:Recumbent position;2:Sitting position) C:Active dorsiflexion of ankle to neutral position and maintain D:Ankle plantar flexion 30°and isometric contraction resistance with closed chain E:Active varus/ectropion exercise of ankle joint(1:non-resistance; 2:Elastic bands resist resistance and resistance gradually increased) F:Proprioceptive practice(1:Stand on both legs and hold the back of the chair;2:Stand on single legs and hold the back of the chair;3:Stand on single legs;4:Stand on single legs,hold the back of the chair and close eyes;5:Stand on single legs and close eyes;6:Stand on the Balance pad with single legs and close eyes)		

Dressing changes were performed every 3 days and stitches were removed after 2 weeks of the sugery. TR groups began full weight-bearing after 3 months of the surgery, EAFR group began full weight-bearing after 2 months of the surgery, and participated in physical activities according to individual condition. (1)EAFR group: we replaced the short-leg thermoplastic ankle brace into an adjustable ankle brace after 24 hours of the surgery, and fixed the ankle at 25°-30°in plantar flexion for 2 weeks, began training toes using piano keys exercise. At the same time, conducted lower extremity chain exercise. From the third post-surgery week, a full-time experienced physiotherapist began to carry out the ankle joint function exercise, adjusting the ankle plantar flexion angle once a week, arranging the ankle active plantar flexion training, toes piano keys training and partial weight bearing. On the 6th postoperative week, the patients' affected ankle would maintain at 0°. On the 7th postoperative week, the active dorsiflexion, active plantar flexion and proprioception exercises of ankle joint would begin, and the internal and external ankle rotation exercises would begin on the 9th week after surgery. (2)TR group: we used the short-leg cast to fix the ankle at 25°-30°in plantar flexion for 6 weeks. On the 7th postoperative week, we dismantled the cast, and began ankle plantar flexion training, passive stretching. The ankle plantar flexion decreasd 5 °every week, and reached to 0 °on the 11th postoperative week. Then the proprioception exercises began. The specific rehabilitation program is shown in Table 2.

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2.5. Follow-up evaluation index

All patients were followed up in the 1 month, 2 months, 3 months, 6 months, 12 months, and 24 months after surgery by outpatient review. The wound recovery was observed 3 months after the operation and the patients in each group were instructed to carry out rehabilitation exercise according to the preoperative plan. Follow-up scores were performed in the 6th, 12th and 24th months after the operation, the AOFAS and ATRS were used to compare the ankle condition of the two groups. The postoperative infection rate, refracture rate and muscle strength recovery rate were recorded in the 24th months follow-up. The MSR was tested by the maximum number of heel lifts in 1min (standard: with complete knee extension, raise the heel off the ground greater than 5cm), and compared with the healthy side (number of heel lifts on the affected side/number of heel lifts on the healthy side), and the good rate was calculated (excellent>90%, 80%<good≤90%, 70%< medium≤80%, poor≤70%) [14]. The AOFAS and ATRS scores were evaluated by a trained orthopedic physician for the two groups of patients, and the scores were recorded and entered in EXCEL.

2.6. Statistical Analysis

SPSS 20.0 statistical software was used for data analysis. The homogeneity test of variance showed the data satisfied normal distribution. The paired sample t test was used for intra-group comparison, the independent sample t test was used for inter-group comparison, and the Fisher exact test and X^2 test were used for counting data, P<0.05 indicated statistical significance.

3. Results

The follow-up time was 24-28 months, with an average of 24.7 months. All patients reached stage I incision healing, without incision complications occurred, and no patients suffered Achilles tendon refracture.

3.1. Comparison of postoperative scores between EAFR gruop and TR group

As shown in Table 3, ATRS score and AOFAS score of the EAFR group were higher than those of the TR group in the 6th and 12th months after surgery (P<0.05).There was no significant difference in ATRS score and AOFAS score between the two groups in the 24th months after surgery (P>0.05). Comparison between 12 months and 6 months after surgery, 24th months and 12th months after surgery (P<0.05), ATRS score and AOFAS score in the EAFR group were all increased. In the TR group, there was no significant difference in ATRS and AOFAS score between the 12th month and the 6th month after surgery (P>0.05), while in the 24th month and 12th month the scores were all improved (P<0.05).

Table 3: Postoperative ATRS score and AOFAS score of the two groups

group	n	ATRS			AOFAS		
		6 month	12 month	24 month	6 month	12 month	24 month
EAFR	17	84.47±4.23	87.79±2.31*	90.12±2.23**	72.23±4.72	84.32±3.96*	91.76±2.79**
TR	15	81.09±3.74	83.02±5.01$^{\#}$	89.74±3.07**	79.03±2.73	78.79±6.32$^{\#}$	90.47±3.73**
t		3.729	1.271	0.413	-4.491	1.972	1.745
P		0.000	0.000	0.319	0.001	0.023	0.327

intra-group* comparison with the 6th month, P<0.05, * intra-group* comparison with the 12th month, P<0.05,*#intra-group* comparison with the 6th month, P>0.05

3.2. Comparison of postoperative MSR between the two groups

There was no significant difference in muscle strength recovery between the two groups in the 24th months after surgery (P>0.05). The good rate of muscle strength in the EAFR group was higher than that in the TR group in the 12th months after surgery (P<0.05).See from Table 4 and Table 5.

Table 4: Comparison of MSR between the two groups in the 12th month

group	n	MSR				Excellent and good rate %
		optimal	good	medium	poor	
EAFR	17	14	3	0	0	100.0
TR	15	8	2	5	0	66.7
X^2	6.72					
P	0.02					

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Table 5: Comparison of MSR between the two groups in the 24 months

group	n	MSR				Excellent and good rate %
		optimal	good	medium	poor	
EAFR	17	15	2	0	0	100.0
TR	15	12	2	1	0	93.3
X^2	1.17					
P	0.28					

4. Discussion

In the past 20 years, ACATR is a common injury, and the incidence of this disease has increased year by year [2,3]. The optimal treatment for ACATR is still controversial [15]. ACATR are treated surgically or nonsurgically, with a subsequent requirement of 3-6 months of rehabilitation. Although many studies have shown that there is no statistical difference between surgical treatment and conservative treatment in the comparison of short-term and long-term postoperative efficacy, some studies have also shown that conservative treatment can lead to decreased muscle strength, re-fracture, and high incidence of complications. Therefore, surgery combined with postoperative rehabilitation is recommended for young athletes with high sports requirements or professional athletes in clinical practice. Surgical treatment within 6h after ACATR has the best prognosis. With the development of the concept of minimally invasive surgery, percutaneous minimally invasive suture technique has become an effective method for the treatment of ACATR, which has relatively less damage to the wound tissue and less blood loss compared to non-micro-wound surgery, compared with traditional surgery, there is no significant difference in prognosis muscle strength and muscle endurance, which is more conducive to early postoperative rehabilitation intervention.Ma et al[16]suggested that minimally invasive repair should be performed on the broken end 2-8cm above the calcaneus in ACATR(<2 weeks). Compared with open suture in the treatment of ACATR, minimally invasive percutaneous suture has more advantages in terms of preoperative patient willingness, early postoperative functional score, complication rate, and patient satisfaction. However, it takes longer time than traditional incision surgery, and also results in a higher rate of sural nerve injury. Based on previous surgical experience, we used preoperative MRI to locate the small saphenous vein and indirectly infer the sural nerve route, which effectively avoided sural nerve injury in all 32 cases [12]. A large number of studies have focused on the efficacy of surgical and non-surgical or different surgical methods in the treatment of ACATR, but few studies have analyzed the efficacy of different rehabilitation programs after ACATR. Postoperative rehabilitation includes non-functional rehabilitation (traditional plaster immobilization) and functional rehabilitation (EAFR or functional mobilization). EAFR refers to weight-bearing, ankle controlled exercises and/or dynamic rehabilitation immediately after surgery. Studies have shown that early weight-bearing can promote the formation of collagen in injured tendons and participate in tissue regeneration [17]. Activation of fibroblasts under stress and generation of collagen fibers under a series of enzymatic actions to strengthen damaged tendons [18]. In the EAFR group, the ankle plantarsal flexion Angle fixed position was restored to 0°in the first 6 weeks, and the patients were involved to a dynamic rehabilitation programs such as ankle adjacent joint chain exercise, subsequent progressive partial weight bearing, ankle multi-directional exercise, proprioceptive exercise and so on, which started within 24 hours after surgery. Although there are clinical data showing that early postoperative functional rehabilitation may increase the incidence of wound infection, patient intolerance, Achilles tendinitis and other complications [14], more and more prospective and retrospective studies have proved that accelerated functional rehabilitation starting from the third week after surgery will not cause side effects such as tendon elongation, muscle atrophy or even rupture [19]. Early weight-bearing (week 2) and early ankle rehabilitation training (week 3) can reduce the incidence of postoperative deep vein thrombosis and improve the postoperative quality of life of patients [20], and prevent the re-rupture of Achilles tendon from 8 to 12 weeks after surgery through closed chain isometric resistance rather than open ankle chain back extension resistance training. None of the 17 patients included in EAFR group showed adverse reactions during the 2-year follow-up, which confirmed the above conclusions. This study compared two treatment options for ACATR: percutaneous minimally invasive suture combined with TR group and percutaneous minimally invasive suture combined with EAFR group. The evaluation method was integrated with ATRS and AOFAS scoring methods used in previous studies, and single leg heel raise was added to evaluate the effect of limb functional recovery [18]. ATRS evaluated postoperative effects from patients' subjective feelings, while AOFAS scored from patients' subjective feelings and evaluators' functional evaluation of patients. The patients included in the treatment group were required to meet the requirement that the clinical signs of the injured Achilles tendon were consistent with the ultrasound results, and to receive the corresponding rehabilitation

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program according to the group after receiving percutaneous minimally invasive suture. Our follow-up results showed that ATRS scores and AOFAS scores of EAFR group were higher than those of the TR group in the 6 and 12 months after surgery, and the difference was significant, indicating that percutaneous minimally invasive suture combined with EAFR can accelerate functional recovery after Achilles tendon rupture and shorten the course of the disease. Although this difference disappeared in the 24 months after surgery, but both scores in the EAFR group showed significant improvement in the 12 months and 24 months after surgery, which proved that the early 12 weeks of accelerated functional rehabilitation intervention could make patients' Achilles tendon function better than the TR Group within 1 year after surgery, and maintain stable improvement of Achilles tendon function at 2 years of follow-up after surgery. 24 months after surgery, there was no significant difference in the recovery of triceps muscle strength between the two groups ($P>0.05$). 12 months after surgery, the recovery of triceps muscle strength between the two groups was significantly better than that of the TR group ($P<0.05$). Early recovery of triceps muscle strength for patients with exercise desire, in particular, it is of great significance for athletes to return to the field as soon as possible within 6 months to 12 months after surgery. At the same time, 2 years after surgery, it was found that after EAFR intervention, the patient's calf triceps muscle strength still maintained 100% good rate without adverse reaction. The above results have been confirmed by studies that when the repaired tendon is stimulated by stress in the healing process, the shape, number, muscle strength and peritendon vascular activity of collagen fibers are enhanced [17], which is similar to Wolff's law in fracture healing: tissue growth is affected by mechanical stimulation. In the early postoperative intervention of fast functional rehabilitation, the stress factor is used to promote the proliferation and differentiation of tendon stem cells into fibroblasts, which wrap around the broken end of the tendon and grow into the tendon to accelerate the healing of the tendon [21]. In addition, stress stimulation can up-regulate the growth factors in the tendine-related internal environment, such as PDGF, TGF-β, IGF-1, VEGF, etc. Promote the transformation of type III collagen and the synthesis of type I collagen in the tendon, and accelerate tendon healing [22]. The percutaneous minimally invasive suture used in this study has a good prognosis in the treatment of acute closed Achilles tendon rupture and effectively avoids the discomfort of plaster fixation in TR. It is confirmed that the application of percutaneous minimally invasive suture combined with EAFR in the treatment of ACATR can restore the strength of the Achilles tendon in a relatively short time, which is beneficial to the functional recovery of the lower leg and has a good long-term prognosis.

There are some limitations to our study. First of all, as a small sample size study of a single center in a short period of time, this study lacks objective assessment of cases or factors other than the samples studied under existing conditions, which may have a certain impact on the results of this study. Secondly, we are unable to supervise and guide the rehabilitation treatment of patients after discharge, and patient compliance may also be a factor restricting the results of our study. Therefore, a multi-center randomized controlled clinical study with a large sample size is still needed for evaluation. In conclusion, our study confirms that percutaneous minimally invasive suture combined with EAFR provides better early clinical outcomes than conventional functional rehabilitation for ACATR.

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